Université de Montréal

The Credibility of Simulation-Based Environments: User Judgments of Verisimilitude

par
Alexandre Francis

Département de communication
Faculté des arts et des sciences

Mémoire présenté à la Faculté des études supérieures
en vue de l'obtention du grade de
Maître ès sciences (M.Sc.)
en sciences de la communication

Février, 2003

Université de Montréal
Faculté des études supérieures

Ce mémoire intitulé :

The Credibility of Simulation-Based Environments:
User Judgments of Verisimilitude

présenté par :

Alexandre Francis

a été évalué par un jury composé des personnes suivantes :

Lorna Heaton
président-rapporteur

Thierry Bardini
directeur de recherche

Marc Couture
codirecteur

Aude Dufresne
membre du jury

Sommaire

Peu d'ouvrages traitent de la crédibilité des simulations informatiques, du point de vue de leurs utilisateurs. Ce mémoire examine cette question sous l'angle des jugements de divers acteurs concernés par ces technologies. Son volet théorique définit une typologie de jugements associés à la crédibilité de divers media et propose un concept de jugement propre aux simulations interactives, fondé sur la notion de *vraisemblance*. Son volet empirique consiste en une étude exploratoire des perceptions des utilisateurs potentiels d'un environnement d'apprentissage fondé sur la simulation (le laboratoire virtuel de physique). Cette étude visait à démontrer la pertinence du concept de *jugement de vraisemblance* dans l'analyse de discours traitant de crédibilité, et à explorer des pistes de recherche future dans ce domaine. Les objectifs spécifiques de l'étude étaient de mettre au jour (1) les préoccupations et représentations des utilisateurs à l'égard de la vraisemblance de l'environnement, (2) les repères sur lesquels ils s'appuient pour poser des jugements et (3) les rôles que jouent ces repères dans ceux-ci. L'approche qualitative et descriptive retenue s'appuyait principalement sur des entrevues en profondeur auprès de treize étudiants universitaires. L'étude a permis d'explorer de nombreux thèmes de recherche inédits; ses résultats ont mis en relief le caractère complexe des jugements et fait apparaître des relations entre ces derniers et des caractéristiques des utilisateurs, telles que leurs antécédents en matière d'usage d'applications informatiques. L'influence de divers éléments ou caractéristiques de l'environnement sur les jugements a également été examinée.

Mots clés : simulation informatique, laboratoire virtuel, crédibilité, vraisemblance, réalisme, jugements, perceptions, modalité

Summary

Few studies have investigated the credibility of computer simulations, from the user's perspective. This thesis tackles the credibility question, construed as inextricably linked to the judgments of actors who deal with simulations. The theoretical part of this work consists in a typology of credibility-related judgments pertaining to various media. This analysis leads to the development of a judgment construct applying specifically to interactive simulation, and based on the notion of *verisimilitude*, the quality of appearing true or real. The empirical part is an exploratory study that investigated the perceptions of potential users of a simulation-based learning environment (the VPLab). This study aimed to show the pertinence of *verisimilitude* in examining credibility discourse, and to explore themes for future research. Its specific objectives were to uncover: (1) users' preoccupations and representations relating to the VPLab's verisimilitude, (2) the cues enabling users to make judgments about the VPLab, and (3) the roles played by such cues in the expression of judgments. Following a qualitative and descriptive approach, the investigation included in-depth interviews with thirteen university science students. As part of the results, several varied research themes were developed and the complex nature of user verisimilitude judgments was highlighted. Furthermore, connections appeared between these judgments and individual traits of users, such as prior use of certain computer applications. The influence of various aspects of the environment on its verisimilitude was also considered.

Keywords: computer simulation, virtual laboratory, credibility, verisimilitude, realism, judgments, perceptions, modality

TABLE OF CONTENTS

THEORETICAL CONSIDERATIONS

EMPIRICAL CONSIDERATIONS

LIST OF TABLES

LIST OF FIGURES

Je dédie cet ouvrage
à ma mère et à mon père
qui m'ont appris à apprendre.

Remerciements

J'aimerais exprimer ici ma gratitude aux gens qui m'ont assisté dans la réalisation de cet ouvrage. Je remercie d'abord les étudiants ayant participé à l'étude empirique en tant que sujets et leurs professeurs, qui m'ont aidé à les recruter. Je remercie la professeure Aude Dufresne de m'avoir initié aux techniques de tests-usagers et de m'avoir mis sur la piste du projet de Laboratoire Virtuel en Physique de la Télé-université. Je remercie aussi mon astucieuse collègue Stéphanie Barker qui m'a fourni de très précieuses références au sujet des études sur la perception des contenus télévisuels.

Ce sont certainement Thierry Bardini, mon directeur de recherche, et Marc Couture, mon codirecteur, à qui je témoignerai la plus profonde des gratitudes. Ensemble, ils m'ont permis de relever bien des défis. Il m'est difficile de dire ici toute l'estime que j'ai pour eux.

Le professeur Couture a constamment fait preuve d'intérêt pour mon travail, de patience, d'ouverture d'esprit, et de compréhension à mon égard. Ses conseils, remarques constructives, et commentaires étoffés ne se comptent plus. Dès le départ, il a bien voulu m'intégrer à ses fascinants projets de recherche au sein desquels j'ai pu bénéficier de sa grande polyvalence en tant que chercheur et de son expertise dans les domaines de la physique et du multimédia, sans parler des conditions de travail extrêmement favorables au succès de mon projet de mémoire. Le suivi serré qu'il m'a prodigué fut exemplaire à tout point de vue, et sa disponibilité, on ne peut plus généreuse. Au cours de cette expérience, il a su me communiquer un goût pour la recherche bien menée, un inlassable souci du détail, et surtout un sens profond de l'intégrité et du professionnalisme que j'espère mettre à l'œuvre pendant toute ma carrière.

J'ai eu l'opportunité d'apprendre auprès du professeur Bardini depuis le début de mes études universitaires. Rares sont les êtres qui m'ont autant stimulé intellectuellement, à un point tel que je voulus profiter de son enseignement à l'occasion de quatre cours différents, plus extraordinaires et enrichissants les uns que les autres. Ce sont en définitive son érudition, sa passion pour la sociologie et son grand humanisme qui m'ont donné le goût de poursuivre des études supérieures et d'en connaître davantage sur l'être humain, l'un des plus beaux désirs qui m'aient été insufflés. Démontrant autant d'ouverture que de sagacité, le professeur Bardini a enrichi mon esprit, puis il m'a aidé à l'exercer sur des problèmes qui m'intéressaient particulièrement. Ainsi, ses commentaires perspicaces, de même que ses astucieuses suggestions conceptuelles et méthodologiques m'ont éclairé et habilement orienté tout au long de ma démarche intellectuelle. Cette dernière perdura, je l'espère, bien au-delà du dépôt du présent mémoire et ce, en grande partie grâce aux professeurs Couture et Bardini.

Enfin, je tiens absolument à remercier parents et amis pour leurs appuis et leurs encouragements. Je n'aurais sans doute pas pu tenir le coup sans cette solidarité.

***

Mon projet de recherche a bénéficié d'apports financiers fournis par le Bureau des technologies d'apprentissage, le Fonds institutionnel de recherche de la Télé-université, Canarie Inc., Cogéco Inc., et la Faculté des études supérieures de l'Université de Montréal.

Chapter 1. Introduction

1.1 PREFACE

This master's thesis is the product of research, both theoretical and empirical, pertaining to the credibility of computer simulations or in other terms, their believability (Tseng & Fogg, 1999a, 1999b). Said research is based on the concept of 'verisimilitude', which I closely relate to credibility. Verisimilitude is literally defined as *truth-likeness*: the quality of appearing to be true or real (Barker, 1988).

Computer simulations are now used in a great number of fields, including areas as diverse as economics, training, and recreation (e.g., video games). Although technically oriented research pertaining to simulation technology abounds, much less attention has been given to more human-centered aspects. The most notable effort, from this latter perspective, has been made in the areas of education and training. Researchers and practitioners in these fields have sought methods of designing simulations and pedagogical scenarios suitable for the activities of learners or trainees. The advantages (or shortcomings), as well as the general impacts, of implementing simulation-based instruction have also been examined. Still, several important human-centered issues relevant to simulation use need to be properly and systematically addressed in many areas, including education.

An underlying premise of my thesis is that simulation, and simulation-based environments, *are media*. Only recently has some attention been focused on simulation from this standpoint, and mostly because of the advent of immersive virtual technologies (commonly called 'virtual reality'). Much of this attention has come in the form of research on 'presence', which I will briefly discuss in one of the following chapters.

Hopefully, my work will shed new light on the medium of simulation and on its users. It may also contribute to a growing interest in examining such media through theoretical frameworks and methodologies inspired by social science research and communications studies.

One will observe that this thesis is split in two parts: theoretical and empirical. The theoretical part aims at defining a 'verisimilitude judgment' concept, directly related to simulation credibility. The empirical part applies this concept in a case study of users' credibility perceptions. This investigation involves potential users of an educational software prototype: a simulation-based experimentation environment called *The Virtual Physics Laboratory* (VPLab).

***

When I began work on this project, I was heavily influenced by sociological approaches to studying technological innovation and other approaches [1] concerned with the collective action of individuals within communities. I have since adopted other approaches, but initially, these frameworks did allow me to think about the subject matter of my thesis in an interesting manner and I have carried that general outlook throughout the project.

In viewing simulation use from a sociological perspective, I realized that a central credibility issue – that which is mostly referred to as 'realism' – could be discussed and investigated from numerous points of view, namely those of the various actors involved in the context of a simulation's design, use and evaluation. From the outset, I have considered the various categories of actors that could be concerned by use of simulation in an educational context, the type of situation with which the empirical part of my research is concerned. These actors include students, simulation designers, school administrators, educators, members of the instructional and scientific communities (in particular, domain experts), etc.[2]

By the same token, my sociological viewpoint was also conducive to the postulate that the notion of 'judgment', as expressed by an actor, was essential to any pragmatic discussion of credibility-related issues. To my mind, in other terms, *judgments* are key as they are almost inextricably linked to any consideration of a simulation's believability. In this, I am also largely influenced by the concept semioticians call 'modality judgment', as will be explained later. I thus show, in the *theoretical* part of my thesis, how a judgment model can be used to explicate various concepts which I relate to the aforementioned notion of verisimilitude.

When defining the scope of my *empirical* study, I chose to investigate credibility issues from the *student's* point of view.[3] Admittedly, it could be equally interesting and pertinent to examine judgments expressed by educators, administrators, designers, domain experts, and even analysts such as myself or other experts working in various simulation-related fields. My reasons for investigating learner judgments, within the context of this exploratory study, are as follows.

The first reason is the most obvious: students are the ones for whom instructional simulations are designed– the end-users. They are the principal actors directly concerned and affected by the use of such simulations. Indeed, I agree with Bell and Waag (1998, p. 225) who state that "positive user opinion is a necessary condition for the acceptance of a simulator." Already, this is sufficient grounds for studying users' credibility judgments.

The second reason for investigating learner judgments, which is related to the first, has to do with the hypothesis[4] that credibility affects learner motivation or the achievement of pedagogical

---

[1] I mainly refer here to the theory of conventions and collective action (for instance, see Thévenot, 1990).

[2] In the case before me, university professors play several of these roles.

[3] Henceforth, the term 'credibility' should thus be taken as meaning 'user perceptions of credibility'.

[4] Hopkins (1975), for instance, discusses this hypothesis in the field of operational skill training. Another author (Alessi, 1988, p. 42) even seems to regard this proposition as more than a hypothesis, but does not offer any evidence of

objectives (conceptual learning, transfer of training, etc.). Indeed, credibility itself must first be studied carefully if its role in these issues is to be eventually ascertained.

Another related motive for considering the student's point of view is that user perceptions of credibility – or the anticipation of such perceptions – can be invoked by the other aforementioned actors in order to justify decisions pertaining to use (or to *non*-use) of simulation-based environments. For instance, some researchers and practitioners contend that simulations should not be used in certain situations, on the basis of *assumptions* that students will not consider them to be credible (see Cooper, 2000 for example). In my opinion, these claims should be properly investigated in those situations.

I thus argue in favor of acquiring accurate empirical information about users' perceptions of credibility. A decade ago, Hennessy and O'Shea (1993, p. 129) expressed deep concerns as to the lack of knowledge in this area:

> *It seems extraordinary that while computer simulations are becoming increasingly prevalent, we know so little about users' perceptions, expectations and attitudes concerning their credibility.*

This statement on the importance of simulation credibility seems to have been largely overlooked; as a result, knowledge about users' perceptions of credibility has made very limited progress since the appearance of Hennessy and O'Shea's paper. This is unfortunate considering that, as these authors point out, this issue has "significant implications for simulation designers who want their systems to be of educational value and their interfaces to be designed in a principled way" (p. 130).

In fact, it seems that few researchers have investigated some form of credibility or perceived realism, from the point of view of simulation users or non-experts. Exceptions are found in the field of operational skill training and assessment. For instance, Dubey (1997) conducted a sociological study of (experienced)[5] pilots' beliefs concerning aircraft simulators. While the credibility-related findings of this study are not entirely negligible, its discussion of field observations is rather limited. In another study that touched upon credibility issues, Fang (1996) investigated the learning attitudes of trainees engaged in shiphandling simulator training, using a mixture of quantitative and qualitative (ethnomethodological) methods. Unfortunately, Fang's report is quite ambiguous, but as far as I can tell, his findings somewhat contradict relevant observations in Dubey's (1997) study.[6] Other studies, claiming to less generality, have reported assessments of given simulators and have provided credibility data concerning specific training simulations and scenarios. Such studies are sometimes called 'acceptance' or 'utility' evaluations (for details, see Bell & Waag, 1998; Jentsch

---

validation: "Actual similarity affects perceived similarity, which affects motivation." Yet another author (Dittrich, 1977) found a relationship between "perceived realism" and "perceived contribution to learning" in business simulations.

[5] It is noteworthy that *experienced* operators are often viewed as *subject matter experts* and, at the same time, as simulation users (see Bell and Waag, 1998; Jenstsch and Bowers, 1998).

[6] One must bear in mind, however, that Dubey's and Fang's samples were quite different culturally – French aviation pilots in Dubey's case, Taiwanese sailors in Fang's – and that the two authors dealt with different simulators.

& Bowers, 1998) and mostly involve the opinions of experienced operators concerning a specific simulator.[7] Bell and Waag (1998, p. 234) propose that the objectives of utility evaluations be to "(a) evaluate the accuracy or fidelity of the simulation environment and (b) gather opinions concerning the potential value of the simulation within a training environment."

Even less substantial credibility-related research has been conducted in the area of academic/school-based learning, the field with which I am more directly concerned. One significant contribution is the work of Hennessy and O'Shea (1993) who briefly explored elements of credibility in a simulation environment used by secondary-school pupils to learn physics[8]; these researchers have broken new ground and have stressed the need for credibility studies. Others (Hatzipanagos, 1995; Edward, 1997) have presented a very small number of observations or "preliminary findings" concerning these issues.

At any rate, most of the research quoted above does not provide any in-depth treatment of questions like the following: How do users perceive computer simulations of physical systems? How do they perceive metaphors and interfaces that allow interaction with these simulations? Are simulation-based environments 'real seeming' to users? How does credibility affect use and effectiveness of such environments? Does credibility affect the motivation of users?

My own interest in simulation credibility was kindled when I joined a team at Télé-université[9] that was working on the design and evaluation of the VPLab prototype. The team's main goal was to create an engaging and effective environment allowing college or university students to acquire not only basic experimental skills, but also a better understanding of physics concepts and laws related to specific experiments.

While conducting usability tests of the VPLab, I found that subjects spontaneously brought forward elements of discussion relating to credibility and verisimilitude. As for reasons why this would happen, perhaps the very fact that the VPLab was designed with concerns of credibility in mind can at least partially explain why these subjects considered credibility to be an issue. On the other hand, it seems only natural that, when faced with a simulation-based laboratory, some students compare the learning experience afforded by this type of environment, with the learning experience that takes place in school labs. In any case, I observed that students themselves seemed to attribute some importance to how realistic and convincing they perceived this simulation-based environment to be.[10] Consequently, I endeavored to focus my research on these questions.

---

[7] Jentsch and Bowers (1998) quote three studies mainly concerned with pilots' acceptance of low-fidelity personal-computer based simulations; one of these studies, according to Jentsch and Bowers, reported anecdotal data concerning perceived realism.

[8] Dittrich (1977) conducted a quantitative and comparative exploratory study of "perceived realism" in *business* simulations but this investigation is less pertinent, as my present preoccupation is simulation of physical systems.

[9] Télé-université is a distance learning institution and is part of Université du Québec.

[10] Hennessy and O'Shea had expressed similar concerns in the above-mentioned study.

For the empirical part of the present work, a full-fledged, working prototype of the VPLab was thus used to conduct an exploratory investigation of various credibility-related issues. To my knowledge, this study is the first whose sole purpose is to investigate such issues in a detailed manner, and to focus on the credibility of an environment featuring simulations (of physical systems) designed for post-secondary students. I propose to begin mapping out this virtually uncharted field of user perceptions through a relatively broad exploratory investigation. As such, this investigation is also a means of surveying themes of research for future studies involving other simulation-based environments.

***

As mentioned, the present thesis begins by examining theoretical elements of simulation credibility. In chapter 2, I define and contrast types of judgments identified with *realism/fidelity*, *psychological fidelity*, *modality*, and *credibility* proper. A synthesis of the most relevant theoretical elements is presented in Chapter 3 through the development of a 'verisimilitude judgment' concept.

The following chapters describe an empirical study that applies this 'verisimilitude judgment' concept to the VPLab and its use. Chapter 4 begins by stating the main research questions which guide the study and goes on to discuss other methodological considerations. My approach, a qualitative and descriptive one, is outlined and the sample of potential users (i.e., the subjects) who participated in the study is described.

Chapter 5 is a detailed discussion of my empirical observations. It is organized around important issues linked with various aspects of the VPLab (a participant-centered exposition is also available in Appendix I). Therein, I shall describe and contrast the verisimilitude judgments of participants, focusing on the *cues* that emerged from the VPLab environment and enabled subjects to make these judgments.

Chapter 6 concludes the thesis by summarizing its findings, both theoretical and empirical, examining its limitations, and suggesting leads for future research. The final part discusses ethical issues related to simulation credibility research and development.

But first, in the two remaining sections of the present chapter, I will describe the prototype used for the empirical study. Section 1.2 exposes the VPLab's 'technological and pedagogical features', thus describing its characteristics as seen from *the designer's point of view*.[11] Section 1.3 examines the characteristics of the VPLab and its status when defined as a medium, thus exposing its attributes as seen from an *analyst's* viewpoint. I give these descriptions immediately because this should allow for a more insightful presentation of theoretical considerations in the next chapter.

---

[11] This description quotes from a report (Francis & Couture, 2001) which I coauthored with the software's author and main designer.

1.2 A DESCRIPTION OF THE VPLAB'S FEATURES

The VPLab[12] is a computer simulation-based learning laboratory. This type of interactive environment is mostly referred to as a 'virtual laboratory', or a 'computer-based laboratory', although these expressions are also often used to designate other types of computer-mediated experimentation applications (e.g., remotely-accessed laboratories that do not involve simulation).

In distance education, such environments will often be the sole or principal means allowing students to learn through experimentation. In school and campus-based learning contexts, virtual experiments can be used to complement regular lab work, or as surrogates for specific experiments that are difficult or impossible to replicate in school labs.

With the VPLab, students conduct virtual experiments (in the domain of classical mechanics) featuring many characteristics and constraints normally associated with real experiments. These include uncertainty inherent to measuring apparatus, small random fluctuations of parameters, and limitations in the range of, or in the experimenter's control over, parameters and variables.

In fact, most components of the environment have been designed following a strong realism principle (I refer here to realism as assessed by the designers) from which guidelines were derived. According to these guidelines, the simulated measuring apparatus, analysis tools, and experimental set-ups must look and function like their real life counterparts– or, at least, as much as allowed by cost and software limitations. Furthermore, the user must be provided with the same opportunities to act upon tools and objects as in actual labs. Departure from strict application of said principle was permitted at times, but only for ergonomic and efficiency-related purposes, and always after substantial – and sometimes heated – debate among the designers. Allowing for these considerations, the minimum requirement was that any feature or behavior, even if not encountered in actual set-ups, could still be considered feasible with respect to current scientific and technological knowledge.

This principle, which is further discussed elsewhere (Couture, in preparation), distinguishes the VPLab from other simulation-based environments used in physics courses, and is mainly justified by the dual purpose of the environment: the VPLab aims not only to provide insight on physical phenomena, like most physics simulation software, but also (and even more importantly) to promote the development of skills related to laboratory work. Other simulation-based environments may allow higher degrees of control over simulated phenomena (compared to actual experiments) in order to create ideal or simplified experimental situations, often impossible to reproduce in real-life labs (e.g., no-gravity rooms, no-friction apparatus, user-defined numerical parameters with

---

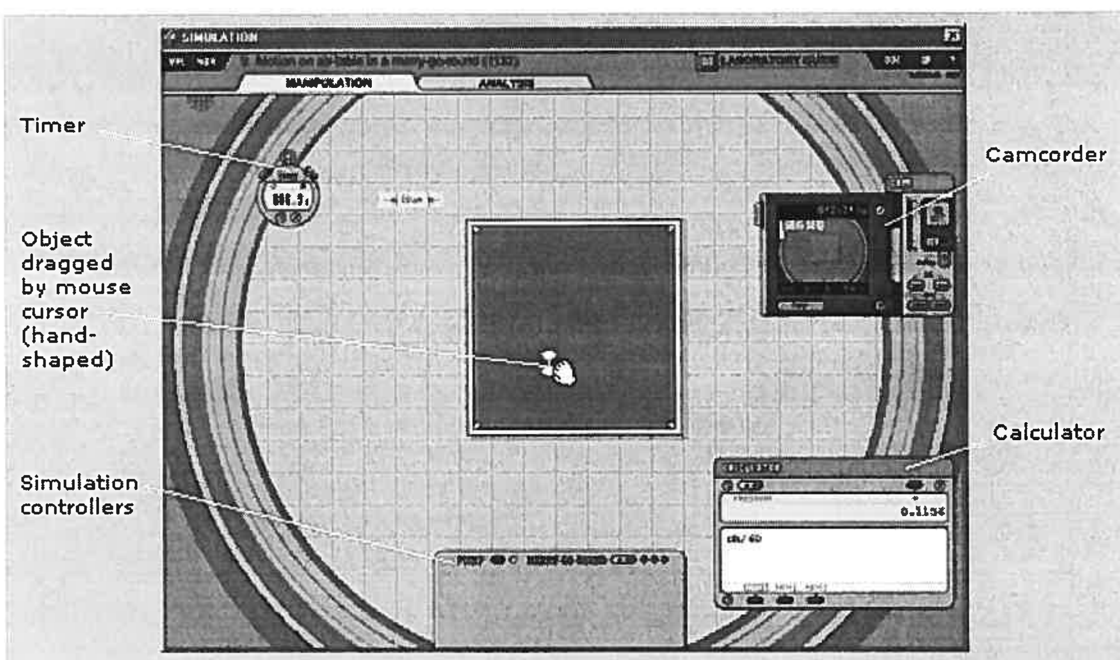
[12] Note that all elements of the VPLab prototype used for the empirical study were contained within Netscape Navigator™ windows (the Macromedia Shockwave™ plug-in was used to run the environment). Also note that a more recent version of the VPLab – which does *not* run within a browser – can be downloaded by accessing the following web site: *http://www.licef.teluq.uquebec.ca/gmec/vplab/lvp.htm*

seemingly infinite precision). But this tends to widen the gap between the simulated and the actual set-ups, which is likely to restrain the range of experimental skills that can be acquired, according to designers' hypotheses.

For each experiment[13] (which, according to the above-mentioned realism principle, should be replicable in a real-world lab), the VPLab environment presents five workspaces. The first two – called Manipulation and Analysis – contain interactive simulations directly related to actual laboratory work. In these workspaces, users conduct virtual experiments in much the same way as they would in actual labs, with no additional control over the objects or apparatus provided. They may move objects directly by 'dragging and dropping' them with the mouse cursor or, sometimes, by means of (simulated) motors driven by mouse clicks on a controller. Most of the simulated apparatus and measuring devices that learners use offer no more features than their real-life counterparts.

In the Manipulation space (Fig. 1.1), users interact with an accurately scaled – albeit videogame-like – depiction of an experimental setup. This image is surrounded by a few 'floating' tools simulating devices that could be provided in a school lab: a stopwatch, a calculator and, most important, a camcorder enabling the user to record the events occurring in the simulation. At the bottom of the window, one finds a control panel used to operate certain components of the setup.

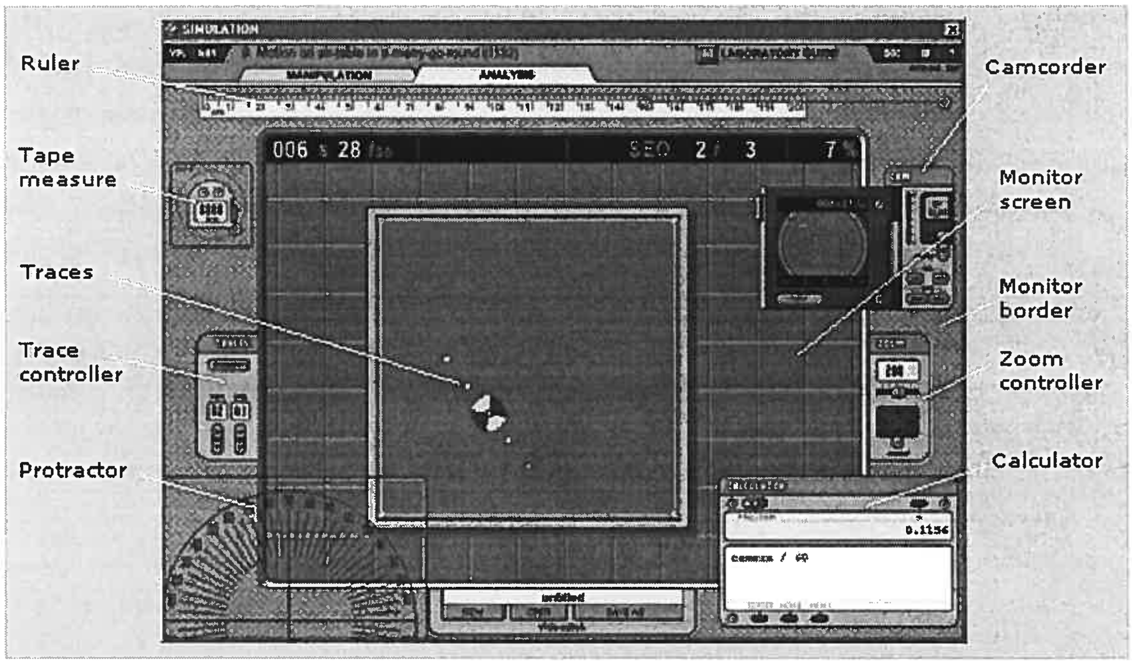
Figure 1.1 The Manipulation workspace of the VPLab, featuring the simulated setup, its control panel and the floating tools (calculator, camcorder, stopwatch).



[13] Hereafter, I use the term 'experiment' alone when referring to the simulated experimentation activities in which students can participate when using the VPLab. In contrast, I use the expression 'actual experiment' to designate experiments performed with physical equipment, in school labs or similar settings (i.e., physically situated laboratories).

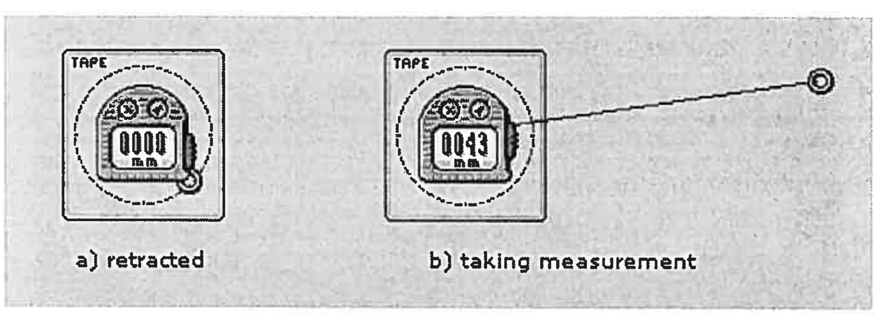
For most experiments, measurements and subsequent analyses are performed in a different workspace: the Analysis space (Fig. 1.2). The main component of the Analysis workspace is a special-purpose monitor (with zoom and multiple-image, or trace, capabilities) on which the sequences recorded in the Manipulation workspace can be reviewed using the camcorder controls. Various features of the monitor and several floating tools can be used to perform the required experimental measurements.

Figure 1.2 The Analysis workspace of the VPLab, featuring the replay monitor, its zoom and trace controllers, and the floating tools (calculator, camcorder, tape measure, ruler, protractor).



These tools have also been designed according to the realism principle, with occasional departures related to software or hardware limitations, to the 2-D nature of the environment, or to efficiency considerations. For instance, the digital tape measure (Fig. 1.3), though presenting many similarities with real tape measures, is not easily seen as having an exact real-life counterpart– in particular, one has to consider that real tape measures are usually manipulated with both hands. Other tools, like the ruler and the protractor, are much more similar to actual objects found in science classrooms.

Figure 1.3 Example of a measurement tool: the digital tape measure, shown with tape retracted (left) and extended for measurement (right).



The other three spaces (named Presentation, Explanation, and Theory & Applications) present interactive multimedia documents. These offer video clips of real experiments, animated comparisons between real and simulated set-ups, demonstrations of meaningful physical situations, and explanations concerning mathematical and (or) physical considerations relevant to the phenomena under study. In order to help bridge the gap between theory and laboratory work, all explanations closely match up against the simulated experimental set-up.

The specific simulated set-up used by participants in the empirical study was comprised of an air-table placed inside a merry-go-round (see Fig. 1.1). Within this simulation, users can grab the air-table and drag it anywhere on the floor of the merry-go-round by using a hand-shaped cursor controlled through the mouse. A disk can also be grabbed and launched on the air-table surface; the disk's thrust is controlled through cursor speed. A pump connected to the table may be activated to reduce most (but not all) of the friction between the disk and the table. The disk then moves almost freely across the table, and may repeatedly collide with the table's sides. Additionally, the merry-go-round (in which, as we recall, the air-table is placed) can be set to rotate at any of three predefined speeds: accordingly, the disk motion will be influenced by non-inertial forces (centrifugal and Coriolis) in a manner similar to that of objects and passengers in a swerving vehicle.

1.3 THE VPLAB AND SIMULATION AS MEDIA

Since the present work is based upon the premise that the VPLab, and simulation in general, are *media*, it is important to describe their attributes as such. Naturally, this should yield an understanding of how these attributes might either be similar or distinct from those of other media, which will in turn set the stage for the next chapter's theoretical description of credibility-related concepts pertaining to visual media (including simulation, of course).

1.3.1 Basic Definitions

Here are a few basic concepts which must be defined before going any further. A *model* is a "physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process" (US Department of Defense [DoD], 1998). A 'computer simulation' is a dynamic representation of a model, often involving some combination of executing code, and control/display interface hardware (DoD, 1998).

I define a *computer simulation-based learning environment* as a system (software and hardware) that integrates simulation – possibly, as the main element – to promote learning, or the acquisition and assessment of skills.

A *simulator* is: "(a) a device, computer program, or system that performs simulation; (b) for training[14], a device which duplicates the essential features of a [specific] task situation and provides for direct human operation" (DoD, 1998). Hence, a simulator is one type of simulation-based environment.

1.3.2 Attributes of the VPLab

Simulation is arguably the most significant component of the environment but other types of elements also take part in its make-up. In the present section, I describe distinctive attributes of the VPLab, many of which apply to the multimedia Presentation document as well as to the Manipulation and Analysis workspace simulations (the three workspaces involved in the empirical case study). In section 1.3.3, I will discuss other important attributes of the VPLab's simulations.

1.3.2.1 Constructedness

The VPLab is a mediated construction, as are newspaper articles, novels, plays, or television programs. Its hardware (comprised of the mouse, computer screen, CPU, etc.) was designed by engineers and built in factories. Its software was designed and built by developers, such as programmers who write code based on models, rules and algorithms. As for all artifacts designed for people to use, the VPLab 'embodies' a certain number of hypotheses and beliefs held by designers concerning future users (Bardini, 1996, 1997) and the nature of the relevant task domain (physics experimentation in a student lab, in the present case). On this subject, Dowling (1997, p. 323) has underscored the role of mediations associated with the simulation modeler as well as the importance of constraints imposed by the medium:

> *[...] as Roszak points out, electronic simulations lack the "messiness" of life. They are generalizations made in accordance with value-judgments which may well ignore or suppress elements of a situation which contribute in a less than obvious way to the total picture. The significance, even the inclusion of particular elements, is a function not only of the judgment of the programmer, but also of the degree to which the information is amenable to being expressed in a computational format.*

Acknowledging this 'constructedness' is important here, in part because any construction may seem flawed to some, but flawless to others, experienced as engaging by some, but perceived as trivial or boring by others, etc. This is to say that *constructedness*, when recognized, is a quality which leaves the 'construction' rather susceptible to *being judged.*

1.3.2.2 State of Prototype

At the time of the empirical study, the VPLab was at the *prototype* stage. No students were actually using it within a formal educational context, but its designers had defined a *potential*

[14] Simulators are used not only for training, but also for "aiding in the maintenance of proficiency by already skilled individuals" (Alluisi, 1978, p. 61), and for the assessment of competencies, some of which would be very difficult, if not impossible, to evaluate otherwise (e.g., emergency maneuvers in dangerous situations).

learner population from which individuals could be recruited to participate in various types of evaluations (such as usability tests, the credibility study described in this thesis, and an overall pedagogical evaluation). Although these potential users would probably know about simulation and be very familiar with personal computers, most would not be familiar with the VPLab or anything quite like it, because this specific prototype does not seem to correspond exactly to any of the *widespread* software 'genres'. In some ways, for instance, the VPLab resembles certain video games (among other things, they share similar graphical attributes) and in other ways it does not[15] (its main purpose being educational).

At the time of the study, the VPLab prototype was 'full-fledged' in the sense that most of its features were operational. However, only two of the experiments listed in the Navigation menu had been implemented in order to test and showcase these features. At any rate, the VPLab was always presented to potential users as a wholly revisable prototype, which was being subjected to evaluation and criticism.

1.3.2.3 Computerized

Not only is the VPLab an artifact at the prototype stage, it is more specifically a *computerized* artifact. The VPLab's computerized nature significantly defines its ontology. It may thus inherit (or be perceived as inheriting) a subset of qualities attributed to computerized artifacts in general, as well as a subset of those qualities attributed to conventional *personal* computing technology in particular (since it relies heavily on several of these specific techniques and practices). Let me give a few relevant examples of such qualities:

- Computers (and simulation) are *opaque* and *internally complex*, and most users either possess partial technical knowledge, or no knowledge at all, concerning their inner workings. Following Turkle (1984), Suchman (1987, p. 16) points out that:

  [...] even for those who possess such knowledge, there is an "irreducibility" to the computer as an object that is unique among human artifacts. The overall behavior of the computer is not describable, that is to say, with reference to any of the simple local events that it comprises; it is precisely the behavior of a myriad of those events in combination that constitutes the overall machine. [...] Insofar as the machine is somewhat predictable, in sum, and yet is also both internally opaque and liable to unanticipated behavior, we are

---

[15] Distinctions between VPLab simulations and 'narrative-based' (i.e., scenario-based) video games, for instance, can be drawn by considering their respective structures and goals. A game player's immediate or ongoing motivation might be sheer performance, but as the narrative unfolds he will try to discover the strategies and 'secrets' needed to achieve the ultimate goal: that is, to 'beat the machine', to fulfill 'the mission', to win the game, etc. Very often, such a goal is even explicitly specified in the game itself. By comparison, a VPLab user's 'goal' is more open-ended (even when his or her activities are clearly purposeful). In principle, while performing an experiment, learners will only have a vague idea, if any, of what 'correct' experimental results constitute, or of what obtaining them fully entails (what's more, educators might even tell their students, for pedagogical purposes, that they should focus on methods and the interpretation of results, rather than on obtaining specific numerical values that agree with theoretical predictions). Also consider that VPLab users can choose their own means of proceeding through the experiment: there can be more than one valid overall experimental method, and more than one way of obtaining data within the same method, etc. By contrast, players engaged in narrative-based video games must usually follow some predetermined path defined by a series of linearly dependent sub-tasks (as when a player strives to get to the 'next level'). With the VPLab, moreover, the activity terminates only when the learner decides he has achieved his objective or when he abandons it, and not before: for VPLab users, there is no such thing as 'game-over'.

> *more likely to view ourselves as engaged in interaction with it than as just performing operations upon it, or using it as a tool to perform operations upon the world.*

Suchman thereby suggests strong links between the computer's opacity, its interactivity, its (un)predictability, and the type of stance adopted by the user toward the computer.

– The applications of conventional personal computing have highly *representational* interfaces. Humans are an indispensable ingredient of the computer's representationality (Laurel, 1991). As Laurel puts it:

> *[The computer's] potential lay not in its ability to perform calculations but in its capacity to represent action* ***in which humans could participate****. [...] it is only through a person's actions that all dimensions of the representation can be manifest.*
>
> (Laurel, 1991, p. 1– original emphasis)

In the case of the VPLab, I can follow Laurel in saying that from the user's point of view, "the representation is all there is," as the technical processes that support the representation remain hidden (that is, I would add, when all goes well). This relates to the computer's opacity, described just above.

– The computer is a *modern* technology and one that bears *historical and social significance*. From a subjective viewpoint, computerized (or digital) artifacts may be perceived as more '*intelligent*' (Kernal, 1999), more *advanced*, more *powerful*, more *trendy*, etc., than non-computerized artifacts. Further questions also come to mind when thus considering the qualities of computers and how people view them. For instance: To what degree are (personal) computers *fallible*, or perceived as such? To what extent and for what purposes are (personal) computers *useful*, or considered as such? To what extent are (personal) computers *threatening* (to one's livelihood, lifestyle, etc.), *intimidating*, *easy to use*, or considered as such? To what extent is society in general – and one's peer group, in particular – favorable to (personal) computers?

1.3.2.4 *Media Form/Content* Dual Nature

With respect to the media *form/content* dichotomy, the VPLab has a dual nature. As I suggest below, one can look upon it as a medium, as content, or as both.

The VPLab as a Medium

Virtual learning environments can be considered *media* (cf. Ellis, 1995; Steuer, 1992). I argue that the VPLab is a medium because it possesses at least two important characteristics of other media. First it links specific agents to one another– designers to users, and educators to students. Second, it does so in a highly representational manner.

As a matter of fact, the environment presents various types of 'content', featured in two very different kinds of 'representational spaces' (simulated experiments and multimedia documents). Available within each of these two spaces are interchangeable elements of content. By this I mean that the user can, for instance, switch between various experiments, all of which play the same basic functional role (a simulated experimental learning activity); at the same time though, each of these content elements has its own specificity, since featured objects and subject matter vary from one experiment to the other. To make an analogy with another medium, the VPLab user who chooses between two experiments can be compared to a viewer who chooses between two movies with different plots and characters.

The VPLab as Content

Although I insist on treating the VPLab and simulation as media, I now consider Alan Kay's (1984, 1990) idea of seeing the computer *itself* as a medium:

> *[The computer] is a medium that can dynamically simulate the details of any other medium, including media that cannot exist physically. It is not a tool, although it can act like many tools. It is the first metamedium...*[16]
>
> (Kay, 1984, p. 59)

From this standpoint, the VPLab can be regarded as content for the computer medium, along side other elements like ubiquitous desktop interfaces and word processors. As when flipping through television channels, one may jump from the VPLab to the World Wide Web, and from there to a video game, a word processor, a spreadsheet, and back to the VPLab.

An Intrinsic Dual Nature

When one considers the VPLab's interface in its entirety (visual interface combined with input devices), it is reasonable to assert that the environment has the *intrinsic* dual nature of *media form/content*; this dual nature becomes somewhat apparent, for instance, when the VPLab is contrasted to applications that have *diverse purposes* and involve *different input devices*, such as musical composition software used with, say, a MIDI piano keyboard, or video games played with a joystick. My point is that the total user experience really becomes a function of interacting with specific *software content/input-device* hybrids.

1.3.2.5 Interactivity

On the whole, the VPLab is fairly interactive and its simulations are resolutely so. With regard to simulation, users should even be considered downright 'participants' rather than mere 'viewers' or 'spectators' (as is the case for non-interactive television, radio, films, etc.).

Steuer (1992) defines interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real time." As an example, he adds that:

> *a book, which cannot be changed easily in real time without cutting it apart, is not considered interactive [...] Conversely, a laser disc system including programming that enables a user to control the order in which its content is presented in real time is considered somewhat interactive, because **the medium itself can change**...*
>
> (Steuer, 1992, p. 85 – my emphasis)

[16] Notice that visual simulation too can be defined as a metamedium in Kay's sense.

Notice, as I have emphasized in the quote, that for interactive media, this realization further undermines the traditional *media form/content* dichotomy discussed above. Steuer goes on to describe three factors that contribute to interactivity: the 'speed' at which input can be assimilated into the mediated environment, the 'range' of possibilities for action at any given time, and the ability of a system to 'map' its controls to changes in the mediated environment in a natural and predictable manner. I will examine the VPLab's interactivity with respect to these three factors.

In regards to the factor of *speed*: input assimilation is almost always instantaneous within the VPLab prototype. This entails that the environment responds in real time when users act upon it.

When considering the *range* of possibilities for action, one notices that they are more limited in the multimedia documents than in the simulations. In the multimedia documents, users can choose between two modes of presentation. In 'manual' mode, they can jump from one place to the other within the document, and go to any other paragraph or page at will. In 'automatic' mode they can change the speed at which the presentation passes. It is not possible, however, to modify, add, or copy/paste the content of the texts, animations, and video clips presented therein.

In the simulations, users can press buttons to activate various features of numerous tools, move (and sometimes throw) objects around so as to change their position and speed, and then record/replay their motion with the camcorder. But they cannot perform destructive actions on the objects or make them disappear completely from the field of view, nor can they perform actions impossible to accomplish in an actual lab, such as changing the rate at which time passes or suppressing gravity. Furthermore, users cannot create new simulation objects nor can they bring modifications to existing ones beyond what has already been planned for by designers (e.g., the assembly or configuration of available components), such that users must make due with provided elements. The VPLab is thus a fairly "asymmetrical" medium, with regard to the respective powers of designer and user (cf. Bardini, 1997).

The *mappings* – i.e., the relationships between (user) inputs and various actions performed within the VPLab – are less natural than they would be in an immersive virtual environment where students could use their own hands to manipulate tools in virtual 3D space.[17] Nevertheless, it must be said that mappings in the VPLab are not highly arbitrary, since conventions found in other situations have been used in the environment. For instance, the mouse cursor[18] can be used to 'push' buttons on simulated tools such as the camcorder or the chronometer. While it is true that designers were constrained by limitations of the medium, they still strove to optimize mappings and managed to do so in several cases.

---

[17] However, Bowman (1999) makes the crucial point that, even in immersive virtual environments, one should not expect wholly natural mappings to be the most intuitive or adequate interaction method, especially when the tasks performed go beyond users' real-world capabilities. Bowman's view is backed up by his empirical findings.

[18] Although handling of the mouse must be learned, it is highly probable that most potential users will *already possess* this skill (and if not, one can acquire it in a relatively small amount of time). For such users, the mouse can function as an 'intuitive' pointing device.

To conclude, it is worth noting that Steuer (1992) rates video games[19] at the high end of the interactivity spectrum, and that these are analogous to the VPLab's simulations in regards to interactivity. Moreover, he rates interactive laser discs – which are analogous to the VPLab's multimedia documents – slightly higher than mid-point of the interactivity spectrum.

1.3.2.6 Asynchronous, Individualized and Localized Use

The VPLab prototype is an asynchronous medium with respect to the (non)correspondence between the moment when its 'content' is produced and the instant that it is used. Contrary to live television viewers, telephone users, and chat room participants, for example, VPLab users do not have immediate access to content as it is being created. Moreover, the VPLab prototype is used individually, which is to say that a student must work alone[20] on a wholly autonomous instantiation of the program situated on his own remotely located computer (in the context of the empirical study, even though the prototype was displayed in Web browser windows, all resources were contained on the computer hard drive).

1.3.2.7 Visual Interface

J.J. Gibson (1966) identified five distinct perceptual systems: the visual system, the auditory system, the haptic system, the taste-smell system, and the basic orienting system (responsible for maintaining equilibrium). The VPLab interface mostly offers stimuli for the visual system. This visual interface operates via a 15 or 17-inch conventional computer monitor (with a resolution of 800 by 600 pixels and 16-bit color, at the time of the empirical study).

It is true that punching keys or moving the mouse does stimulate the haptic system, however the computer system offers no haptic stimuli[21] beyond the usual 'resistance' of the mouse and keyboard to the user's hands and fingers.

Moreover, no sound effects were included in the environment and although verbal voice-overs were not completely ruled out by designers as an alternative for textual information in the multimedia documents accompanying the simulations, those too were not included in the prototype. The short video clip's sound track is thus the only significant source of stimulus of its kind in the VPLab.

---

[19] Note that Steuer refers to the video games of the early 90s, and that these have considerably evolved since then.

[20] In future prototypes, learners will be able to engage in cooperative learning. As they work independently (and from remote locations) on a virtual experiment, they will nonetheless have the possibility of sharing virtual camcorder and lab notebook data files in order to help each other, or compare experimental results.

[21] The meaning of 'stimuli' here is Gibson's (1966, p. 28): "patterns and transformations of energy at receptors."

1.3.3 Other Characteristics of VPLab Simulations

In this section, I discuss two additional considerations regarding the simulations: their highly dynamic nature, in section 1.3.3.1, and the type of instructional simulation included in the VPLab, in section 1.3.3.2.

1.3.3.1 Dynamic Nature

Not only are VPLab simulations highly interactive, as I have already mentioned, but they also have a particularly dynamic nature. As in many instructional simulations, the phenomena simulated in the Manipulation workspace behave *autonomously* once they have been set forth. For instance, if a user turns on the air-table pump and launches the disk while the merry-go-round is rotating, the disk will behave somewhat unpredictably and its motion will persist autonomously until the user performs another action (or until the disk comes to rest in a corner of the table).[22]

I therefore argue that this autonomous character, combined with the possibility for the user to affect behavior at any given time, makes the interactivity of simulation more dynamic, so to speak, than that of certain other media. Friedman (1999) has pointed out that browsing the Web, for instance, entails incremental rather than fluid feedback, whereas the contrary is true in the case of interactive simulations:

> *Every response you make provokes a reaction from the computer, which leads to a new response, and so on, as the loop from the screen to your eyes to your fingers on the keyboard to the computer to the screen becomes a single cybernetic circuit.*

Friedman thus accurately describes a distinctive trait of several instructional simulations, including those that are part of the VPLab prototype.

1.3.3.2 Type of Instructional Simulation

The prototype's simulations are characterized as 'instructional' because they are used for educational means rather than for scientific, industrial or other means. It is true that scientific and industrial simulations (for instance, those used for the study of highly complex systems) might sometimes also serve instructional purposes. In light of this fact, I must point out that unlike certain scientific simulations, the VPLab's simulated experiments do not involve subject matter related to unconfirmed theories or data belonging to emergent fields of research, but instead deal with behavior of phenomena which can be quite satisfactorily described by elementary laws of physics.

Alessi and Trollip (1988, 1991) define four types of instructional simulations, two of which each correspond to a specific aspect of the VPLab's simulations. In the first type, 'physical' simulations, the phenomenon students learn about "is a physical object or system of objects and

---

[22] This unusual motion is the result of simulated forces: centrifugal, Coriolis, and friction.

their behavior" (Alessi, 1988, p. 43). Obviously, this is a trait of the VPLab's simulations: its users will, for instance, learn about the behavior of a disk on an air-table.

In the second type, 'procedural' simulations, "a student learns how to operate a device such as an airplane or how to engage in a systematic procedure like diagnosing an illness" (Alessi, 1988, p. 43). Since one of the VPLab's objectives consists in allowing students to acquire skills related to lab *devices* (instruments and apparatus), and other experimental skills related to *procedures* such as data collection and uncertainty assessment, its simulations also fall under the 'procedural' category.

In summary, the simulations are of both the physical and procedural types. Note that their procedural nature grants them an affiliation with training simulations.

1.3.4 A Semiotic Description

In the remainder of this chapter, I outline a semiotic description of the VPLab that focuses on issues regarding the construction of meanings through interaction with the environment. I begin by briefly exposing elements of C.S. Peirce's concept of *sign,* which will be useful not only here, but also in the next chapters.

1.3.4.1 Peirce's Concept of Sign

My exposition of Peirce's sign theory is based on the commentaries and analyses of Greenlee (1973), Zeman (1977), and Fisette (1990), and on Peirce's own writings, as can be found in recently published collections of his works (cf. Hoopes, 1991; Peirce Edition Project & Houser, 1998). For the purposes of this thesis, I will mostly apply Peirce's theory heuristically, as a map or an aid for the explication of various ideas, without worrying much about its true worth as a *general* theory of signification. This semiotics should therefore not be regarded as a definitive theoretical framework.

To Peirce, a sign is "anything which is related to a Second thing, its Object, in respect to a Quality, in such a way as to bring a Third thing, its Interpretant, into relation to the same Object, and that in such a way as to bring a fourth into relation to that Object in the same form, *ad infinitum*" [23] (cited in Greenlee, 1973, p. 23).

This definition, arguably, is rather obscure to the layperson. For present purposes, however, it is not necessary to elucidate all the intricacies of Peirce's model, but it is important to understand that the "identity of a sign depends upon relational properties" defined with respect to three main

---

[23] Greenlee quotes this definition from a paper entitled *Partial synopsis of a proposed work in logic*: see the *Collected Papers of Charles Sanders Peirce* (1931-58), vol. 2, paragraph 92 (Cambridge: Harvard University Press). This definition is general and rather typical, though Peirce gave many others during the course of his life. One Web site has referenced as many as 76 different wordings! (cf. *Peirce's Arisbe: R. Marty's 76 definitions of the sign by C.S. Peirce* <URL> http://members.door.net/arisbe/menu/library/rsources/76defs/76defs.htm).

entities: the 'sign-vehicle' (which is only implied in the above definition), the 'object', and the 'interpretant' (Greenlee, 1973, p. 32).

Following Charles Morris, Greenlee (1973, p. 33) defines a 'sign-vehicle' (not to be confused with the sign itself) as any "concrete object or event" which turns out to be a "particular *means* of signifying."

The 'object', in Peirce's theory, is the entity (though not necessarily a material entity) represented by the sign-vehicle. It is subdivided into two components ('dynamical' and 'immediate'):

> *The dynamical object is the represented thing, as it is in itself apart from relation to thought, while that same thing, brought into relation to thought, is the 'immediate' object. This latter is the object as represented, or let us say, objectified from the standpoint or perspective of representation* [the Ground or Quality, in the above definition]... *Now Peirce appears to hold that every sign has both sorts of objects. Taking the weathercock again as a paradigm, there is a dynamical object in the wind, which causally (dynamically) determines the direction in which the indicator points and which possesses many properties irrelevant to its representation by this sign. And there is an immediate object in the wind-as-thought or cognized as an air current moving in an indicated direction.*
>
> (Greenlee, 1973, p. 66)

An 'interpretant' can be defined as any sign which represents another in someone's mind [24] (Fisette, 1990, p. 10). About the interpretant, Greenlee says that:

> *In general, it is best to think of Peirce's 'interpretant' as any sign which interprets another sign, whether that interpreting sign be a thought in somebody's mind, a written translation, a sentence spoken, or anything else that is interpretative.*
>
> (Greeenlee, 1973, p. 26)

I will further illustrate these three sign components with a fictitious example involving the VPLab. Say that an individual is looking at a computer screen that displays a depiction of a pendulum in motion. The three components of Peirce's sign can be exemplified as follows:

(1) The *sign-vehicle* is the material image, i.e. the pixels forming the image on the glass surface of the computer screen.

(2) The *object* is a pendulum as such (or so at least if the sign is interpreted closely enough to what was intended). The *immediate* object is the pendulum as cognized, which has the properties relevant to representation by the sign (in this case, geometry, color, motion, etc., similar to those of the sign-vehicle). The *dynamical* object can be seen as the pendulum-in-the-world that was envisaged by the designer of the image: among its properties, this object has many attributes irrelevant to its representation by the sign.

(3) The *interpretant* is the proper significate effect, or in other terms, the associative entity in the user's mind which connects the pixels on the computer screen (the sign-vehicle) to the object. It is the sign's interpretation.

---

[24] In Peirce's theory of signs, the interpretant $_1$ is the ground for another triad: *sign-vehicle* $_2$ / *referent* $_2$ / *interpretant* $_2$. The interpretant $_2$ in this second triad may in turn become the *ground* for a third triad, and so on. A chain of signs is thus constituted through this process called 'semiosis' (Fisette, 1990). Some semioticians are quick to point out that the interpretive process described here is situated in, and is contingent upon, a specific social and cultural context (cf. Hodge & Tripp, 1986).

Greenlee mentions Peirce's acknowledgement of the fact that signs can represent fictive entities or objects that no longer exist. Concerning the representational quality of signs and the problem of non-referential signs, such as abstract paintings, Greenlee (1973, p. 69) further specifies that:

> *If an object represented cannot be found for every sign, it yet remains the case that any sign is RE-presentational in the sense, admittedly tenuous, that its signification involves cumulative experience represented [...] A painting, however abstract, is representational just because it cannot avoid containing some familiar lines or shapes, or colors.*

Even if non-*referential* signs do exist, I will mostly use the term 'referent' to designate Peirce's *object*, in order to avoid confusion with common meanings of the word 'object'.

By examining the relationships between various sign-vehicles and their referents, Peirce categorized some of the modes whereby signs come to signify. The resulting classification – that of the symbolic, iconic, and indexical 'modes of relationship' – is well known:

> *every sign is determined by its object, either first, by partaking in the characters of the object, when I call the sign an* Icon; *secondly, by being really and in its individual existence connected with the individual object, when I call the sign an* Index; *thirdly, by more or less approximate certainty that it will be interpreted as denoting the object, in consequence of a habit (which term I use as including a natural disposition), when I call the sign a* Symbol.
>
> Peirce (1991, p. 251)

It is a common mistake to equate these three modes of relationship to 'types' of signs; actually, this scheme only describes one aspect of the overall nature of the sign (Fisette, 1990). I find this particular aspect important, however, and although some have introduced qualifications on Peirce's views (for instance, see Greenlee, 1973), I believe that this classification can be usefully applied to explain how various signs function within the VPLab. Before doing so, it will be helpful to give a few examples from more common contexts.

Smoke can function *indexically* as a sign of fire; footprints, too, can so function as a sign of the animal that made them. Smoke and footprints have a direct existential connection to their respective referents (a causal relationship, in those cases). Pointing to something with one's finger also functions indexically as the '*pointing* to' is in a relationship of contiguity with the '*pointed* to' (see Fisette, 1990).[25]

Numbers, for their part, generally function as *symbols*: it is only or mostly by convention or rule that the shape *2* refers to a pair of objects (Fiske, 1990). Words also generally function symbolically.

Maps and pictures function *iconically* because they bear a resemblance to (or, partake in the

---

[25] Concerning the pointing finger's indexicality, Greenlee (1973, p. 89) insightfully adds that:

> *the pointing finger might be aimed at the surface of an object, with that surface then being ITS object, or at the color, size, motion, glint, and so on, or all of these. Some property or complex of properties must be stated or supposed. The provision for this condition was, we saw, the meaning of reference to an idea as a GROUND of representation. It is the 'selection' of an aspect of the object in terms of a standpoint of representation.*

characters of) their referents[26]; as we recall, this resemblance "may be to a nonexistent and hence imagined object, as when a map of a demolished town is taken to be iconic of the no longer existing town" (Greenlee, 1973, p. 72).

Peirce indicates that these three modes of relationship are not mutually exclusive. While he maintains, for instance, that photographs and filmed motion pictures work iconically, he also claims that they function indexically since they "were physically forced to correspond point by point to nature," through the effect of light (reflected by the referents) on the photographic emulsion (Peirce, 1998).

Having briefly considered Peirce's semiotics, I may now turn to the VPLab's own signs. The environment is a very rich medium, as it allows for great semiotic diversity. In the next two sections, I will describe the VPLab in terms of the three modes of relationship just described (iconic, symbolic, indexical). When doing so, I only consider those signs emerging from workspaces visited by participants in the course of the empirical study involving the air-table simulation: the next section deals with the multimedia Presentation document and the one that follows it will deal with the Manipulation and Analysis workspaces.

1.3.4.2 Modes of Relationship within the Multimedia Presentation Document

It is true that the symbolic mode is very important in the multimedia Presentation document (Fig. 1.4) wherein textual explanations about the air-table simulation should retain much of the user's attention. Iconic representations (of the pictographic sort) are also present in animations that show and explain some of the Manipulation workspace's images with which the user will be dealing.

Furthermore, the indexical mode is also of particular interest in the multimedia document. As mentioned, this document offers a video clip (filmed, then digitalized) depicting the real objects upon which the simulation is based: in the video, a man is shown launching a disk on an air-table placed in a rotating merry-go-round. Recall from the preceding section that filmed images work indexically as their production, via the video camera, necessarily involves light reflected by the images' referents. But Chandler (1994) makes a crucial point concerning the digital processing of such images:

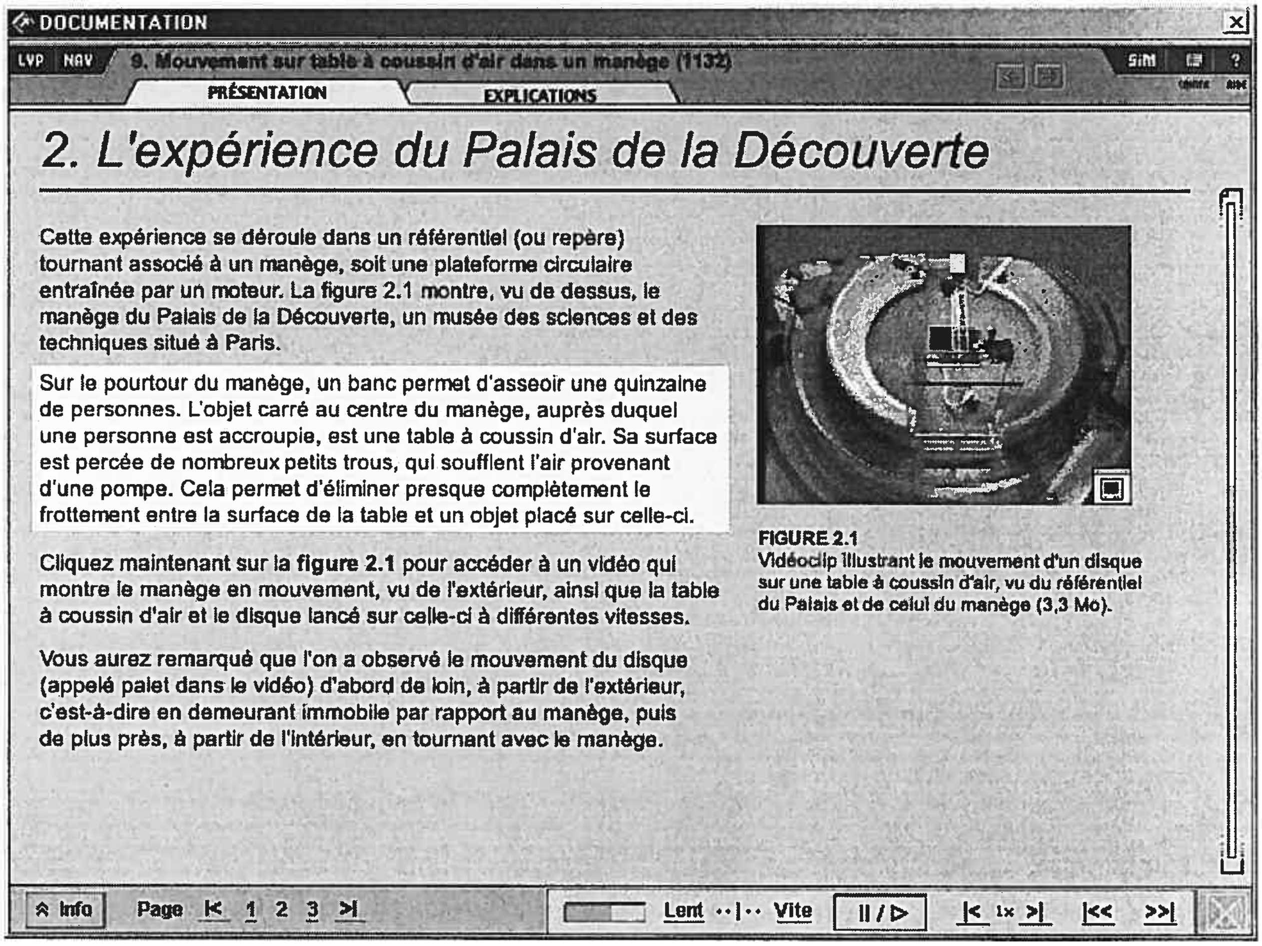
> *whilst digital imaging techniques are increasingly eroding the indexicality of photographic images, it is arguable that it is the indexicality still routinely attributed to the medium which is primarily responsible for interpreters treating them as 'objective' records of 'reality'.*

In the case before me, no manipulation other than digitalization was performed on the original video footage. Still, Chandler's comment sets the stage for the study of verisimilitude judgments involving such video clips. Indeed, their supposed indexicality is an important consideration.

---

[26] Greenlee (1973, p. 77) defines this *resemblance* as "similarities (as genus) among given objects which are recognized, that is, are determinate in relation to cognition."

Figure 1.4 The multimedia Presentation space



The video clip image contributes in another way to a second indexical sign. This sign operates through an animation wherein a video key frame transforms into an analogous computer-generated (simulation) image: the video key frame slowly 'dissolves' leaving the simulation image in its place. What designers wish to convey through this animation is that the video image and the simulation image correspond to one another. The procedure used to promote this inference consists in placing the video image in a relation of contiguity with the computer-generated one (the former transforms into the latter, both occupying the same space during a brief lapse of time), hence the indexical nature of the resulting sign.

1.3.4.3 Modes of Relationship within the Manipulation and Analysis Workspace Simulations

In the Manipulation and Analysis workspaces, the simulations feature two-dimensional[27] pictographic representations of the main apparatus and tools. I agree with Sonesson (1999) who convincingly argues that such representations bear a resemblance to their referents (as strange as it may seem to laypersons, this idea has been the subject of heated debate since Peirce first stated it).

---

[27] The only depth cues used to impart an impression of the third dimension are monocular depth cues, such as linear perspective, occlusion, shading, and relative size as a function of the apparent distance from the observer (cf. Christou & Parker, 1995; Messaris, 1994; Stuart, 1996).

In Sonesson's words, these signs are "motivated" and there is indeed an "impression of similarity" to referents.

A highly relevant characteristic of iconic representations is that – because they bear a resemblance to their referents – an interpreter's inferences about such signs may become inferences about the *referents themselves* (Zeman, 1977).[28] It must also be noted that because they are computer-generated, the simulation images do not possess the *specific* indexical character of the (Presentation document's) video footage, to which I referred in the previous section.

Since the Manipulation and Analysis workspaces make up the core of the environment, one might say that the iconic mode is prevalent overall. But indeed, certain key signs mainly function symbolically or indexically in these two workspaces. For instance, the components and buttons of tools are labeled (relationship of contiguity, i.e. indexical) with words (symbolic); these elements are important because they constrain the meaning of labeled pictographic representations. Other significant examples of the symbolic mode (but one might also say, the indexical mode) are the numerical values in the digital readouts of simulated instruments, which change according to measured values.

Finally, it seems important to point out that if events occurring in the simulation are to take on key meanings, one must correctly interpret certain indexical signs defined by causal relationships between depicted events and one's own actions. For example, an event such as the disk gliding freely on the table surface can (and hopefully will) be taken as a sign that turning on the pump has a specific effect within the simulation (i.e., suppressing most of the friction on the table surface).

1.3.4.4 Structural Isomorphism of Simulation

In the simulations, VPLab designers wished to attain more than just basic iconic modes of relationship (i.e., meaningful visual resemblance to referents). By working under the aforementioned realism design principle, they were aiming for something closer to 'structurally isomorphic' relationships. These are defined by two conditions:

1) There must be one-to-one relationships between sign-vehicles and their referents;
2) The relationships amongst sign-vehicles themselves must be analogous to specific relationships amongst referents.

In other words, an isomorphic simulation could be understood as a projection of a section of reality (or of one's conception of reality) onto the computer medium (which certainly does *not* entail, by the way, that most or all properties of this reality can ever be preserved). A scale model

[28] Similar considerations had lead both General Semanticist Alfred Korzybski and artist René Magritte (with his painting *La Trahison des Images*) to warn, each in their own ways, against unwarranted associations or confusions between signs and their referents. In a similar area of interest, Schwartz (1995) obtained empirical evidence suggesting that people who perform mental tasks with pictographic (as opposed to schematic) representations often enrich these representations with their "dynamic knowledge" of the physical referents. This supports Peirce's general semiotic model wherein the relationships between the sign-vehicle, the referent, and the interpretant are paramount.

train, for example, illustrates structurally isomorphic relationships in that (1) the components of the model are in one to one relationships with certain key components of the actual train (they might have the same geometry and color, for instance), and (2) the relationships amongst the components of the model are analogous to the relationships amongst the corresponding components of the actual train (e.g., proportions are kept, components have the same functional relationships, etc.).

The possibility of structurally isomorphic relationships in simulation has interesting implications. For instance, it distinguishes simulation from other mediums such as those exclusively involving natural languages (speech and texts in English, French, etc.), for which structural isomorphism must be ruled out, according to Nef (1991). Again, we should keep in mind that isomorphism of simulation is more likely to be observed from the designer's or the expert's point of view, and acknowledge the possibility that certain users (if not most of them) may not even be remotely sensitive to its existence or implications.

Also, by no means do I assert that the VPLab's simulations are *in fact* fully isomorphic to reality, but rather just that such a possibility exists (e.g., simulators) and that simulation designers might seek to attain it. Yet, in regards to the prospect of the VPLab simulations' isomorphism to reality, an important caveat should be addressed. Consider that the simulation modeling process, in this case, followed two somewhat distinct paths depending on the items designed. As we recall, certain elements represent particular objects that actually exist, as such in reality[29] (e.g., main apparatus like the disc, the air-table and the merry-go-round; measuring tools like the protractor and ruler). However, other items (tools like the Analysis Workspace monitor, the camcorder, and the tape measure) were intended to represent objects which, even if technically feasible, do *not* actually exist as they appear and function within the VPLab (though these representations do bear marked similarities to existing objects). Therefore, should isomorphism ever fully apply to simulation-based environments designed in this manner, it would not be sufficient to rely on *actual reality* as the sole domain of definition of isomorphic relationships: rather, this isomorphism would need to resort to the less restrictive domain of *possible reality*.

In regards to potential relations between isomorphism and interactivity, the following point bears mentioning: many exploratory actions that *can* be performed with real-world lab set-ups (e.g., tilting the air-table) cannot be executed in the corresponding virtual experiments. This is so either because designers deemed these actions and their consequences superfluous with respect to what students should be learning during those particular experiments or because their implementation was technically unfeasible (or too costly). This reiterates the fundamental fact that selection is always part of the modeling/simulation process (and of construction/mediation processes in general).[30] Now it appears reasonable to hold that the circumscription of the set of possible user

---

[29] In these cases, note that designers did not aim to simulate a physical *system* (in the sense of a general abstraction devoid of context) but instead tried to represent a specific object in a particular context.

[30] Interestingly, Laurel (1991, pp. 100-101) has argued that some constraints are *necessary* "to contain the action within the mimetic world." She even goes so far as to say that "people experience increased potential for effective agency, in

actions affects isomorphic relationships; just how is a complex question that goes beyond my present concerns.

1.3.4.5 Stances toward the VPLab's Referents

When considering structural isomorphism, one must look upon the referents of a simulation-based environment from a very specific point of view. There is, however, more than one way of regarding the VPLab's *potential* referents. I insist here on the qualifier 'potential' because different users (as well as other actors such as experts, designers, etc.) may associate slightly, and even significantly, varying referents with the very same sign-vehicles. Interpretation of the representations may *lead to* – but may also *be constrained by* – outlooks such as the three views illustrated in figure 1.5:

a) The first is an *open* outlook: It is characterized by a more or less high degree of uncertainty as to the identification of referents or the possibility of their existence in reality.

b) The second is a *holistic* outlook: It is based on the postulate (or the realization) that a learning situation (which would include all individual referents indicated on the right-hand side of figure 1.5) exists, or could exist in reality as a true counterpart to the entire VPLab environment.

   Such an outlook, or one very near to it, was usually adopted by VPLab designers, particularly when they framed the environment as the representation of an actual laboratory wherein students record experimental sessions with a digital camcorder and then walk over to a place where they can replay and analyze the recordings by plugging the camcorder into a video monitor. Designers knew that such student labs really do exist (though probably not in Québec); their conception of the VPLab was thus heavily influenced, and even driven, by this referent. Let us also note that it is from this standpoint that the environment can most readily be likened to training simulators which, as we recall, usually simulate the essential features of *specific* task situations.

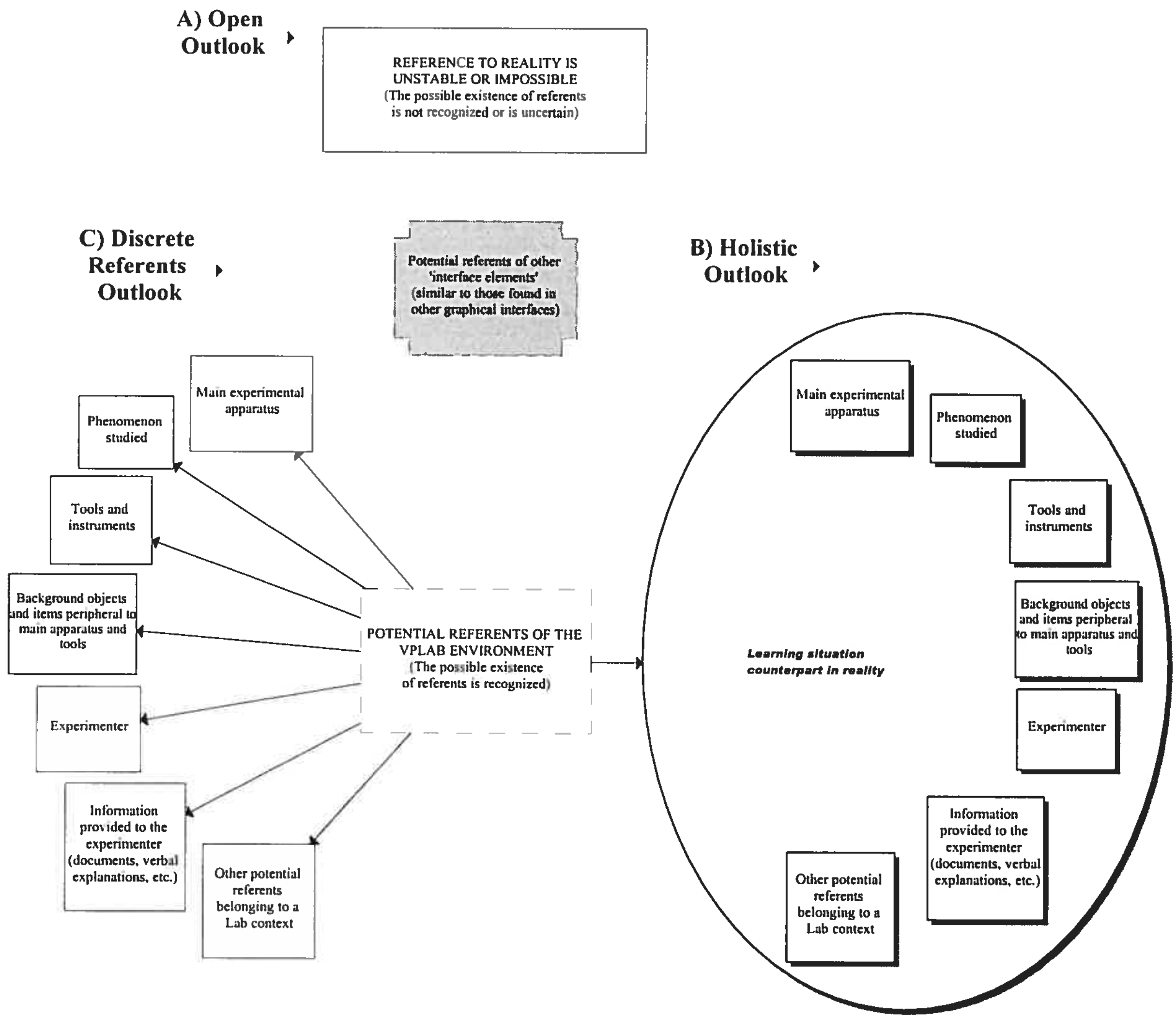
c) The third is an outlook that involves *discrete* referents. It does not resort to a real or posited learning situation wherein all referents are brought together into one coherent context.

   Rather, each of the VPLab's sign-vehicles – the main apparatus, each tool or instrument, each background object (e.g., the drain on the floor of the room containing the merry-go-round), each information unit provided to the student (e.g., Presentation document) – can be seen as representing a real (or posited) object 'in isolation'. That is, one does not envisage a global real-world situation which encompasses the set of individual referents.

---

worlds in which the causal relations among events are not obscured by the randomness and noise characteristic of open systems (like 'real-life')."

Figure 1.5 Three ways of regarding the VPLab's referents



If the above model is to be adequate with regard to everyday situations involving VPLab use, one cannot assume that users would *necessarily* be constrained to only one such outlook. It is plausible that, in certain circumstances, users may shift from one outlook to the other; perhaps novice users, or individuals unfamiliar with design intentions, are more prone to do so as they explore features of the environment. One can also consider that these three outlooks represent extreme views on a three-way spectrum– in other words, that individuals may adopt intermediate, or hybrid outlooks, such as a *quasi*-discrete outlook involving the exclusion of a few referents from an analogous real learning situation.

What's more, certain representations (e.g., window management buttons, folder tabs used to navigate between workspaces) are rather associated with conventional personal computing interfaces. I suggest that these items map to a 'fuzzy' referential domain, symbolized by the gray corner-less rectangle in figure 1.5. Martial (1997, pp. 144-147) argues that when a user acts upon such graphical entities through direct manipulation (e.g., by "clicking" on them), these can also be considered Peircean 'objects' in and of themselves, rather than just signs. This is a thought-provoking proposal, but one need not go this far to acknowledge that such elements have somewhat different status since, as Martial puts it, they refer to things like the computer's processing capabilities "which do not have materiality other than that given to them by the graphical representation" (Martial, 1997, p. 147).[31] Basically, one can consider these specific features as truly 'metaphorical' (see next section) from both the user's and the designer's point of view.

With the VPLab, however, this 'fuzzy' referential domain is of lesser importance than in the case of other software such as desktop operating systems or word processors. My argument here is that the VPLab's interface design rationale is different from that of the desktop operating system or that of widespread computing applications (e.g., word processors, spreadsheets).

First, the desktop interface (through a metaphorical device) aims to enable management of 'non-material' resources *proper to the computer* (e.g., read-write and processing capabilities, memory, etc.). As for applications such as word processors, they allow for the possibility of creating and working on an entity (namely, an original document) the existence of which only begins within the software's representational space[32] and the document's data file or, arguably, within the user's mind. Neither of these two criteria thoroughly applies to the VPLab, as its design rationale entails that users manipulate representations of objects which already exist, or could exist in material form, out there, in reality, and which have *little to do with the user's computer itself.* In this, the VPLab is more closely related to certain types of video games (so-called 'realistic' video games).

Taking this discussion from the top then, I am lead to point out that:

- The VPLab environment cannot be wholly reduced to a 'pure' simulator representing one single and agreed-upon real-world situation because (1) various referential outlooks can be adopted and (2) certain representations akin to those of conventional application interfaces map to a 'fuzzy' referential domain;
- Nor can the environment be reduced to such current application interface types as were mentioned above because the VPLab still mostly features representations of objects which have an existence independent of the computer's, or so at least from the designer's point of view.

Yet, it is entirely possible that users will purposefully interact with the VPLab environment, as they would with other computer products, and be totally oblivious or indifferent to this duality.

---

[31] This citation is translated from the original work in French.

[32] Granted, the user can then sometimes bring his creation out into the physical world, as when he prints a document created with a word processor, for example.

1.3.4.6 The Main Metaphor: The Virtual Camcorder and Virtual Monitor with its Trace and Zoom Functions

That which I temporarily call the 'main representational feature' of the VPLab's interface is the combination of the virtual camcorder and virtual monitor with its Trace and Zoom functions (see Fig. 1.2).

From the designers' viewpoint, the main representational feature employs direct mappings between functionality (gathering and analysis of experimental data, in the form of video recordings, in actual labs) and representation (the sign-vehicles that designers call 'virtual camcorder/monitor'). These direct mappings do not fit the canonical description of an 'interface metaphor'. Metaphors usually "draw incomplete parallels between *unlike* things, emphasizing some qualities and suppressing others," and "seed the constructive process through which existing knowledge *is transformed* and applied to the novel situation" (Alty, Knott, Anderson, & Smyth, 2000, p. 303 – my emphasis).

Let us clarify this by considering metaphors more generally. Following Saussurian semiotics, Chandler (1994) states that any metaphor involves "one signified acting as a signifier referring to a different signified." Rather than reinterpreting this in Peircean terms, it might be more helpful here to consider metaphors in literary terms, as did Alty et al. (2000, p. 303):

> *Literary theory characterizes the role of metaphor as the presentation of one idea in terms of another, such that understanding of the first idea is transformed in the process. From the fusion of the two ideas, a new one is created. Richards proposed a nomenclature in which he defined the original as the "tenor" and the second idea imported to modify or transform as the "vehicle."*

It must be noted that "the linking of a particular tenor and vehicle is normally *unfamiliar* in a metaphor" (Chandler, 1994 – my emphasis). However, VPLab designers rather believe that the respective elements which would play the roles of tenor and vehicle *are* related in the VPLab's case– i.e., the designers think that the gathering and analysis of data in actual physics experiments can be linked with the sign-vehicles which they call 'camcorder/monitor' because they know of actual labs where video analysis is performed. It is therefore reasonable to assert, if one *only* considers the designers' point of view, that the term 'metaphor' would not accurately characterize the VPLab's main representational feature, since the (would-be) 'tenor' and 'vehicle' *are* related, in a way.

Nevertheless, there are *no* guarantees that *users* oblivious to the specificities of design intentions (novices, for example) will see direct analogical relationships between the representations which designers call 'virtual camcorder/monitor'[33] on the one hand, and the process of data analysis in familiar lab settings on the other (indeed, this issue is investigated in the empirical study). With respect to the context of my empirical study, I can rather safely assume that the majority of science

[33] The monitor is not labeled as such in the prototype.

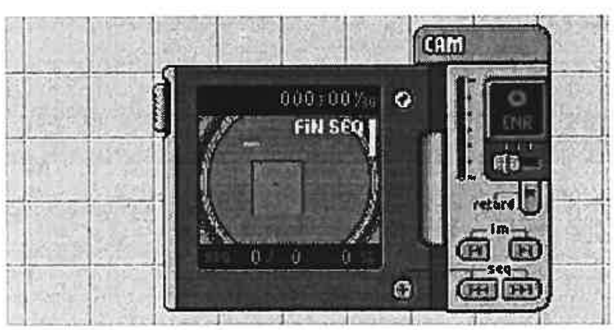
students from Québec have never seen or worked in an actual lab where phenomena are recorded with a camera and recordings are analyzed via a video monitor. It is therefore plausible that, for some users, the VPLab's main representational feature will appear to function or 'behave' metaphorically, or so at least at the outset.

Moreover, it must be said that designers took the main representational feature very literally, imagining, for instance, that the images recorded with the virtual camcorder are stored on a virtual 'videodisc'[34], in an analogy to real-world digital storage units such as rewriteable Digital Versatile Discs (the virtual 'rewriteable videodisc' is construed as more flexible than, say, an imagined virtual 'videocassette', thus accounting for the powerful viewing capabilities of the virtual camcorder and monitor).

Users, however, might not go as far as the designers. Although they may, for instance, recognize that figure 1.6 *represents* a camcorder, it does not necessarily follow that they will automatically endow this representation with the qualities of such real-world objects, or that they will construe it truly as a *surrogate* for a complex real-world digital device involving highly flexible data storage and retrieval.

In fact, one should not expect this when dealing with personal computer users who often encounter interface features incompatible with their knowledge and experience of reality. To take an example from a well known context, it is safe to assume that most novice users who notice that the desktop's waste paper basket has seemingly unlimited capacity, do not make any attempts *whatsoever* to justify this by referring to reality; does it not seem inevitable (and often desirable, even) that certain features should "violate the metaphor"? (cf. Smith, 1987; Kay, 1990; Alty et al., 2000) Indeed, there is no reason to think that VPLab users would react any differently toward the environment's potentially 'unexpected' functionalities *if* the main representational feature appeared to function like a metaphor; in this mindset, aspects that do not 'map' to reality (i.e., aspects that 'violate' the metaphor) would probably not be viewed very differently than usual. Nevertheless, seeing the main representational feature in a metaphorical way might still have an important impact on the overall credibility of the environment, for certain users.

Figure 1.6 The 'virtual camcorder' sign-vehicle



[34] In the prototype used for the empirical study, there was no explicit mention of 'videodiscs'. Also note that, at the time of the study, rewriteable DVDs were almost unheard of.

The designers' standpoint notwithstanding, and given the above considerations and the need for conciseness, I will use the term 'main metaphor' to designate the virtual camcorder/monitor (instead of 'main representational feature').

1.4 LOOKING BACK

In this chapter, I have outlined my research theme, described the VPLab's features, and defined its characteristics as a medium. While these considerations should provide important points of reference for the theoretical developments which come next, they will indeed prove even more crucial for an adequate understanding and conceptualization of the case study presented afterward.

Theoretical considerations

Chapter 2.

Characterization of Judgment-Types

This chapter exposes the theoretical foundation of my research. First, I present my conceptual approach and I develop an analytical judgment model. With this model, I then explore various constructs linked with verisimilitude, describing them as different kinds of assessments, or 'judgment-types'. I thereby present a survey of relevant literature regarding visual media and computerized artifacts, including simulation. This paves the way for the next chapter wherein I develop a 'verisimilitude judgment' construct.

2.1 FOCUSING ON JUDGMENTS

2.1.1 Preliminary Remarks

When one wishes to describe judgments relating to verisimilitude – defined as "the quality of appearing to be true or ***real***" (Barker, 1988, p. 43) – it is obvious that one can hardly avoid dealing with the words 'real' and 'reality'. But how should these be understood? Delineating reality is not a simple undertaking; while setting boundaries for 'the real', it is easy to get entangled in complex problems that have been debated among thinkers for millennia. Metaphysical realists[35], for instance, believe that reality exists independently of us, that it transcends the human mind. In the opposite camp, anti-realists deny that the world is distinct from our perceptions or conceptions of it and some even deny that a real world exists at all– they might say, for example, that reality is *purely* subjective and that it "is constructed in our use of signs" (cf. Chandler, 1994).

What's more, as Barker (1988, pp. 42-43) has argued, the complexity of these thorny metaphysical issues has been compounded by the advent of modern communications technologies:

> *Much of the difficulty in dealing with any notion of realism is that centuries of debate have left it remarkably complex and hopelessly value laden [...] such confusion is obviously tied to specific cultures at specific points in time in such ways that as the culture changes so, too, will concepts of reality, realism, and the relationship between them.*
>
> *In addition to the centuries of phenomenological baggage it carried, realism was also made to shoulder the burden of technology. Can any mechanical medium present a pristine (i.e., unmediated) view of reality? Or is it more accurate to consider the existence of varying degrees of reality, that some forms of aural-visual communication represent less techno-human mediation, and thus more reality, than others?*

---

[35] Note that I employ the term 'metaphysical realist' very differently, it seems, than some philosophers like Heim (1993, p. 157):

> *[...] realism refers to metaphysical theories that attribute priority to abstract entities [...] In a related sense, realism is the approach that treats cyberspace as an actual (phenomenological) world [...] Realists speak of the net and the matrix as actual places.*

In short, the 'reality question' is unbelievably problematic and, if Barker is correct, the consideration of representations conveyed through modern media gives rise to further questions that are no less intricate. Yet, I must still give some prior indication of what will be meant by 'reality' or 'real' in descriptions of judgment-types relating to verisimilitude– I need a working definition of reality, so to speak. For the sake of clarity, I thus find myself before the task of making difficult ontological choices.

In my view, adherence to a metaphysical position has a lot to do with personal influences and beliefs; the very notion that significant metaphysical debate is *possible* can even be questioned (cf. Wright, 1994, p. 202). Nonetheless, in the interests of examining my own tendencies, I must acknowledge taking somewhat of a realist slant both in the present chapter and the preceding one. Consider, for instance, my use of Peirce's model which, as Chandler (1994) puts it, "allocates a place for an objective reality[36]" in its description of how signs function. I do believe, however, that an extreme realist position is not adequate, at least as far as this study is concerned, nor is an extreme anti-realist one. Williamson (1995) wrote:

> *To assert that something is somehow mind-independent is to move in the realist direction; to deny it is to move in the opposite direction. No sane position is reached at either extreme. Not everything is in every way independent of minds; if there were no minds, there would be no pain. Not everything depends in every way on minds; if I forget that Halley's comet exists, it does not cease to exist.*

Following Williamson's urging for a "sane position", I will use the terms 'reality', 'real', 'real-world' and so on, to refer to physical, social, cultural (etc.) entities which can be considered as existing independently of our individual perceptions and conceptions, *but also* those entities that are *consensually acknowledged* as existing. Certainly, by this definition, the physical objects that surround me as I write these words are real (independently of my own conceptions). But this definition also entails, for instance, that intangible things like mental tasks performed by students in a classroom are real and that things such as elves and fairies, which are held to be fictitious, are not.

Additionally, as a matter of *lexical* choice, I opt to exclude simulated (and computer-generated) entities from the domain designated by the word 'reality'. This allows 'simulation entities' to stand in contrast to 'real entities' without worry of semantic contradiction. Finally, when considering other media (such as television, movies, etc.), it will often be the case that 'mediated' entities (i.e., those conveyed by media) will stand in opposition to 'non-mediated' entities (elements in the latter class can be seen as referents to elements belonging to the former); for the sake of coherence, such non-mediated entities will be deemed real if they conform to the above-mentioned 'reality' criteria. Furthermore, saying that "a person compares some mediated thing to reality," should be understood as saying that this person is comparing his or her knowledge or experience of that mediated thing to his or her perceptions, experience, beliefs, knowledge, or model of reality. (Still, this does not deny the sheer *existence* of real entities that are independent of the person's mind.)

---

[36] The 'object' of a sign can be characterized as such, in certain cases.

More to the point now, I would argue that the actors' views on media and reality have primacy over my own; indeed, it is precisely their representations and preoccupations which I aim to investigate. The idea I wish to get across at this juncture is that my approach highlights the agency of judges – be they media users, experts, analysts, instructors, scientists, etc. – in the 'assertion' of a simulation's fidelity, realism, modality, credibility, or any other such quality. In other words, I am acknowledging the almost self-evident fact that, in order for *any* discussion to take place concerning a simulation's qualities (its fidelity, for instance), individuals or groups of individuals must first *evaluate* these qualities and *express* the result of this evaluation.[37] That is, they must be the *judges* of such qualities. Objectivists might contend, regarding formal or expert judgments, that individuals performing such assessments simply make others aware of a simulation's existing qualities through analytical descriptions. However, I contend that such descriptions also consist in judgments of sorts, as they are at least partly contingent upon the describer's dispositions, analytical competencies, choice of criteria, or other individual and situational factors.[38]

The objective of this research – an exposition of various judgments yielding insight into how people perceive simulation – allows me to focus on fairly manageable and pragmatic questions dealing with simulation credibility. Instead of getting totally caught up in the metaphysical debate and trying to define the 'true nature' of real entities or of the relation(s) between our representations and reality, I try to address the following questions: Who expresses judgments that can be linked with credibility? What do these judgments focus on? How can they be described? These interrogations are at the core of both my theoretical and empirical preoccupations.

Now, the judgments that I will examine are not merely the products of mental acts, but they also involve enunciation either in written or oral form (which can be accompanied, of course, by non-verbal language and further actions): in other words, I am currently interested in *ostensibly expressed* assessments.[39]

When considering the beliefs of simulation users – methodological issues not yet withstanding – one might ask if it is *conceptually* sound to thus disregard unexpressed judgments, even as an initial simplification of the process under study. In support of my position, I quote C.S. Peirce who wrote that:

> *the act of assertion is not a pure act of signification. It is an exhibition of the fact that one subjects oneself to the penalties visited on a liar if the proposition asserted is not true. An act of*

---

[37] This certainly does not preclude one from viewing simulation 'fidelity' objectively or from a realist standpoint, if one is so inclined, because it also allows for the possibility of considering that the rationale underlying certain judgments is flawed, while that underlying others is justified.

[38] Again, this only serves to underscore the agency of judges and does not trivialize the distinctions made by such judges regarding various simulations or other media contents.

[39] One may justifiably ask whether *non*-enunciated judgments can indeed be observed and described with a degree of assurance and precision comparable to that possible for descriptions of enunciated judgments.

> *judgment is the self-recognition of a belief; and a belief consists in the deliberate acceptance of a proposition as a basis for conduct.*
>
> (cited in Zeman, 1977).[40]

As Hodge and Tripp (1986, p. 143) remarked, however, some may still object that studying media users' discourse alone might not accurately reveal what "they 'really' think or everything they think [about media content], without suppressions or distortions." But I would follow these authors in replying that discourse about media "is itself a social force":

> *What is established by discussion as a consensual set of meanings [...] acquires public force and status. It is likely to feed back into social life, and the choice and interpretation of [media content].*
>
> (Hodge & Tripp, 1986, pp. 143-144)

I thus argue that the consideration of individual judgments is a necessary step to achieving an understanding of simulation credibility and its dynamics. With this in mind, I may now explain the judgment model to which I will refer in the remainder of this chapter.

2.1.2 The Judgment Model

Above all, the model exposed here has heuristic purpose. Although it appropriately describes certain types of judgments fairly well, I do not presume that it can account for all of the cognitive, social and cultural subtleties peculiar to the widely diverse judgment processes of individuals and communities.

In my approach, the term 'judgment' indicates 'the **outcome of a process** of assessment or evaluation', although the process itself might be designated by the same term (see Fig. 2.1). The word 'process' is used here broadly, to label everything that goes on, or appears to occur, when individuals perform assessments, be they formal or informal, planned or spontaneous, etc. Let us also acknowledge that judgments are performed under specific social and cultural conditions and postulate that the judgment process is often, if not always, affected significantly by its **context**.

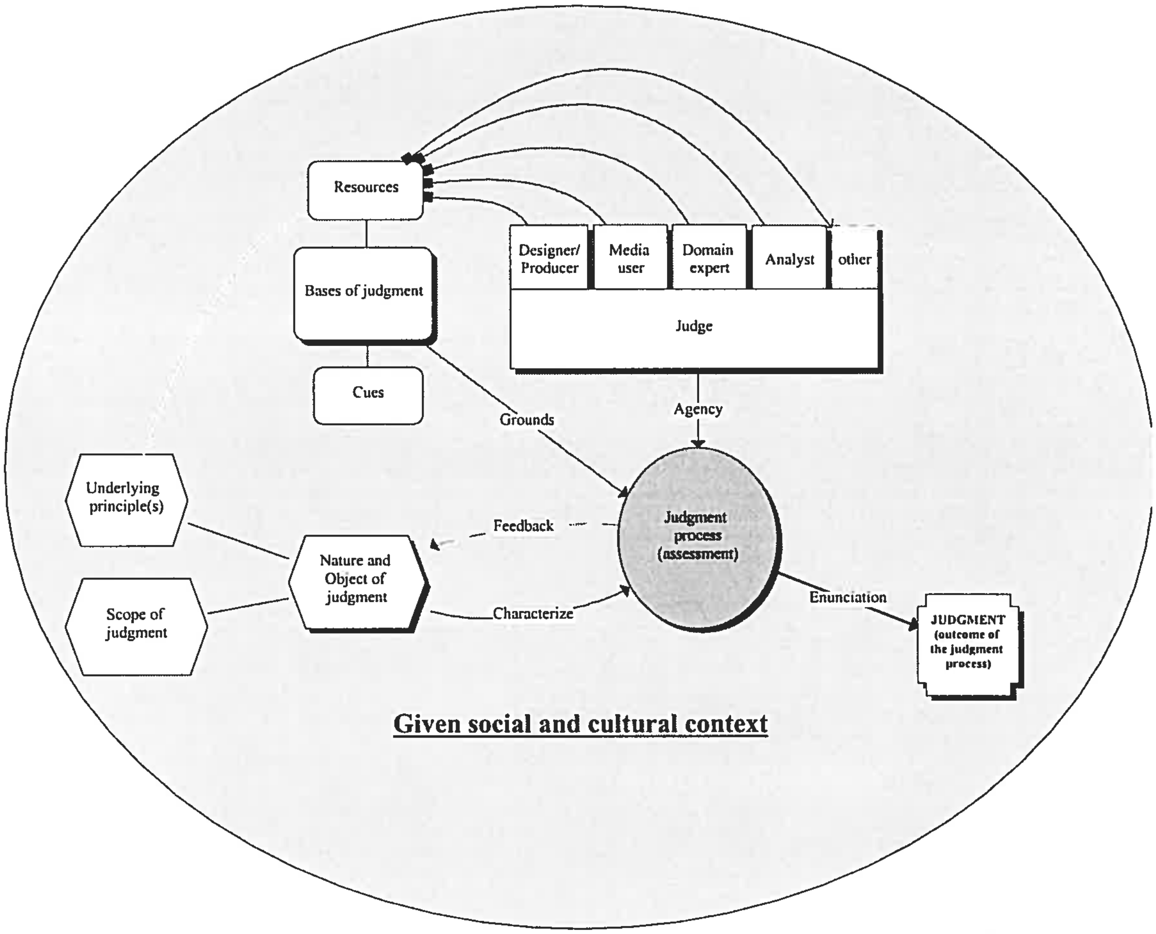
2.1.2.1 Judge(s)

Judgments follow from the thoughts and actions of individual **judges** (agents which have diverse status within various judgment processes) or from those of a group of judges. With regard to the VPLab's context, for instance, individual judges might bear the status of designer, user, domain expert, analyst, or a combination of such statuses.

---

[40] Zeman quotes this characterization of judgments from the *Collected Papers of Charles Sanders Peirce* (1931-58), vol. 8, par. 337 (Cambridge: Harvard University Press).

Figure 2.1 The judgment model



2.1.2.2 Nature and Object of Judgment

The **nature and object** of a judgment-type are characterized by its **underlying principle(s)** and by its **scope**. An example of an underlying principle in legal judgments is 'innocence pending proof of guilt beyond reasonable doubt'. As for the notion of 'scope', it describes the target(s) of the evaluation process, i.e. the elements upon which the assessment bears. In a criminal trial, the scope of the judgment is limited to the innocence or guilt of the person on trial (though it may also include the nature of the crime and the sentence, as in first and second degree murder). In some credibility-related cases examined later, however, the scope of judgments is not necessarily predetermined: a VPLab user's judgment, for instance, might bear upon a few features of the simulation-based environment, or upon several of the environment's components, or even on the environment as a whole. Principles and scope can be chosen or determined *a priori* and/or within the judgment process itself.

2.1.2.3 Bases of judgment

In order to perform assessments, a judge resorts to his own **resources** (knowledge, skills, etc.) and public resources to which he and others have access. Available resources vary with the status of judges and also with the particular conditions under which the judgment is performed. For instance, media users possess experience/knowledge of media and reality which is usually less formal and theoretical than that of domain experts; such experts might also use predetermined 'criteria' that add specificity to underlying principles and frame evaluation processes (in figure 2.1, the possible involvement of principle-specifying resources is symbolized by a curved white line). In certain cases, moreover, judges rely on additional resources, such as information (and even outright assessments) provided by third parties.

These resources form part of a judgment's **bases** or, in other terms, its grounds. Of course, elements peculiar to the judged object – features and aspects that emerge from interaction with a given television program, simulation, computer product, etc. – might also serve as bases for judgments; I call these elements **cues**.

2.1.2.4 Criteria

Certain types of judgments involve *a variety* of principles. For instance, a television viewer might say: "This situation is not *likely* to occur in reality," thus assessing the reality status of a television program with the principle of 'plausibility'; or he might say: "It is absolutely *impossible* for this situation to occur in reality," and would thus be using another principle – that of 'possibility' – to assess the program's reality status. Multiple principles are sometimes referred to as 'criteria'. Now, the viewer might also use verbal narration, for example, as a **cue** for the unrealism of a program (he might say: "The cheesy narration made it feel so unrealistic."). Such cues can also be called criteria.

The *verbal narration*, the *plausibility* of the situation presented, and the *impossibility* of its occurrence, can all be characterized as 'criteria' used by the viewer, in the above examples, to judge the reality status of the television program. In this capacity, both cues *and* multiple principles mark the evaluation process, and are available to different individuals engaged in similar acts of assessment– unlike individual resources (e.g., idiosyncratic skills, knowledge, beliefs, or past experiences), such cues and principles are not specific to any one judge. This commonality allowing the classification of both cues and (multiple) principles as 'criteria' indicates that the boundary between a judgment's **bases** (among which cues have been included) and its **nature** (first described, in part, by underlying principles) is not necessarily clear-cut.

Below, I proceed to analyze various judgment-types relevant to verisimilitude, applying this model as an expositional tool.

2.2 ANALYSIS OF JUDGMENT-TYPES

2.2.1 An Overview of Judgment-Types

Each judgment-type analyzed herein provides singular insight into simulation credibility and, as such, will contribute distinct elements to the construction of an operational 'verisimilitude judgment' concept.

I first examine '**realism/fidelity**' judgments concerning simulators. Because these are formal judgments expressed by experts alone, they are the least relevant to *user* perceptions of verisimilitude. They can serve, however, as an introduction to '**psychological realism/fidelity**' judgments, which involve the opinions of users concerning simulation environments. Although the underlying principle of such assessments (i.e., similitude to a specific and agreed-upon referent) is somewhat narrow, their potential scope is fairly broad and includes aspects essential to simulation-based environments (e.g., input/output mechanisms and interface features, interaction between the user and the environment).

I then discuss '**modality/perceived reality**', a key judgment-type which exclusively targets *media content* (television programs). The main judge, in this case, is the media *user* who expresses *informal* assessments. Contrary to psychological realism/fidelity assessments, modality judgments are *not* limited, in their underlying principles, to evaluations of strict correspondence between the content and a specific, agreed-upon referent, nor is their scope usually determined *a priori*. Moreover, modality judgments may involve a variety of criteria, such as the 'plausibility' of represented situations and events, the ontological status of the content, elements relating to the content's genre, etc.

Finally, I will examine '**computer credibility**' judgments, which address an even broader range of concerns than modality. These assessments regard the general 'trustworthiness' and 'expertise' of various computer products. Their scope may cover a wide range of aspects, such as the product's hardware, brand, information output, and more. Also notable here is the assumption that these informal judgments can build upon very diverse elements, including the user's preconceived ideas, knowledge or conceptions of the product acquired through its inspection, third-party reports, etc.

2.2.2 Realism/Fidelity of Simulation-Based Environments

The realism/fidelity judgment-type discussed herein applies to training simulators and other instructional simulation-based simulations. Before proceeding with the analysis of this construct, I should first explain why I have conflated realism and fidelity into a single term ('realism/fidelity'). As a means for this explanation, but also in order to gain preliminary insight into these types of judgments, it will be useful to examine how one particular aspect – the *perceptual* facet of realism and fidelity – has been described in literature devoted to virtual reality (VR) and simulators.

2.2.2.1 Perceptual *Realism* versus Perceptual *Fidelity*

Carr (1995, p. 68) distinguishes two kinds of perceptual realism applying to virtual reality:

> *On the one hand, virtual reality can try to create a perceptual experience which would be believable if it were experienced in the real world, and in this case realism in virtual reality is a simulation of possible real worlds. On the other hand, even if virtual reality is creating an experience which would not be possible in the real world, it can still only be perceived with the same perceptual mechanisms we use in the real world; the more accurately these mechanisms are stimulated, the greater the perceptual realism.*

Carr's statement seems to be based upon a distinction between *substratum* and *perceptual qualities*. She appears to be saying that the perceptual qualities of material objects which are picked up by our "perceptual mechanisms" in the real world can be mimicked (or reproduced) in virtual realities representing objects that *do not* or *could not* exist in the real world; another interpretation is that our "perceptual mechanisms" can be fed computer-generated stimuli which somehow fool our mind into attributing realism to sign-vehicles representing entities that cannot exist in the real-world. At any rate, the important point here is that the distinction between the two kinds of perceptual realism discussed by Carr rests on the possibility/impossibility of the referent's existence in reality.

Now, general use of the word 'fidelity' entails a comparison *to* some thing– that is, one may always ask: "Fidelity ***to** what*?" It is thus my understanding, within the scope of the simulator and VR literature which I have reviewed, that use of the expression 'perceptual fidelity' (often limited to '*visual* fidelity') is more appropriate in designating a perceptual realism that applies to environments simulating *existing* entities (e.g., simulators); the same expression, conversely, would be rather inappropriate when speaking of virtual environments representing *impossible* worlds or objects that have never been sensed by humans (e.g., VR depicting living dinosaurs). My argument is that the question "*Perceptual* fidelity to what?" is much more difficult to answer in these latter cases, wherein there is nothing tangible at which one may point his finger to indicate an accepted (or acceptable) visual referent. Hence, the status of the referent is one criterion whereby one can define, and distinguish between, 'perceptual fidelity' and 'perceptual realism'.

Another way of distinguishing between these two expressions, when applied to the visual perception of simulations of *existing* worlds, was described by Caird (1993) who reviewed literature pertaining specifically to simulators:

> *Physical visual fidelity was defined as, "The realistic degrees of freedom of spatial resolution, a correct rendering of luminance and color characteristics, the provision of field of view, as much depth of field in a flat plane presentation, and a continuous change in perspective to match the*

> *relative motion of the aircraft [or automobile] with respect to the outside world,"* [41] *[...] Realism is not synonymous with fidelity, and is instead taken to mean the comprehensiveness or completeness of a simulated environment. Overall, the various interpretations of visual fidelity and realism indicate that realism appears to be related to scene content and visual cues, whereas, fidelity is more closely aligned with the accuracy of visual display characteristics.*
>
> (Caird, 1993, p. 972)

In this context, the term 'realism' thus refers to 'completeness' or 'comprehensiveness', which I interpret as addressing the following question: To what extent are objects (and details of objects) that could (or should) be included in a given simulation indeed present in that simulation? 'Visual fidelity', on the other hand, seems to refer to the *quality* of visual presentation, which can be assessed with respect to general visual characteristics (resolution, luminance, hue, field of view, etc.).[42]

Despite the above distinctions between 'fidelity' and 'realism', it would appear, again according to Caird, that over time these two terms have often been used synonymously and in most ambiguous ways. In order to account for this ambiguity, and since I have myself observed that both expressions often seem to designate the same broad category of judgment, I will endeavor to describe an inclusive 'realism/fidelity' judgment-type, thus designated by the combination of both terms.

2.2.2.2 The Realism/Fidelity Judgment-Type

Many varieties of the realism/fidelity construct have been developed in literature pertaining to simulators and instructional simulation-based environments (see Baum et al., 1982 and references cited therein). For example, Hays and Singer (1989) defined 'physical and functional fidelity'[43], Matheny (1978) developed 'behavioral fidelity', and more recently, Stoffregen, Bardy, Smart, and Pagulayan (in press) have discussed 'action fidelity'.

Operational definitions of realism/fidelity vary, understandably, depending on the type of training or learning activity considered (Baum et al., 1982). It is possible, however, to approach the question of realism/fidelity in a general way, as did Baum et al. (1982, p. 9):

> *A working definition of fidelity must contain at least the following three components:*
>
> *- Fidelity must be defined in terms of a domain of interest (X)*
>
> *- Fidelity must be defined relative to something else (Y)*
>
> *- Fidelity must be defined so as to be measurable.*
>
> *A definition of fidelity must therefore be of the form "fidelity of X relative to Y as measured (or indicated) by Z procedure."*

---

[41] In this excerpt, the author cites *'National Research Council (1975). Visual elements in flight simulation. Assembly of Behavioral and Social Sciences, Washington, D.C.: National Academy of Sciences, p.21'*.

[42] Let me add that use of the term 'fidelity' to designate the 'quality' of the image is analogous to use of the same term to describe the quality of the signal or stimuli outputted by an audio system (as in ***High-Fidelit***y stereo systems, for instance).

[43] The concept of 'physical and functional fidelity' was first exposed in a paper cited by Hays and Singer (1989): *'Hays; R.T. (1980) Simulator Fidelity: A Concept Paper. ARI Tech. Rep. 490. Alexandria, VA: U.S. Army Research Institute'*.

Following this definition, I can expose the characteristics of realism/fidelity judgments, using the main elements of the general judgment model previously exposed:

– *Judge* (agent active in the judgment process)
– *Nature and object of the judgment* (scope and principles)
– *Bases of judgment* (resources and cues)

Judge

Realism/fidelity judgments are expressed by *domain experts* or *analysts*. Taking flight simulators as an example, aeronautical engineers, specialists in the modeling of complex systems, and specialists in flight maneuvers or crew coordination are among the experts that could judge the fidelity of various aspects of a simulator.[44] Simulation *designers,* too, may express these types of judgments (designers might very well happen to be domain experts themselves but their affiliation with the simulation environment grants them a different status, in my view).

Nature and Object of Judgment

> *The specification of training media characteristics is often referred to as the "fidelity question." Essentially the fidelity question asks,* ***how similar*** *to the actual task situation must a training situation be to provide effective training?*
>
> (Hays & Singer, 1989, p. vi – my emphasis)

Realism/fidelity judgments are *formal* assessments that rest upon the principle of *similitude* to a specific referent. Experts thus perform comparisons between (a) the situation involving the simulation-based environment, and (b) the real system or situation after which the simulation was modeled (e.g., a given military operation, flight with a commercial airliner, an electromagnetic phenomenon in physics, etc.). It is therefore important to realize that fidelity judgments are characterized by reference to *very specific* and *agreed-upon* situations, objects, phenomena, or tasks (e.g., fidelity of a flight simulator when compared to a real DC-9 commercial jet).

Rather than being of a categorical (fidelity/no-fidelity) nature, this similitude is expressed along a continuum (or continua, in the case of multidimensional definitions of realism/fidelity). As for their scope, realism/fidelity judgments are usually first concerned with the simulation-based environment itself (including software content and hardware input devices), but might – some say *should* – also be concerned with the whole situation involving both the environment *and* the user (or interaction between the two).

In other terms, given the principle and scope just defined, fidelity assessments might involve:

---

[44] In the case of operational training and assessment, realism/fidelity judgments might be expressed, for instance, in the course of the process known as 'validation' at the U.S. Department of Defense. Validation is "the process of determining the degree to which a model or simulation is an accurate representation of the real-world from the perspective of the intended uses of the model or simulation" (U.S. Department of Defense, 1998).

– comparison of simulation *events*, *objects*, *situations* and *scenarios* (wherein the user may encounter these objects and events), to corresponding elements of the actual situation represented by the simulation (see 'physical and functional fidelity' in Hays & Singer, 1989);

– comparison of the *tasks* performed in the simulation-based environment, to the tasks which are inherent to the situation represented by the simulation (see 'task fidelity' defined by Baum et al., 1982 and references therein);

– comparison of *user behavior*, or *user performance* in the simulation environment to behavior or performance in the actual situation (see Matheny, 1978, for 'behavioral fidelity' and Stoffregen et al., in press, for 'action fidelity').[45]

Bases of Judgment

To perform realism/fidelity assessments, experts and specialists must evidently resort to their analytical competencies and methods, as well as to their relatively extensive knowledge and experience of the actual situation that has been simulated. This knowledge or experience might relate to observed physical appearance and functioning of objects, to models describing their behavior, to activities or tasks performed by users in the situation that has been simulated, etc. Such knowledge can be gained via systematic analyses of activities taking place in, and systems inherent to, the situation represented by the simulation.

As I mentioned, realism/fidelity judgments are formal assessments usually performed with respect to more or less well established criteria.[46] These constitute important resources for experts. While discussing visual fidelity, I have already mentioned such criteria related to the presentation of simulations (resolution, hue, luminance, field of view, 3D versus 2D, use of pictorial depth cues such as linear perspective in 2D representations, etc.).[47] Formal fidelity criteria also exist for other aspects of simulation, such as those pertaining to the underlying model, user actions afforded by the environment, feedback provided to the user, user performance, etc. (see Alessi & Trollip, 1991; Stoffregen et al., in press).

The foregoing elements of the realism/fidelity judgment-type are summarized in Table I (p. 64), which also summarizes other judgment-types presented below.

Note on a Similar Judgment-Type: Literalism-Magic

'Literalism-magic' judgments are very similar to fidelity assessments. Smith (1987) developed the notion of literalism-magic in his analysis of the *Alternate Reality Kit* (ARK), a physics simulation-based environment with an interface "built upon a physical-world *metaphor*."

---

[45] Hays and Singer (1989, p. 49) have argued, however, that "the term 'fidelity' should be restricted to descriptions of the required configuration of the training situation and not be used when discussing behaviors."

[46] One might observe that such criteria are also used to compare various simulation-based environments to *one another*.

[47] Regarding fidelity criteria pertaining to presentation of simulation, see Alessi and Trollip (1991), as well as Christou and Parker (1995), and Stuart (1996).

Literalism-magic is relevant to the present study because some instructional simulation-based environments have so-called "metaphor-based" interfaces. Essentially, literalism-magic judgments are like realism/fidelity assessments with different scope: the distinction is that 'literalism-magic' judgments apply only to the *interface features* of metaphor-based systems:

> *Interface features that are true to the designer's metaphor might be called* ***literal****. [...]*
> *Capabilities that violate the metaphor in order to provide enhanced functionality might be called* ***magical****.* [48]
>
> (Smith, 1987, p. 61)

But Smith excludes consideration of certain interface features from the scope of literalism-magic. "External factors" that violate the metaphor without providing enhanced functionality cannot be called 'magical':

> *Input devices, computer performance limitations, or other constraints can cause the metaphor to be violated in a way that does not necessarily enhance functionality. These fixed requirements are called external factors because they are imposed upon the designer. [...] The use of an indirect input device like the mouse breaks the real world metaphor, without providing enhanced functionality. [...] it does not even enable users to do things within the capability of their physical world hand. [...] But due to unfortunate constraints, I believe that metaphor-based interfaces will usually have some features that are neither literal nor magical.*
>
> (Smith, 1987, p. 64)

The use of such formal criteria to exclude certain features from the literal-magical domain, combined with the fact that specialized knowledge is likely to be involved in these assessments, strongly suggests that literalism-magic assessments are *expert* judgments (Smith, for instance, holds a Ph.D. in physics, the domain of application of the ARK interactive environment).[49]

Summary

Realism/fidelity judgments are formal judgments expressed by experts (or designers). Such assessments are characterized by the principle of similitude: the simulation-based situation is compared to a very specific referent. As for their scope, realism/fidelity assessments bear upon the specific characteristics of the simulator, including software content and hardware input/output devices, but may also bear upon the entire situation involving both the environment and the user. Fidelity assessments are based upon well-established criteria, and the expert's relatively extensive knowledge and/or experience of the simulation's referent.

---

[48] An example of a 'highly magical' feature in Smith's interactive environment is an 'interactor', a widget with which the user can switch gravity on or off, for instance. This feature violates the environment's 'real-world' metaphor. An example of a 'literal' feature is the use of a hand cursor to pick up objects (as the grasped object is carried about, it casts a shadow on the objects beneath it; when a grasped object is released, it falls back into the scene and maintains any velocity imparted by the hand's motion). Alty et al. (2000) studied interface metaphors with a very similar, but even more systematic approach.

[49] In their brief study of simulation credibility, Hennessy and O'Shea (1993) referred to "learner *perceptions* of realism and magic" and spoke of "*attributions* of magic." The words 'perception' and 'attribution' underscore that Hennessy and O'Shea were discussing an altogether separate type of judgment: these authors were assessing and reporting the judgments of *users* (secondary school pupils).

The literalism-magic judgment-type is very closely related to realism/fidelity. The major difference between the two is in scope, as the former only applies to *interface* elements of systems with real-world metaphors.

2.2.3 *Psychological* Realism/Fidelity of Simulation-Based Environments

2.2.3.1 A Distinction Between Two Constructs: Behavioral versus Introspectional

In training simulator and instructional simulation literature, the expression '*psychological* realism/fidelity' has been used to designate two distinct constructs. The first, *behavioral fidelity* (Matheny, 1978), brings nothing new to our discussion, for it falls under the type of expert judgment described in the previous section:

> *There is then behavioral fidelity between two systems or situations when both, under the same circumstances, elicit the same operator behavior.*
>
> (Matheny, 1978, p. 3)

It is rather the second construct designated by 'psychological realism/fidelity' that is relevant here, as its distinct character moves us closer to a 'simulation verisimilitude' concept. The following quotes help characterize this construct, which focuses on the perceptions or conceptions of users, as opposed to their behaviors:

> *Salomon (1979) argued that such characterizations of resemblance must also include a distinction between* psychological *and real resemblance. He held that the similarity between one's mental conception and symbols is more important than the actual similarity between symbols and what they refer to [...] Thus depicting an object with a high degree of realism may not be required and may even be perceived as being unrealistic by a viewer if it does not match the person's internal conception of the object. Conversely, a convincingly dense, but essentially symbolic depiction will be perceived as being realistic if it fits the learner's internal map of the object. For example, a (notational) wiring diagram can be mistakenly accepted as a realistic depiction of the internal configuration of an electronic device.*
>
> (Wetzel, Radtke, & Stern, 1994, p. 183) [50]

> *[...] the term "psychological fidelity" was introduced (Gagne, 1954) to represent the trainee's perception of the "realism" of the simulator. A distinction here is that the trainee may perceive a system that departs significantly from duplication as, nevertheless, highly realistic.*
>
> (Baum et al., 1982, p. 10) [51]

To study psychological realism/fidelity from this point of view, an analyst must arguably rely, at least partly, on *users*' judgments or "opinions." This stands in contrast to 'behavioral fidelity' assessments based upon user manifestations that are construed as not directly involving introspection. Below, I analyze the introspectional variety of psychological realism/fidelity judgments targeting instructional simulations.

---

[50] The authors quote '*Salomon, G. (1979). Interaction of media, cognition, and learning. San Francisco: Jossey-Bass*'.

[51] The authors quote '*Gagne, R.M. (1954) Training devices and simulators: Some research issues (Technical Report AFPTRC-TR-54-16). Lackland Air Force Base, TX: Air Force Personnel and Training Research Center, ARDC*'.

2.2.3.2 The Psychological Realism/Fidelity Judgment-Type

Judges

Psychological realism/fidelity judgments involve two types of judges: the *user* and the *analyst*. In consequence, 'realism/fidelity' assessments and '*psychological* realism/fidelity' judgments are distinct from an epistemological standpoint. In the latter case, a basic judgment is first expressed by the user. To be known or discussed, though, psychological realism/fidelity assessments need to be described (processed, interpreted, evaluated, presented) by analysts such as psychologists, sociologists, human factors specialists, learning specialists, etc.; the analyst will thus have to produce his or her own assessment of user judgments. Whenever an analyst asserts something concerning the psychological realism/fidelity of a simulation, the assessment thus expressed should therefore be viewed as a *second-order* judgment. Evidently, this is not the case for the 'fidelity/realism' judgments discussed in the previous section: those are *first-order* judgments since only one type of judge (the expert) need be a party to the expression of such assessments. This distinction is crucial because all judgment-types described in the remainder of the present chapter (as well as verisimilitude, discussed in the next) are second-order.

Nature and Object of Judgment

The underlying principle and potential scope of the *user's* judgment are essentially the same as those of expert 'realism/fidelity' assessments exposed previously. The underlying principle is still similitude. Indeed, the user compares the situation wherein he or she participates in a simulation-based activity, with the real situation represented by the simulation (or, as some would insist, with his or her mental representation of that situation).

Judgments may apply to the entire situation, to software content and hardware input devices, or to interactions between these and users themselves. The exact scope, however, is likely to be pre-determined for users by the analyst. Users may, for instance, be brought to compare the appearance and behavior of simulation objects with those of actual objects, or the tasks performed in the simulation-based environment with those executed in the real environment, etc. Above all, and regardless of whether or not one stresses the role of the user's mental representation in his judgment, it should be emphasized that the similarity judgment still involves a *specific* and *agreed-upon referent* fixed a priori by the analyst:

> *[...] the trainee's perceptions of the training environment* ***relative to the operational environment*** *[...] became known as psychological fidelity.*
>
> (Hays & Singer, 1989 p. 37 – my emphasis)

Often, users expressing psychological fidelity judgments even have direct experience with the very system or situation after which the simulation is modeled.

Now, as stated before, the analyst needs to 'process' user judgments and, in turn, perform his own assessment of these. At the most basic level, the analyst can create, be involved in, assess and relate the conditions under which user judgments are expressed. Obviously, the nature of the analyst's judgment, here, differs from that of users. Whilst the latter is characterized by the principle of similarity, the former is to a large extent determined by the analyst himself (who is likely to refer to the conventional practices of a research community).

Bases of Judgment

To perform judgments, users evidently rely on their own knowledge and experiences of both the simulation-based environment and the specific situation which they are told it represents. In doing so, of course, users also bring their individual judgment competencies to bear upon said comparison. Additionally, they might sometimes use specific materials and criteria provided by the analyst; such criteria relate to diverse aspects of the situation involving the simulation-based environment (physical appearance of simulation objects, tasks performed, behavior of the environment, behavior of the user, etc.).

A psychological realism/fidelity judgment process is exemplified in the following citation (although most elements of the analyst's own judgment process are not included):

> *With flight simulators the operator has been asked to compare his behavior in controlling the air-craft to the behavior he exhibits in controlling the simulator and then to express his opinion as to the degree to which they are alike. In order for the measurement to be as reliable and discriminating as possible, we have selected the most experienced operator of the system possible and supplied him with rating scales to assist him in objectifying his opinions.*
>
> (Matheny, 1978, p. 5)

One can also infer from this citation that the resources utilized by the *analyst* to perform his or her own assessment consist of the methods, tools and criteria selected to collect, interpret, process, and evaluate user judgments (not to mention the criteria whereby users are chosen), as well as the related analytical competencies that he or she possesses.

Summary

In contrast to 'realism/fidelity' assessments, 'psychological realism/fidelity' judgments have been characterized as second-order judgments involving two kinds of agents. It is the user (instead of a specialist) who judges the simulation's similarity to its referent (perhaps, by utilizing specific criteria and materials provided to him). The analyst then produces an assessment of user judgments by processing, evaluating, or interpreting these, usually with tools and criteria inspired by, or inherent to, a methodology that he has chosen.

Again, it has been stressed that users' similarity judgments are made with respect to very specific and agreed-upon referents. The exact scope of such assessments is likely to be pre-determined by the analyst. It should nonetheless be borne in mind that hardware interface components such as input/output devices – as well as the relationships between these and the actions allowed in the environment – are notable elements within the potential scope of psychological realism/fidelity judgments.

2.2.4 Modality/Perceived Reality of Media Content

> *Modality decisively affects interpretations and responses, so it cannot be ignored in any account of media.*
>
> (Hodge & Tripp, 1986, p. 130)

The concept of 'modality/perceived reality' developed in communications and media studies is at the very heart of my conception of verisimilitude judgments. Media researchers have extensively investigated viewers' attribution of reality to television *content* (for instance, see: Elliot, Rudd, & Good, 1983; Potter, 1988; Hodge & Tripp, 1986; for a review essay, see Chandler, 1997).[52] Although fiction has often been the focus of such investigations, modality/perceived reality studies have actually involved television content of diverse genres including cartoons, news, educational programs, dramas, sitcoms, etc.

2.2.4.1 The Origins of 'Modality'

The notion of modality was developed in classical logic (cf. Kiefer, 1998). C.S. Peirce[53] adopted this concept to "refer to the truth value of a sign" (Chandler, 1994). He identified three kinds of modality: *actuality*, (hypothetical) *possibility*, and *logical necessity* (as in 'given proposition *x*, fact *y* necessarily follows').

Semioticians Robert Hodge and Gunther Kress begin with what seems to be a broader definition of modality, referring to "the status, authority and reliability of a message, to its ontological status[54], or to its value as truth or fact" (Hodge & Kress, 1988, p. 124). When modality is construed in such a broad manner, its domain encompasses *all* judgment-types exposed in the present chapter. From this perspective, 'modality' indicates a wide range of considerations concerning representations, messages, or mediated entities, in regards to truth or reality; Chandler (1994) thus associates modality with diverse notions including 'plausibility', 'credibility', 'truth', 'accuracy', and 'facticity' (in the same trend of thought, realism, fidelity, and psychological fidelity could justifiably be added to this list).

But Hodge and Tripp (1986, p. 104) have stated, also, that "modality concerns the reality *attributed* to a message," (my emphasis). These authors add that:

---

[52] Outside the realm of television, Klein (1992) dealt with audience perception of a non-representational theatre play based on biographical facts about the early life and work of painter René Magritte.

[53] Peirce himself was a logician.

[54] Here, I interpret the expression 'ontological status' as referring to the degree of techno-human mediation involved, and to whether a given representation is live or recorded, staged or spontaneous, computer-generated or not, etc.

> *The modality of a statement is not its actual relation to reality, its truth, falsity or whatever: it is the product of the judgment about that relationship which the speaker makes, wants or enables the hearer to make, and the judgment that hearers do actually make by drawing on their selective reading of the variety of cues that are available as potential bases for modality judgments. Thus it cannot be assumed that modality according to the speaker is the same as for a hearer: nor for different hearers.*
>
> (p. 106)

This emphasis on "attributed" reality is also consistent with the expression '*perceived* reality', a widely used designation for modality in studies investigating perception of television content. In what follows, I examine the modality/perceived reality judgment-type relevant to this research context.

2.2.4.2 The Modality/Perceived Reality Judgment-Type (Applied to Television Content)

Judges

As in the case of psychological realism/fidelity, two types of judges participate in modality judgments (when these are discussed, or made known to others): the analyst (or observer) and the media user (or viewer). Hodge and Tripp (1986, p. 117) have indicated that:

> *Responses to television are themselves messages, with their own modality value, ranging from concrete actions to various dramatizations or expressions by words or other means. Again, the weaker the modality of the response, the weaker the connection to the reality of the responder, and the weaker the emotional charge they express.*

If, like television messages, viewer judgments also 'have modality', then anyone considering those viewer responses must be the judge of *their* modality too (since according to Hodge and Tripp, as we recall, modality is never fixed or absolute, but always attributed by individuals). Thus, viewers judge the modality of media content, and then an analyst or observer, in turn, judges the modality of assessments uttered by viewers. This further justifies the notion of second-order judgment previously explained.

I distinguish two kinds of situations wherein viewers may express modality judgments. First, analysts can ask viewers to give their opinions about television, using Likert scales or other such means.[55] Second, viewers may come to express modality judgments spontaneously, in the course of an activity, a discussion, or (in response to) general questions pertaining to television content.[56] Evidently, this second type of situation comes closer to everyday life.

Nature and Object of Judgment

The scope of modality judgments is *not* determined *a priori*– depending on the viewer's approach, the judgment might bear upon a very limited aspect of the content, several of its elements, or even the television program as a whole. Notice, however, that modality judgments are

---

[55] Participants in such studies are sometimes not even shown specific content– see Potter (1992), for instance.

[56] In this type of situation, logically, the criteria and bases of such spontaneous judgments may only be *inferred* post hoc.

constrained to considerations of *content*, and do not target extraneous elements such as the viewing device itself (e.g., IMAX vs. TV). In contrast, psychological realism/fidelity judgments could be concerned with the hardware (input/output) devices of simulation-based environments.

Again contrary to psychological fidelity, modality does not necessarily entail comparison to a specific and predetermined referent. Indeed, no one necessarily points out to the viewer the entity or entities with regard to which he or she should judge the television content. Most often, individuals interpret and evaluate the televisual representation on its own terms, while relying on their general knowledge of media and reality. Moreover, in contrast to training simulators, many televisual representations have referents that do not actually exist in non-mediated reality. For example, Thomas Magnum, the main character in the 80's American television series *Magnum PI*, does not exist (although there surely are private investigators in Hawaii, the setting of this show).[57] What's more, modality judgments concerning an episode of Magnum PI do not *even necessitate* strict comparison between Thomas Magnum and an actual private investigator.

I link this issue with the diversity of principles which may underlie viewer judgments. Such principles are often designated either as 'criteria', or as 'dimensions' / 'components' of perceived reality (Chandler, 1997; Potter, 1988; Elliot et al., 1983). These include:

- Recognition of absence;
- Constructedness;
- Possibility;
- Probability or Plausibility;
- Existence (physical actuality);
- Genre and consistency within the genre;
- Perceived utility.

Recognition of absence. To paraphrase Chandler (1997), this criterion involves the (very basic) ability to recognize that entities appearing on television are not solid, physically present objects, but simply insubstantial images which are not subject to the same constraints as the former. Chandler points to a relatively small class of viewers *unable* to make such judgments: children under 3 years of age seem to think that a popcorn bowl shown on television will spill if the television set is turned upside down.

Also relevant to this criterion is a viewer's ability to recognize that objects appearing on screen are incontrollable.[58]

Constructedness (cf. Chandler, 1997). This criterion relates to acknowledgment of the television program's ontological status as a construction. Usually, in such judgments, the very nature of the

---

[57] Notice the analogy between these televisual representations and some of the VPLab's tools (e.g., the virtual tape measure), which also have no exact counterpart in reality.

[58] In the case of interactive environments, this would translate as the recognition that on-screen objects cannot be 'influenced' in quite the same fashion as material objects, by touching them with our hands, for example, or by blowing on them.

television program is blamed for a perceived distance between it and reality. Viewers may attribute constructedness to any program, be it a soap opera, a documentary, a news report, so-called "Reality TV", etc. This attribution can take an explicit form, but also an implicit one, when viewers allude to the program's production process– i.e., its script, cast, crew, etc. (as an example unrelated to fiction, viewers might refer to the things that go on in a news room).

Under the heading of *constructedness*, I would also include an aspect which I distinguish among elements of Potter's "magic window" dimension (Potter, 1988, 1992). Certain negative "magic window" judgments entail attribution of an *undetermined* alteration to a phenomenon after it has gone through the mediation process of television. To illustrate this notion, I offer the following propositions taken from a Likert scale used by Potter to study the evolution of teenagers' perception of television reality:[59]

> *– When it comes to sports, TV changes the events it covers so that the events will look better than they really are.*
>
> *– The news would still be the same if it weren't for TV; TV doesn't really make things look different.*
>
> *– When I go to a sporting event, it has the same look and feel as it does when I watch sporting events on TV.*
>
> (Potter, 1992, p. 405)

The idea underlying these propositions is quite similar to the 'recognition of the production process' discussed above. The only difference between the two is that viewer perceptions posited through the notion of 'undetermined alteration' are, by nature, more vague. Indeed, the blame for the 'reality gap' is laid here on television itself, as a medium, while no specific elements of the mediation process are invoked.[60]

In general, the *constructedness* criterion can apply to all genres and contents. Further principles (exposed below) can intervene in a judgment process, even if the viewer has already acknowledged the constructed status of a television program.

Possibility (cf. Chandler, 1997). "Is this possible in reality?" represents the class of issues that viewers using the 'possibility' criterion would address. The answer to such a question can only be 'yes' or 'no'. The viewer may thus evaluate (either in a spontaneous, or a directed manner) whether or not an event or situation presented on television *could* occur in reality, and whether an object or phenomenon presented on television *could* exist in reality.

---

[59] Such propositions are meaningful insofar as they are about television content referring directly to situations which exist or have existed in reality: televised sports events are thus compared to sports events where the spectator is physically present, and the news on television is compared to current events (posited as unmediated by television). This was not necessarily the case for considerations of production process, discussed above, which could also apply to content perceived as fictitious.

[60] This vagueness should *not* be dismissed as a methodological flaw since it appears to be intrinsic to certain modality judgments.

Probability or Plausibility (cf. Chandler, 1997). Viewers who make this type of judgment might be thinking: How *likely* is this event to occur? How *plausible* is this object's existence in reality? How plausible is this character's behavior? How plausible is this entire situation? Answers to these questions vary along a continuum ranging from extremely unlikely (implausible, improbable) to extremely likely (plausible, probable).

It is important to note that situations, objects, and events deemed *possible* (as per the previous criterion) might still be considered *implausible*. Practically speaking, moreover, viewer judgments of *possibility* may sometimes be falsely interpreted as judgments of *plausibility,* and vice versa, because viewers might not use the terms 'plausible', 'likely', 'possible', etc. with the same specificity as analysts.

Existence (physical actuality, cf. Chandler, 1997). This criterion can be made manifest through the following questions: 'Does this event or situation *actually* occur in reality, or has it truly occurred in the past?' and 'Does this object or phenomenon actually exist in reality, or has it existed in the past?' [61]

In logic, 'existence' expresses a stricter requirement than 'plausibility' or 'possibility'; indeed, something that is both possible and plausible may yet not exist. Nonetheless, it is hard to predict the extent to which these three criteria will actually be conceptually disentangled for given media users (or the extent to which they will employ these terms interchangeably for the same constructs).

Genre and Consistency within the genre (cf. Chandler, 1994, 1997). Media content can be classified according to categories called 'genres'. Cartoons, news, dramas, sitcoms, soap operas, and documentaries are television genres. Derek Bunyard has stated that:

> *[...] familiarity with a genre generates a sense of what is plausible within its typical system of representation, while also allowing for the recognition that some aspects of the representation are 'not realistic'.*
>
> (D. Bunyard, personal communication, Apr 30, 2002; Bunyard, 2000)

'Consistency *within* the genre', which relates to internal coherence and adherence to conventions inherent to a particular system of representation, is thus another potential criterion of modality judgments. Chandler (1994) calls this 'generic realism':

> *Viewers familiar with the characters and conventions of a particular soap opera may often judge the program largely in its own generic terms rather than with reference to some external 'reality'. For instance, is a character's current behavior consistent with what we have learnt*

---

[61] In some cases, the 'existence' criterion has complex epistemological implications. Consider, for instance, a documentary discussing 'wormholes' – gravitational phenomena predicted by the theory of General Relativity – for which there is currently no experimental evidence. How does one judge visual representations in such a documentary (supposing that it is *theoretically* accurate) with respect to the 'existence' criterion? People who possess knowledge in this field could judge that such representations are scientifically accurate or plausible, but would still have to admit their *ignorance* concerning the *actual existence* of the representations' referent. In a similar trend of thought, consider the epistemological axiom according to which the *absolute* denial of an entity's existence is a non-empirical and relatively risky undertaking, whereas affirming the existence of given things (the page you are reading, for instance) does not seem perilous at all, by comparison.

> *over time about that character? The soap may be accepted to some extent as a world in its own right, in which slightly different rules may sometimes apply.*

Evidently, genre *itself* can also be used as a criterion in modality judgments (cf. Chandler, 1997). Viewers might automatically assume, for example, that documentaries are more truthful than biographical films involving actors and scripted dialogue.[62]

Perceived utility (Elliot et al., 1983; Potter, 1988). Elliot et al. identify 'personal utility' as a dimension of perceived reality, defining it as "the extent to which the information contained in a program is seen as useful by the viewer" (p.13). In a very similar way, Potter (1988, p. 28) described perceived utility as the degree of "belief in the applicability of television-conveyed lessons to a viewer's own life." He also adds that:

> *Given a particular television program, some viewers should feel that they can learn a great deal vicariously by watching the role models succeed or fail.*
>
> (p. 28)

This criterion is especially interesting for the study of judgments concerning *educational* media, as it does not seem to rest completely on an assessment of the 'substance' of television content with respect to reality, but rather on the *applicability,* in one's life, of information or "lessons learned" through this content. For the same reason however, one might argue, contrary to the authors quoted, that this construct has actually nothing to do with 'perceived reality' itself.

This concludes the exposition of principles underlying viewer judgments. As for principles (and resources) possibly involved in analysts' assessments of viewer judgments, again these vary with the methodologies chosen for the investigation of viewer judgments. When assessing these, a basic question for the analyst is: How valid a picture of the viewer's modality perceptions are we getting from this judgment he or she has expressed? Other important issues might regard analysis across several judgments expressed by one or many individuals.

Bases of Judgment

Hodge and Tripp (1986, p. 118) divide the bases of viewer judgments (which, at times, they call "markers" or "indicators", and at other times "criteria") into two categories: "internal" and "external". Some external elements refer to the viewers' beliefs and knowledge about, or experiences of, reality. There is an obvious link between these and the principles of 'possibility', 'plausibility', and 'existence' explained above: that is, media viewers who apply those principles will rely, at least partly, on such resources.

Naturally, information provided by third parties is also considered "external":

---

[62] But notice that in a biographical film, truthful elements that cast featured persons in an unfavorable light might be revealed, for instance, whereas such aspects might well remain hidden in a documentary produced with the collaboration of subjects.

> *Feshback showed that modality can be affected simply by telling viewers that a film was either real or not, and there are many other ways of influencing peoples' judgments.*
>
> (Hodge & Tripp, 1986, p. 118)

Internal criteria – which have much looser connections to those principles just mentioned (viz., possibility, plausibility, existence) – relate to knowledge concerning *media*, or to specific cues emerging from content. Chandler (1994) calls such cues "formal features" of visual media. Some of these formal features – 3D versus 2D, detailed-abstract, color-monochrome, moving-still, etc. – are very similar to 'visual fidelity' criteria discussed in section 2.2.2.1. One difference, in the present case, is the status of such criteria: viewers' criteria do not follow from some standardization or explicit consensus (as would be the case when criteria emerge from the research activities of experts in a scientific community); another difference is that television viewers do not, *of their own initiative*, go through a predefined list of such items to perform judgments, as would scientific experts. Nevertheless, the vast majority of viewers can, for instance, tell hand-drawn cartoon images from filmed images, and *might* use such distinctions as bases for modality judgments. Other types of "internal" bases include knowledge and awareness of the production process and conventions peculiar to the medium of television (e.g., *genres*, usual visual effects of the editing process, visual conventions used to convey transitions across time and space such as flashbacks, etc.).

Modality judgments have also been shown to depend upon individual competencies or characteristics of viewers, such as age and 'anomia' which indicates "a sense of normlessness and hopelessness [...] highly anomic [viewers] have a lack of information [and] may also lack the motivation to seek information" (Potter, 1992, p. 396). All things considered, some viewers might also be more adept, or more inclined than others to make thorough distinctions within judgment processes.

I recall that analysts sometimes choose to have viewers express their judgments through standardized means, namely questionnaires containing scales involving such principles as discussed above. These too must be considered resources for media users.

Summary

Modality judgments are second-order assessments involving an analyst who 'supports' the judgment process and assesses the judgments of viewers concerning media *content*. It is of chief importance that these informal judgments are *not* restricted to relationships between a representation and a specific, agreed-upon referent. Whereas psychological realism/fidelity judgments (of media users) are sufficiently characterized, generally, by a single principle (similitude to a referent), modality judgments can be performed according to various principles or criteria (e.g., constructedness, existence, plausibility, consistency within the genre, etc.). Viewer judgments are based on elements which have been qualified as "internal" (viz., medium features and knowledge about media), and other elements characterized as "external" (viz., experience or knowledge of reality, information given by third parties).

2.2.5 Credibility of Computer Products

'Computer credibility' addresses broader concerns than the concepts previously exposed. In the last few years, members of the Human Computer Interaction (HCI) research community have focused on the credibility and persuasive virtues of various types of computer products. Such research draws from the fields of communications and psychology for much of its theoretical grounding.

Tseng and Fogg (1999a, 1999b) have reviewed credibility literature (including work unrelated to computers) and developed models of computer credibility. My analysis of the following judgment-type is based on their work. To begin, let me state the first three axioms of credibility which these authors have inferred from their review:[63]

– Credibility means 'believability';

– Credibility is a *perceived* quality:

> *[Credibility] doesn't reside in an object, a person, or a piece of information. Therefore, in discussing the credibility of a computer product, one is always discussing the perception of credibility.*
>
> (Tseng & Fogg, 1999a, p. 80)

– Credibility perceptions "result from evaluating multiple dimensions simultaneously" (Tseng & Fogg, 1999a, p. 80).

2.2.5.1 The 'Computer Credibility' Judgment-Type

Judges

Again, two kinds of judges – user and analyst – participate in the expression of 'computer credibility' judgments, when these are discussed or described. Hence, such assessments are second-order, and can be of a higher order still, when *user* assessments are themselves based upon the judgments of third parties, as in 'reputed credibility' defined below.

The proposition that credibility judgments are at least second order is supported by the two following citations wherein Tseng and Fogg explain "credibility errors":

> *The most notable aspects of this conceptual framework are the two errors. The first type of error is what we call the "Gullibility Error." In this error, even though a computer product (such as a web page)* ***is not*** *credible, users perceive the product to be credible [...] The second type of error*

[63] It seems that there has been little or no work pertaining specifically to simulation-related products, from this perspective (B.J. Fogg, personal communication, Aug 9, 2001).

> *is what we call the "incredulity error"[...] even though a computer* ***is*** *credible, users perceive the product to be not credible.*
>
> (1999a, p. 83 – my emphasis)

> *In contrast,* ***experts*** *face another problem: They may reject information or services from a computer that might have been useful to them–the "incredulity error."*
>
> (1999b, p. 44 – my emphasis)

These considerations suggest that some alternate evaluation of credibility has to be carried out independently from that performed by users, so that its outcome may serve as a yardstick to gauge user judgments. An independent evaluation is necessary if one wishes to claim that users have committed a credibility 'error', given that credibility is by definition a perceived quality; that is, we may ask: "A credibility *error* with respect to what?"

Now, one cannot rely on a yardstick based upon the judgments of expert users because they too can commit errors, as can be inferred from the last citation above. It follows that the analyst must use some other credibility assessment as a yardstick (e.g., his or her own opinion, or some sort of consensual or 'average' judgment).

The notion of 'credibility error' thus entails some normative assessment on the part of the analyst. Although it can be argued that this notion is inherently flawed given the conceptual detours needed to preserve its validity in the face of potential contradictions, it still reveals a strong inclination to judge user credibility evaluations in an active way.

At any rate, as I have previously insisted, judgment gathering, interpreting, and processing are intrinsic to observation and analysis activities. This highlights the agency of analysts in the final (re)expression of user judgments, giving credence to the notion of second-order judgments. Again, the nature of the analyst's contribution and of the resources that he uses depends on his methodological choices and analytical competencies.

Nature and Object of Judgment

User credibility judgments are mainly characterized by two underlying principles (or "key components", in Tseng and Fogg's terms). The first principle is 'expertise', which indicates qualities such as knowledgeable, experienced, competent, intelligent, capable, and powerful.

The second principle is 'trustworthiness'. Tseng and Fogg warn that the word 'trust' bears at least two different meanings in HCI literature. According to the first meaning, 'trust' indicates:

> *a positive belief about the perceived reliability of, dependability of, and confidence in a person, object, or process. For example, users may have trust in a computer system designed to keep financial transactions secure. We suggest that one way to interpret trust [in this sense] in HCI literature is to mentally replace it with the word* ***dependability****.*
>
> (Tseng & Fogg, 1999a, p. 81)

But this meaning is *not* relevant to credibility, in the authors' view. Rather, it is the second use of the word 'trust' – as in 'trust the information', 'trust in the advice' or 'trust the output' – that pertains to credibility. Tseng and Fogg (1999a) propose various terms that can be used to assess trustworthiness of computer products, in this sense. These include 'good', 'well-intentioned', 'unbiased', 'honest', and 'truthful'. I should emphasize that perceived truthfulness, which was also relevant to modality, may now more closely relate – as an aspect of 'trustworthiness' – to considerations of *intent* or *intentionality*. This means in part that the user may make value judgments which call to mind the agency or intentions of the people or institutions affiliated with the technology:

> *The trustworthiness dimension of credibility captures the perceived goodness or morality of the source.*
>
> (Tseng & Fogg, 1999b, p. 40)

Of all the judgment-types considered thus far, credibility assessments have the broadest potential *scope*. It is important to note that like modality judgments, the scope of credibility assessments is not predefined (unless analysts decide to do so), such that users will likely target salient aspects or elements they find important. Tseng and Fogg (1999a, p. 85) propose the following list of targets:

– The *device*: hardware and physical aspects of the product (e.g., the keyboard, mouse, computer screen of a personal computer; the joy-stick of a flight simulator, etc.);

– The *interface*: the display of the computer product and the interaction experience. (On-screen characters are singled out as particularly significant interface targets of credibility judgments.);

– The *functional* aspect, or what a computer product does and how it is done (e.g., performing calculations, services, or processes);

– Any *information output* of the system or product;

– Computer *qua* computer: i.e., the computer itself; [64]

– The product's *brand*: the brand name and company or institution affiliated with the computer product;

– The *expert creator* of the product.

Research quoted by the authors suggests that these potential targets represent categories applied by the analyst rather than by the user himself:

> *[...] people may not naturally separate the credibility of one aspect of a computer from another. Subsequently, the credibility perceptions about one part of the computer – good or bad – will likely affect credibility perceptions of the entire product.*
>
> (Tseng & Fogg, 1999a, p. 85)

[64] Tseng and Fogg (1999a) quote research showing "that evaluations of the computer [itself] are more natural for users than evaluations of the person who created the computer product" (p. 85).

Analysts can nevertheless combine these various targets to the two principles stated above (expertise and trustworthiness) in order to describe the overall nature and object of a user's judgment. One might deduce, for instance, that a user has judged a product by assessing the *expertise* of its *creator*, the *trustworthiness* of the *information output*, etc; users may thus be thought to judge the credibility of a product: by the skills and knowledge which, they perceive, has been applied in creating its features (expertise issues in the credibility of the creator); or the perceived validity, or intent, of the information provided by the product (trustworthiness issues in information credibility); or the perceived validity of the processes through which the product accomplishes what it is supposed to do (trustworthiness issues in functional credibility); etc.

Bases of Judgment

Tseng and Fogg (1999a, 1999b) have outlined four different types of credibility distinguished by that which serves as their basis: *presumed* credibility (based on users' general assumptions or preconceived ideas concerning the product itself, the expert creator, etc.), *reputed* credibility (based on what is reported by third parties), *surface* credibility (based on simple inspection of a computer product), and *experienced* credibility (based on first-hand experience of a product).

Presumed and *reputed* credibility represent aspects not explicitly covered by other judgment-types (with the exception of modality, in certain cases). These types of credibility formally address the social dimension of judgment bases, since general assumptions and third-party opinions are grounded in or emanate from the user's social system (including the user's peer group(s), media outlets from which he obtains information, etc.).

Tseng and Fogg (1999b) also stress the importance of individual resources, such as knowledge regarding subject matter related to application of the computer product (e.g., experimental physics in the case of the VPLab) and knowledge pertaining to the internal workings of the computer product. Additionally, the authors suggest that "ability to process information", "ability to compare various sources of information," and "interest in the issue" at stake in use of the product may also affect the judgment process (Tseng & Fogg, 1999a, pp. 82, 84).

Summary

Like modality judgments, computer credibility assessments are second-order. However, unlike modality, which only applies to media *content*, credibility may target a wide variety of aspects of computer products: hardware, product brand, information, the creator of the product, etc. This is in part due to the fact that the underlying principles of credibility judgments – *expertise* and *trustworthiness* – can address a very broad range of concerns. For instance, as an aspect of 'trustworthiness', perceived truthfulness which was also relevant to modality, may now more closely relate to considerations of intent or intentionality. Another important characteristic of these informal judgments is that their *bases* are also quite diverse (e.g., knowledge of subject matter, cues picked up during simple inspection, general assumptions and preconceived ideas, third-party reports, etc.).

2.3 LOOKING BACK

In this chapter, I have exposed several theoretical aspects of my research. I first described my theoretical approach and defined a judgment model. Using this model, I then analyzed the 'realism/fidelity', 'psychological realism/fidelity', 'modality', and 'computer credibility' judgment-types. Next, I shall synthesize several elements of these judgment-types into a 'verisimilitude judgment' construct.

Chapter 3.

A 'Verisimilitude Judgment' Construct Applying to Interactive Computer Simulation

In the present chapter, I refer to elements of judgment-types previously described to develop a concept of 'verisimilitude judgment' appropriate for the study of users' discourse about simulation. I then contrast verisimilitude with 'presence' and consider the issue of 'willing suspension of disbelief'.

3.1 TERMINOLOGY

Barker (1988) contends that, in discussions of visual media such as television and film, the term 'realism' should be replaced by 'verisimilitude'. First, he argues that the latter is less problematic than the former, as 'realism' has been left "hopelessly value-laden" by centuries of philosophical debate (which I discussed at the beginning of the last chapter). Second, he maintains that 'the quality of *appearing* to be true or real' (i.e., verisimilitude) is a more accurate notion because it "connotes *work*," the necessary process of meaning and value construction in which *both* the encoder and the decoder of the message participate (Barker, 1988, p. 43).[65] This view is congruent with my own, which underscores the agency of judges and the user's role as an interpreter of signs and active participant in the simulation-based environment. I will therefore use the word 'verisimilitude' to designate relevant judgments of users, since this expression has the additional virtue of being more communicative than 'simulation modality', a term that could also have been appropriate.

3.2 DESCRIPTION OF THE SIMULATION VERISIMILITUDE JUDGMENT-TYPE

3.2.1 Judges

It should be evident by now that verisimilitude judgments will be construed as second-order judgments, much like psychological fidelity, modality and credibility assessments (and for the same reasons). To be known, the judgments of students or trainees must indeed first be processed, interpreted, and described by analysts who have their own views of the simulations being used.[66]

---

[65] In French, verisimilitude translates to '*vraisemblance*', a word commonly used to indicate 'likelihood' or 'plausibility'.

[66] My own contribution to overall judgment processes taking place during the empirical study of VPLab users' discourse is discussed in chapter 4.

3.2.2 Nature and Object of Judgment

3.2.2.1 Modality: At the Center of Verisimilitude Judgments

As I have mentioned a few times already, modality/perceived reality is at the heart of my conception of simulation verisimilitude. First off, the expression "quality of appearing to be true or real" can be seen as an accurate interpretation of Hodge and Tripp's general definition of modality, namely "the reality attributed to a message" (Hodge & Tripp, 1986, p. 104).

Furthermore, like viewer modality judgments, user verisimilitude assessments may also be informal and may not necessarily rely on comparisons between the simulation and a very specific, agreed-upon referent. This postulate is suitable to the everyday learning situations relevant to my empirical study because, in such contexts, there are no *a priori* guarantees as to the exact referents that will in fact play a role in students' assessments (see Chapter 1).

Modality criteria can easily be transposed to the context of simulation use– as examples, consider the following (fictive) judgments, concerning a VPLab instrument, associated with five such criteria which I hold to be particularly relevant:

– the criterion of *possibility* (e.g., "This instrument **is impossible** to construct in reality");

– the criterion of *probability* or *plausibility* (e.g., "This instrument could be constructed **but it's highly improbable** that you would find one in a lab");

– the criterion of *existence* (e.g., "This instrument could be made **but I would say that nothing like this actually exists** in reality");

– the criterion of *recognition of absence* (e.g., "I cannot touch or control this simulated instrument directly with my own two hands, so it's not the same as in a lab.")

– the criterion of *constructedness* (e.g., "This is just a virtual instrument and not a real one – it's pre-programmed.")

The last criterion is defined by reference to the simulation's *very nature* as a virtual entity or computer-generated construction fabricated by humans. 'Constructedness' may be acknowledged at any time by the user. As with television modality, this acknowledgment can take an implicit form when, for instance, users refer to the design process, or to modelers, designers, programmers and their roles, with regard to a perceived distance between simulation and reality.

With the criteria of 'possibility', 'plausibility' and 'existence', it is understood that users judge elements which are *already* present (or appear to have been included) in a simulation. It is a different thing altogether, though, for individuals to perceive that something specific *is missing* from a simulation. This extra principle might be dubbed the 'missing entity' criterion. Hennessy and O'Shea found occurrences of students recognizing such specific lacks:

> *[...] children treated the 'cardboard box' simulation as a real world case* ***(occasionally realizing that even quite realistic simulations do not usually incorporate extraneous real-world factors such as 'wind')****.*
>
> (Hennessy & O'Shea, 1993, p. 134 – my emphasis)

In addition to the types of judgments already mentioned, user assessments of the *educational value* of activities performed within learning environments are also pertinent to the present research context, provided that such assessments be made with at least some reference to real-world learning activities. This 'perceived educational value' is analogous to 'utility' which, as we recall, was identified by Potter (1988) as a component of the perceived reality of television.

Of all the modality criteria discussed earlier, 'genre/consistency within the genre' is the only one that has been completely left out of the present discussion. In the context of simulation use, genres could eventually serve as frameworks for verisimilitude judgments of individuals who have been exposed to various types of simulation-based environments. The study of these judgments, however, obviously presupposes the existence and identification of a number of different 'simulation genres'. Yet, outlining such a taxonomy of genres would be premature given the present status of the simulation medium, as computer technology is evolving rapidly and use of simulation by the general public is still fairly limited in comparison to more established media (e.g., novels, television shows, films, or even other types of software).[67]

As a side note, I should mention – in order to avoid confusion later – that systematic classification of user judgments according to the above-mentioned criteria is beyond the scope of the exploratory study described in the next chapters.

3.2.2.2 Relationships Between the Underlying Principles of Verisimilitude and Credibility

A basic relationship between verisimilitude and 'computer credibility' can be established by considering Tseng and Fogg's discussion of the potential importance of credibility for simulation:

> *Credibility is important when computers run simulations, such as those involving aircraft navigation, chemical processes [...] In all cases, simulations are based on rules provided by humans– rules that may be flawed or biased. Even if the bias is unintentional, when users perceive the computer simulation lacks veridicality, or authenticity, the computer application loses credibility.*
>
> (Tseng & Fogg, 1999b, p. 41)

[67] One may hypothesize that video games – such as Microsoft Flight Simulator – relying heavily on complex simulations of existing situations could eventually constitute one such genre. 'Simpler' educational simulations in the form of Java Applets (on the World Wide Web) might constitute another. At any rate, should any taxonomy of simulation genres be elaborated, it would be unwise to assume that *unvarying* determinate relationships exist between genres and the degree of verisimilitude attributed to diverse simulations so categorized. Regarding television, for instance, comedy series might be thought of as less verisimilar than dramatic programs (perhaps due to aspects such as the continuous flow of humorous elements, the way characters act toward one another, the 'laugh track' or reactions from the audience, etc.). Now consider the 70's and 80's series *MASH* set in a Mobile Army Surgical Hospital during the Korean War. It is safe to say that, for some time, *MASH* was construed as a *comedy* series, or sitcom, by almost everyone: it prominently featured humorous elements, a laugh track (for the North American broadcast), etc. Yet reportedly, this series was highly praised for its '*realism*' (notably by viewers who had worked in Mobile Army Surgical Hospitals) because of its authentic-looking sets and (more dramatic) situations perceived as accurately depicting the vicissitudes of life for patients and medical personnel during the Korean War. (In addition, see Elliot et al. [1983] for empirical evidence of attribution, by 'ordinary' viewers, of greater verisimilitude to *MASH*, over TV dramas like *Quincy*.)

The last sentence of this citation bears closer inspection. According to the authors, "when users *perceive* that the computer simulation *lacks veridicality*, or authenticity [this phrase can often be replaced by 'when users perceive that simulated entities/events, or aspects of these, do not *exist*, or are not *plausible*, are not *possible*, etc.'] the computer application loses credibility." The authors are thus indicating a direct connection between "perceived lack of veridicality" (in my terms, lack of verisimilitude) and lack of 'credibility'. I adhere to this point of view, and so I shall treat verisimilitude as a dimension of credibility (and a most important one, at that).

In addition, Tseng and Fogg (ibid, p. 41) argued that:

> *Related to simulations is the computer's ability to help create virtual environments for users. [...] However, virtual environments don't always need to match the physical world; they simply need to model what they propose to model. For example, like good fiction or art, a virtual world or a fanciful arcade game can be highly credible if the world is internally consistent.*

Obviously, this 'perceived internal consistency' principle, albeit relatively loose, is quite analogous to the aforementioned 'consistency within the genre' modality criterion. I would say, moreover, that perceptions of internal consistency are very likely to carry weight with regard to the overall credibility of simulation-based environments like the VPLab.

Lastly, because I have characterized verisimilitude as a dimension of trustworthiness/credibility, I must reemphasize the relevance (in certain cases) of perceived *intent* or *intentionality,* as a characteristic of user judgments. This aspect – which had little or no weight in television modality judgments (or at least in those pertaining to content believed to be fictitious) – also speaks to the agency (and perhaps to the expertise) of individuals and institutions affiliated with a simulation. Such verisimilitude judgments would thus reflect considerable social depth in user perceptions.

3.2.2.3 The Scope of Verisimilitude

In order to characterize the potential scope of verisimilitude judgments, I must first return to the theoretical transition from modality of television content to verisimilitude of simulation. In this shift, provisions must be made with regard to the nature of the simulation medium. One must bear in mind, notably, that television programs, regardless of whether they are assigned to fiction or non-fiction, very often capture a linear or otherwise orderly chain of events. Interactive simulation, on the other hand, may proceed in a much more accidental and uncertain manner, as the user partly determines how the content will be altered, how events will progress, if they will be repeated or omitted– and in doing so, he or she may even commit mistakes. The user's very active, even physical participation in shaping his experience is key. The medium of television, in contrast, does not tolerate detours, accidents and mistakes: flashbacks and bloopers aside, everything is almost always presented in a 'clean' and straightforward manner.

It follows that any conception of verisimilitude resting primarily upon considerations related to a linear or straightforward semiotic structure (as per some construals of 'narrativity') is likely to be inadequate for the study of interactive simulation. Instead, simulation verisimilitude must reflect the specific nature (and implications) of the interactivity and user participation afforded by the medium (see chapter 1). We may recall that the potential *scope* of both psychological realism/fidelity and computer credibility takes the interaction experience into account.

As expected, the scope of verisimilitude judgments is not predefined (unless analysts decide that it should be so), such that users will likely target salient aspects or elements they find important. These may include:

– specific events and objects (or particular aspects of these) presented by the simulation;

– the simulation-based environment as a whole;

– the entire situation involving *both* the environment and the user (including, for instance: the user's own behavior; the nature of his or her activities within the environment; various scenarios wherein the user may encounter simulation objects and events, etc.);

– the *interaction experience*, as well as the software and hardware interface features which make it possible (as per "Device credibility" and "Interface credibility");

– specific information[68] presented in the environment (as per "Information credibility");

– the simulation's very nature as a computer-generated construct;

– other aspects peculiar to given simulation-based environments.

Following Tseng and Fogg (1999a, p. 85), I will assume that the verisimilitude of one aspect of the simulation-based environment may affect the credibility of the entire environment.[69]

3.2.3 Bases of Judgment

It is of chief importance to note that, in actual learning contexts, users of environments like the VPLab most often do *not* have access to the actual objects and situations represented by these environments. Given the variability with which potential referents might be envisaged (see Chapter 1), the concept of 'psychological *fidelity*' (which rests upon the identification of specific referents) is not appropriate to characterize user judgments in actual learning contexts. The domain of verisimilitude, in contrast, must be made to encompass informal judgments of trainees and students who tend to draw upon resources that are readily available to them. Users may thus make verisimilitude judgments based upon:

(a) Their own (potentially limited) knowledge and experience of *whatever they think* is represented by a simulation, as well as general knowledge of subject matter[70] which they perceive as being relevant to the simulation (as per "External modality criteria");

---

[68] Values on digital readouts of measuring instruments are an example of important information presented within the VPLab. Tseng and Fogg (1999b, p. 40) specifically mention that:

> *computer credibility is at stake when computing devices act as measuring instruments [...] Introducing digital measurement instruments to replace analog devices in the 1970s and early 1980s raised questions about credibility.*

[69] This is a very good reason to conduct qualitative studies for which one objective is to evaluate overall credibility of an environment and the factors that may participate in overall credibility judgments.

[70] Examples in the VPLab's case might include knowledge of lab work as well as knowledge of physics and specific concepts under study.

(b) General knowledge and competencies relating to computers (and other media), as well as (more or less limited) knowledge of simulation design, programming, and modeling processes (as per "Internal modality criteria");

(c) Information, opinions and assessments provided by third parties [71] (as per "Reputed credibility" and "External modality criteria");

(d) *Simple inspection* of the simulation-based environment (as per "Surface credibility") or *first-hand experience* of the environment (as per "Experienced credibility") [72]

> Judgments made through simple inspection or first-hand experience of the environment can be based on ***cues*** emerging from interaction with the environment, including, for instance: (1) perceived limitations of, or opportunities afforded by, the environment and (2) distinct aspects, qualities, or physical features of the environment, as perceived by the user (e.g., general visual presentation and graphical attributes of the simulation);

(e) General assumptions, preconceived ideas, or a priori attitudes regarding *simulation as a medium*, the specific simulation-based environment being used, the environment's creators, or the institutions with which the environment is affiliated (as per "Presumed credibility").

In my view, it is very difficult or even impossible, in reality, to definitively isolate **(d)** "Surface" and "Experienced" credibility from **(e)** "Presumed credibility." This important postulate is based on the idea that assumptions, preconceived ideas, *a priori* attitudes, etc., may be at work in a user's verisimilitude judgments even when an 'outside observer' (e.g., an investigator such as myself) has no ostensible evidence to this effect.

3.3 A SUMMARY OF JUDGMENT-TYPES

Table I summarizes elements of the judgment-types exposed thus far, including simulation verisimilitude. It states the field of research concerned by each kind of assessment, the main judge (*Judge*$_1$) and second order judge (*Judge*$_2$) involved in its expression, the underlying principles used by the main judge, the judgment's scope, its bases, and other comments regarding its expression.

---

[71] This too differs from psychological fidelity, which does not seem to account for 'outside influences'.

[72] It seems difficult to define the exact boundary separating surface credibility from experienced credibility. Furthermore, Tseng and Fogg (1999b, p. 43) propose that:

> *experienced credibility may be the most complex of the four types of computer credibility. Because it hinges on first-hand experience with the computer product, such credibility includes a chronological component that leads to a dynamic of computer credibility.*

Table I: Summary of judgment-types

		Field of research	$Judge_1$	$Judge_2$	Principle(s) used by $judge_1$	Scope	Bases	Other comments
First order judgment	Realism/fidelity	Training simulators and other instructional simulation environments	Domain expert or analyst	n/a	Similitude to a very specific referent	- Elements of the simulator, including software content and hardware input/output devices - May take into account the entire situation involving *both* the environment and the user (including user behavior or performance, nature of tasks performed, etc.)	- Formal criteria - Analytical competencies and methods - Extensive knowledge and/or experience of the simulator's referent	Formal assessments
Second order judgments	Psychological realism/fidelity	Training simulators and other instructional simulation environments	Simulation user (student or trainee)	Analyst	Similitude to a specific and agreed-upon referent fixed a priori by the analyst	Scope is likely to be predetermined by the analyst and may include: - Elements of the simulator, including software content and hardware input/output devices - The entire situation involving the environment and the user (including user behavior or performance, nature of tasks performed, etc.)	- Knowledge and experience of the simulation environment and of its referent - Often performed with specific evaluation materials and criteria provided by the analyst	- Often expressed by users who have direct experience of the referent - Relatively formal if evaluation materials and predefined criteria are involved

Second order judgments	**Modality/perceived reality of media content**	Perception of media content (TV programs)	TV viewer	Analyst	- Recognition of absence - Constructedness - Possibility - Plausibility - Existence - Genre and consistency within the genre - Perceived utility	Scope is usually not predetermined, but almost always restricted to elements of content	*External criteria:* - General knowledge and beliefs about (or experiences of) reality - Additional information provided by third parties *Internal criteria:* - Cues (formal features) - Knowledge concerning media	Judgments *not* restricted to relationships between a representation and a very specific referent (the referent does not have to exist in the real world)
	Computer credibility	Human-Computer Interaction (Credibility of computer products)	Product user	Analyst	- Expertise - Trustworthiness	Scope is not predetermined and can be very broad: - Device - Interface - Functional aspect - Information output - Computer *qua* computer - Product brand - Creator of the product	Bases are diverse and may include: - Preconceptions regarding the product, the expert creator, etc. - Third-party reports - Simple inspection of the product - First-hand experience of the product - Knowledge about subject matter related to application of the product - Knowledge about internal workings of the product	- Credibility is a perceived quality - Captures the perceived goodness or morality of the source and may relate to considerations of designers' intents - Social aspects are likely to be important

Second order judgments	**Simulation verisimilitude**	n/a (present work)	Simulation user (e.g., trainee or student)	Analyst	Modality principles (see above)	Scope is not necessarily predetermined and may include: - Elements of the simulation: objects and events presented by the simulation, as well as hardware input/output devices - The entire situation involving both the environment and the user (including scenarios, nature of tasks performed, the user's own behavior, etc.) - The interaction experience - Information presented in the environment - The simulation's nature as a computer-generated construct	Bases are likely to be readily accessible resources and cues, including: - More or less limited knowledge/experience relating to the simulation's *attributed* referents, and knowledge of general subject matter - Simple inspection or lengthier first-hand experience of the environment (cues and impressions thereby obtained) - More or less limited knowledge and competencies relating to computers and simulation - Information provided by third-parties - Preconceptions regarding simulation as a medium, the environment itself, its designers, etc.	- Simulation verisimilitude is linked with trustworthiness (as such, social aspects may play important roles) - Like modality judgments, there are no guarantees as to the exact referents that will play a role in judgments - Users do not necessarily have prior experience with the simulation or its attributed referents - Judgments are likely to be informal

3.4 PRESENCE AND WILLING SUSPENSION OF DISBELIEF

In this final section, I will explain why the verisimilitude framework described above does not include the notions of 'presence' and 'willing suspension of disbelief', both of which might mistakenly be associated too closely with credibility.

3.4.1 Verisimilitude versus Presence

Verisimilitude can – and often should – be considered distinct from the recent, albeit well-known construct of presence, or tele-presence. Initially, this concept was somewhat tautologically defined as "the sense of being in an environment" or "the experience of presence in an environment by means of a communications medium" (Steuer, 1992, p. 76). It is related to the appraisal of efforts in enabling users to be "present" in a space other than that in which their body is located (for instance, in tele-manipulation, immersive Virtual Reality, immersive television, etc.).

Admittedly, this is an important issue, and one which has come up in the course of the empirical study. Nonetheless, it is clearly not my main focus. Although presence may somehow influence verisimilitude (or vice-versa), these two constructs are actually distinct, in my opinion.[73] For one thing, I believe that it is possible for users to feel *present* in a simulated environment *and still* feel that it lacks verisimilitude if, for example, experienced events are not considered plausible or if the environment is not perceived as being internally consistent. Conversely, stronger modality may not always lead to greater tele-presence: content conveyed through print media (e.g., a newspaper article) can be considered very plausible without providing much in the way of tele-presence.

Recently, an effort has been made to integrate verisimilitude-like constructs – called 'social realism', 'perceptual realism', and 'social reality' by some – into multidimensional 'presence' frameworks (see Lombard et al., 2000). 'Social realism', for instance, is assessed with the same kinds of criteria as modality/perceived reality (e.g., possibility of, plausibility of, existence of depicted events– although 'social realism' criteria do not seem to include 'constructedness'). I argue that the use of such criteria within a presence framework raises major problems which further motivate a distinction between presence and verisimilitude.

Interpreting and summarizing discussions that are relevant to the definition of presence (and which transpired on the Presence-l listserv, an electronic forum for announcements and academic discussion related to the concept of presence), Matthew Lombard states:

---

[73] It must be recognized, however, that there is a link between '*presence*' and the '*recognition of absence*' criterion of modality judgments. Still, at least one difference remains between the two, given that modality criteria can be used in retrospective judgments, whereas, to my mind, presence should *ideally* be measured *in situ* by virtue of its very definition (for practical reasons, presence is very often measured retrospectively through questionnaires, but the validity of resulting indicators is questionable in my opinion).

> *Social realism occurs* ***when part or all of a person's perception fails to accurately acknowledge the role of technology that makes it appear*** *that s/he is in a physical location and environment in which the social characteristics correspond to those of the physical world [...]*
>
> (Lombard, 2000 – my emphasis)

This definition of 'social realism' is in phase with Lombard's general definition of presence as "the perceptual illusion of nonmediation." [74] In my view, "failing to accurately acknowledge the role of technology" (i.e., illusion of nonmediation) should not be a *sine qua non* condition in the definition of verisimilitude judgments, or at least not for the sake of empirical investigation. In fact, when it comes time to *measure* user perceptions of social realism *as a dimension of presence*, these presence researchers do not always directly consider the condition of 'illusion of non-mediation' (perhaps because this condition itself may well be impossible to measure directly). Of course, potential connections between verisimilitude and 'transparency or invisibility' of the medium are worthy of study (including the extent to which a person may be aware of the role of technology in creating credible environments). Nevertheless, presence should not be confused, at the outset, with the question of credibility, as such. I believe it entirely possible, in certain circumstances, for a simulated environment (or other mediated experiences) to be deemed credible by users, *without* the medium appearing to be "invisible or transparent."

3.4.2 Willing Suspension of Disbelief

The distinction between presence and verisimilitude having been established, I now turn to the notion of 'willing suspension of disbelief', which was construed by Lombard and Ditton (1997) as a "determinant" of presence, and is articulated in terms that readily evoke credibility (*disbelief*).

It was Samuel Taylor Coleridge who first spoke of a "willing suspension of disbelief for the moment, which constitutes poetic faith" (cited in Compagnon, 1999), thus referring to our state of mind when we read stories or attend plays. I will discuss Coleridge's meaning very shortly, but first let me present Lombard and Ditton's adaptation of this concept to their presence framework:

> *A person participating in a videoconference, exploring a virtual environment, or watching an IMAX film or a television program has chosen to engage in the activity and knows that it is a mediated experience. She or he can encourage or discourage a sense of presence by strengthening or weakening this awareness. If we want to increase a sense of presence for ourselves we try to "get into" the experience, we overlook inconsistencies and signs that it is artificial,* ***we suspend our disbelief*** *that the experience could be* ***nonmediated****. When we want to decrease presence, as when we watch frightening or disturbing media content, we remind ourselves that "this isn't really happening;* ***it's only a movie/TV show/game/etc.****"*
>
> (Lombard & Ditton, 1997 – my emphasis)

It is essential that this interpretation strays from Coleridge's original concept in at least one very significant way. As I understand it, Coleridge did not speak of a willingness to suspend disbelief "that an experience could be *nonmediated,*" but instead of a willing suspension of

---

[74] One way for this illusion to occur, say Lombard and Ditton (1997), is that "the medium can appear to be invisible or transparent and function as would a large open window, with the medium user and the medium content (objects and entities) sharing the same physical environment."

disbelief that a given story is *not fictitious.*[75] (One "willingly suspends disbelief", according to literary theory, in order "to experience other emotional responses" [Laurel, 1991, p. 113].)

Like Coleridge, Hodge and Tripp, who characterized "willing suspension" as a "collapsed modality structure," seem to apply it exclusively to fiction:

> *However sophisticated the modality structures children or adults may have developed, they can still operate with a collapsed modality structure. Coleridge called the process a 'willing suspension of disbelief'. It is a kind of double-think experienced by everyone who enjoys television. It is a recognition simultaneously that* ***the show is unreal, a mere fiction****, and also that it engages with the feelings as though it were real.*
>
> (Hodge & Tripp, 1986, p. 137 – my emphasis)

Lombard and Ditton's shift from fiction to technological mediation is problematic insofar as they do not in any way indicate how willful regard or disregard for *mediatedness* would be relevant to situations wherein one is experiencing technologically-mediated content purporting or believed to be *factual* (non-fiction). In fact, the example given by the authors themselves at the end of the prior citation seems to rely upon fictitious content: "we remind ourselves that "this isn't really happening; it's only a *movie/TV show/game/etc.*" " We might slightly alter this example to consider non-fiction: Would reminding oneself of technological mediation matter as much, say, when watching a report on the six o'clock television news depicting violent acts – a confrontation between a riot squad and demonstrators, for instance – purported to having taken place in a nearby neighborhood? Or when watching a disturbing documentary? Probably not. Though viewing such events on television might not be like witnessing them in person, neither 'suspension of disbelief' nor 'reminding oneself of technological mediation' seems to be pertinent in these cases. (What I have done here is suppose that Lombard and Ditton admit the *fiction/non-fiction* distinction within their framework, which is based on a mediated/non-mediated dichotomy. It seems indisputable that media users sometimes do end up judging content as non-fiction. If this is granted, then Lombard and Ditton's 'willing suspension of disbelief' regarding mediatedness becomes problematic, as just explained.)

From this perspective, Coleridge's concept – even with an attempted change of focus to technological mediation – does not provide much insight into verisimilitude of simulations purporting to be veridical: after due consideration, I reason that this concept can only apply to content *already* judged or accepted as being primarily fictitious. In a related matter, moreover, 'willful suspension of disbelief' often seems to be understood as resting upon simple binary schemes like the following:

(a) either the content is fictitious or it is not;

(b) if it is fictitious, the viewer, reader, or virtual environment user is either aware of this fictitiousness or he is not;

(c) if he is so aware, then he either willfully suspends disbelief or he does not.[76]

---

[75] It is important to keep the negative form to preserve Coleridge's original meaning since he construed willing suspension of disbelief as a "negative faith" (Compagnon, 1999).

In contrast to such a scheme, I argue against construing disbelief as something that can be activated and deactivated by 'throwing a switch'; it is more fitting to think of disbelief as being *rarely* or *never* fully suspended, such that:

(1) *a priori*, disbelief may apply to *any* media content – which is interpreted as containing references[77] to reality, possible worlds, or even impossible but conceivable worlds – regardless of whether or not such content purports to be fictitious;

(2) in such cases, disbelief must *always* be seen as a distinct possibility at the outset– the so-called "suspension," if such a thing ever actually occurs, can be interrupted at any time;

(3) overall, disbelief varies and in some cases it can be expressed along a continuum (as per the 'probability/plausibility' criterion of modality judgments).

I suggest that it might be better, with regard to simulation, to consider a more specific '*partial* willful disregard' for the computer-generated nature – i.e., for the ontological status – of the simulation entities (evidently this relates to the *constructedness* criterion of verisimilitude). An even better way of going at this issue, however, would be to simply replace 'willful suspension of disbelief' (regarding both fictitiousness and mediatedness) by the notion of 'engagement'[78] or 'engrossment'. To do so, we may follow Goffman (1974) who distinguishes between "engrossment" and "an individual's sense of what is real":

> *During any spate of activity, participants will ordinarily not only obtain a sense of what is going on but will also (in some degree) become spontaneously engrossed, caught up, enthralled. [...] Involvement is a psychological process in which the subject becomes at least partly unaware of the direction of his feelings and his cognitive attention. That is what engrossment means.*
>
> (Goffman, 1974, p. 345)

> *[...] these students neglect to make clear that what they are often concerned with* ***is not an individual's sense of what is real****, but rather what it is he can get caught up in, engrossed in, carried away by; and this can be something* ***he can claim is really going on and yet claim is not real****.*[79]
>
> (ibid., 1974, p. 4 – my emphasis)

Individuals can become engrossed or engaged in – or, on contrary, feel disengaged from – *any* activity, not just technologically mediated ones. The conceptual framework developed by

---

[76] In regards to this particular point, Brenda Laurel presents a more nuanced view of 'willful suspension of disbelief':

> *Coleridge noticed that, in order to enjoy a play, we must temporarily suspend (or attenuate) our knowledge that it is "pretend." [...]* ***Pretending that the action is real*** *affords us the thrill of fear;* ***knowing that the action is pretend*** *saves us from the pain of fear.* (Laurel, 1991, p. 113 – emphasis in the original)

[77] Yet this meaning of 'reference' should not be taken so broadly as indicating the sense in which isolated utterances might generally 'refer' to the world. The isolated utterance "Hey, you!" – which can be uttered through some media – might sufficiently refer, in some broad sense, to a real entity (the referent of 'you'), but it is difficult to see how disbelief could apply to it *alone*.

[78] Following Brenda Laurel (1991), Steuer (1992, p. 88) has stated that: "engagement is likened to [...] willing suspension of disbelief." Laurel and Steuer both discuss 'willing suspension' under the heading of 'engagement'.

[79] Lombard and Ditton's (1997) own clarification of their definition of presence, as the '*illusion* of nonmediation', is congruent with Goffman's framework:

> *It should be noted that this illusion does not represent a perceptual or psychological malfunction or psychosis, in which the mediated experience is consciously confused with what is nonmediated or "real." Clearly when asked, users of any current or likely future medium can accurately report that they are using a medium [...]*

Goffman (1974) in *Frame Analysis* applies just as well to theatre, games played by children, buying things in a department store, or any other activity regardless of whether it is technologically mediated or not, staged or not, etc. Engrossment can thus be considered somewhat independently of presence and simulation verisimilitude, and as such, it is a less confounding and more widely applicable concept than 'willing suspension of disbelief'.

This brings us to deeper considerations that further undermine the general usefulness and validity of Coleridge's scheme. Consider that its value is often justified by pointing to audience reactions to emotionally charged content, such as heartbreaking or touching scenes in a movie. We are told, for instance, that for a spectator to shed tears in reaction to such content, he or she must first suspend disbelief– if the spectator responds to the mediated and fictional death of a character in a way resembling that in which he or she would respond to a real death, then he or she *must necessarily* have suspended disbelief. Affective response to content conveyed by media has thus become very closely associated with 'willing suspension of disbelief'.

But this association is actually unnecessary and highly misleading. People sometimes find themselves weeping when listening to music – even recorded music – that evokes great sadness or joy. Just how could disbelief and its suspension be relevant in this case? Not in *any* way, is the most acceptable answer. The listener weeps, I think, simply because such evocative music strongly *resonates* with him. It *engages* him.

Now, let us grant that emotional reaction to movies, TV shows, novels, and virtual environments cannot be very different, in essence, from emotional response to recorded music. It follows that we needn't posit 'willing suspension of disbelief' as a prior condition for affective response, or as a mediator between representations, emotional reactions to these, and emotional reactions to real situations. All we need do here, really, is think in terms of resonance and engagement. That is, an individual will respond affectively to any media content if he or she is engaged in its experience and if it resonates with him or her, very much like in the case of affective response to a moving piece of music; those are the *only* requirements, at this level. We must therefore now conclude that the chief motivation for the notion of 'willing suspension of disbelief' (i.e., to account for affective response to media content) has effectively vanished, a realization which, in addition to arguments given earlier, definitely justifies substituting this concept by 'engagement' or 'engrossment', as defined by Goffman. We are thus freed of any confusion between disbelief (or in-credibility) and engagement.

That said, one may nevertheless ask whether the very expression of a verisimilitude judgment entails disengagement, to some extent, from an ongoing activity involving simulation. Is engagement necessarily disturbed at the instant that a verisimilitude judgment is expressed? It seems reasonable to suppose that this would often be the case; such an issue, however, should itself be the focus of in-depth inquiry, and investigating it would take us beyond the scope of the current discussion. At present, I may yet entertain the notion that engrossment – this *partial* unawareness of the direction of one's feelings and cognitive attention, in Goffman's words – might *partially* 'phase out' or take up cognitive resources necessary for the expression of verisimilitude judgments. A priori, one must nonetheless consider that these assessments (which may apply to any content regardless of whether it purports to be fictitious or not) can be carried out at any time by discerning individuals, unless other factors or constraints prevent or discourage them from doing so.

Finally, I should note that 'engagement' (as a process internal to *ongoing* activity) logically has little bearing, if any, on verisimilitude when media users discuss or think about a mediated experience retrospectively, that is, after the content has been read, viewed, interacted with, or whatever.

3.5 LOOKING BACK

In this chapter, I developed a 'verisimilitude judgment' construct appropriate for studying users' discourse about simulation credibility, and then contrasted it with 'presence' and 'willing suspension of disbelief'. In the following chapters, I will expose a case study that focuses on the verisimilitude judgments of potential VPLab users.

Empirical Considerations

Chapter 4. Methodology

This chapter presents the methodological aspects of the empirical study. I begin by outlining the general approach and main research questions. I then try to portray the contexts in which students would normally use the VPLab, as well as the conditions under which this study was conducted and, in so doing, I discuss various perspectives upon which I drew as a researcher. Lastly, I expose the data-gathering and analytical methods employed, describing the user sample along the way.

4.1 GENERAL APPROACH

This case study is exploratory and serves three purposes. First, it begins to show how verisimilitude can be applied to the study of users' discourse about simulation. By the same token, it is also a means of developing themes of research for future credibility studies involving other simulation-based learning environments. Finally, it provides feedback on choices made by the VPLab design team.

To attain these goals, it is not necessary that all elements of the foregoing theoretical framework be taken to form strict analytical categories, as in some kind of systematic 'tallying' scheme; formal validation of this framework is not a primary objective here. Instead, the concept of *verisimilitude judgment* can serve as an overarching theme for a general exploration of students' discourse. In this spirit, the following questions will guide the study:

(1) What are the main preoccupations and representations that are significant to potential VPLab users in regards to verisimilitude?

(2) What cues enable potential users to make judgments of verisimilitude pertaining to the VPLab and to its use?

(3) What roles do these cues play in potential users' judgments?

Because of the exploratory nature of this study, I have treated these questions as starting points for my investigation, establishing its scope in a broad and flexible manner, rather than tightly constraining it. My approach in addressing them, moreover, is qualitative and descriptive. I aim at obtaining a general picture of verisimilitude judgments concerning environments like the VPLab, and this general strategy is congruent with all of the study's objectives stated above.

4.2 CONTEXTS OF USE AND CONDITIONS OF THE STUDY

4.2.1 Contexts of Use

As mentioned in the opening chapter, only a French language prototype existed at the time of the investigation (spring 2000), and there were no actual users. Designers had nevertheless envisioned the potential user population as comprising college and first-year university students in science or engineering. Such learners might use the VPLab in two different contexts: the first is campus-based education and the second is distance learning.[80]

On campus, students would use the VPLab's virtual experiments to complement regular lab work – or as surrogates for actual experiments difficult to conduct in laboratory settings – and would do so under the supervision of professors or teaching assistants. For distance learners, the VPLab would constitute the principal means by which to learn through experimentation for a given course. In this context, moreover, students would require collaboration and assistance functionalities that were not included in the prototype used for the investigation. The present study therefore better addresses the on-campus situation.

4.2.2 Conditions of the Study

The context of this study was clearly different from that of a course. Subjects each participated in one-on-one sessions during which they individually explored and used the VPLab. Rather than perform a whole virtual experiment, per se, participants engaged in activities *representative* of experimental work. Moreover, this took place at a research facility, rather than in a more natural context (at home or in class). During the sessions, it was also impossible for participants to interact with other students, tutors, and professors. The VPLab would normally be used in a somewhat more 'purposeful' way and with resources like on-line help, a coherent and goal-driven pedagogical scenario (or protocol), tutor assistance, peer collaboration, etc. None of these were provided to participants, mainly because one of the study's aims was to identify verisimilitude cues that would emerge primarily from within the software environment itself. Besides, resources were insufficient to implement a method according to which participants would collaboratively conduct full-fledged lab experiments during an extended period, analyze results at length, and hand in lab reports.

Given these constraints, the solution was to set up sessions wherein students would individually interact with a single simulation, and for a limited amount of time (around two hours). As a result, studying the latter phases of 'experienced credibility' was not possible; I therefore studied its earlier

[80] It is important to note that a given student may take both on-campus and distance courses to fulfill the requirements of his or her academic program. For instance, a science student registered in a campus-based university might take a physics course featuring the VPLab, at the Télé-université.

phases,[81] together with 'presumed credibility', which is related here to *a priori* attitudes toward computer simulation as an educational medium.

The involvement of an interviewer during sessions is another factor that distinguishes the context of this study from more natural contexts of use. I will return to this topic below.

4.2.2.1 Actors, Perspectives, and Observational Stances

I first came into contact with the environment as a usability consultant for the design team. For two years, I advised designers and made concrete recommendations (many of which were implemented), thereby influencing the development of the prototype. I invested much time and effort in the development process and became 'intimate' with the VPLab itself. This intimacy places me in a potentially conflicting position, and this should be borne in mind when considering what follows. On the other hand, this study is not fundamentally about finding the strengths and weaknesses of the environment (as in a usability study), in which case too much intimacy with the system being assessed can constitute a real setback.

At any rate, the work of usability consultant itself often involves advocacy on behalf of potential users, and efforts to anticipate and promote their point of view, such that a certain detachment from the system under development is always highly preferable. I think I have been successful at maintaining such a distance most of the time. It is also the case that 'slipping into the skin' of potential users was facilitated by my own fairly recent experiences as an undergraduate science student,[82] if only because these experiences have provided me with insight into the needs and preoccupations of such learners. What's more, while participating in the project, I was almost always the very first person to 'beta test' new prototypes or features. In this sense, I have sometimes played a role similar to that of an end-user though, it should be mentioned, one who possesses considerable knowledge of design intentions, and one who does not need to attain externally defined learning objectives.

On the whole, I might go so far as to say that my particular standpoint has been a privileged one from which to conduct exploratory research on objects like the VPLab, precisely because I have drawn upon multiple perspectives vis-à-vis such an object. Working closely with designers has been beneficial, in this sense, as it has enabled me to better understand their views on the environment. This deeper understanding of – and intimacy with – the prototype has, for instance, contributed largely to a more complete characterization of the system and of its main metaphor, as laid down in chapter 1.

---

[81] Actual users would normally be in contact with the VPLab for longer periods, measured in days or weeks given cumulative use over several virtual experiments. It is conceivable, however, that first impressions will significantly affect how learners view the environment in the long run, and in that case, it becomes essential to study the earliest phases of experienced credibility.

[82] I hold a minor in physics, which I obtained just three years prior to conducting the user trials.

Seeing the VPLab as a medium between educators-designers and users compels me to contrast these different perspectives with one another. In this mindset and in the context of this study, confronting first-hand knowledge of the designers' outlook to the views of potential users is a sound methodological principle. All in all, my familiarity with the environment and the various actors involved in its development and use can be considered valuable assets with regard to the process of shifting between these diverse perspectives.

4.2.2.2 Relationships and Stress

The main method for which I opted – i.e., to have students interact with the prototype in a 'user trial' format – necessitated that I act as an interviewer/facilitator during sessions. The relationship between an interviewer (who might be suspected of having close ties to expert designers) and a trial participant entails that the former is in a position of power over the latter.[83]

It is also the case that subjects often feel stress during trials, and sometimes act in ways which they think will be looked upon favorably by the interviewer or the designers (cf. Rubin, 1994).[84] Even the mere presence of an interviewer or of a camera can affect the behavior of participants in significant ways.

In a real course setting, evidently, authoritative or asymmetrical relationships also exist between tutors and students, as well as between professors and students, but these rapports do present certain differences compared to the interviewer-subject relationship. A major difference is found in the types of interaction among actors: professors and tutors do not usually watch over students constantly, as will an interviewer or facilitator during software trials. Also, while it is true that students taking a course are put under pressure to perform by educators, their peers, and the educational system, this pressure is different from that which can be felt during software trials. In a course setting, learners must conduct experiments in the allotted time, they are periodically required to hand in assignments (such as lab reports) or pass exams, and their work is usually graded over an extended period; notice, though, that students have little choice but to comply with whatever educators ask of them if they wish to pass the course. Such imperatives tied to formal sanctions did not exist in this study's setting.

What I have striven to do here is describe the general context and conditions of the study, such that one may take them into account when appraising the ensuing results, analyses, and conclusions

---

[83] It is possible, in the present case, that the relationship was leveled out slightly, in terms of authority, if participants perceived that I, the interviewer, was roughly of the same age group as them (the average difference in age between participants and myself was in fact around 3 years).

[84] Accordingly, steps were taken at the beginning of sessions to minimize the effects of authority and stress, as recommended by Rubin (1994, pp. 147-149): participants were offered refreshments; I introduced myself as "a consultant and not a designer"; I expressed my appreciation for subjects' willingness to participate and told them how much their input would help improve the VPLab, regardless of what they answered or how they performed; I encouraged them to be frank, to make comments, to ask questions and to take breaks when needed; I assured participants that they themselves were not being tested and that they could put an end to the session anytime they so desired (the complete script read to subjects before they interacted with the VPLab can be found in Appendix D).

discussed in further chapters. I now turn to the task of detailing the specific methods used during trials.

4.3 METHOD FOLLOWED DURING SESSIONS

4.3.1 Information Given to Participants Concerning the VPLab

Participants naturally learned about the environment's affiliation with the Télé-université (since the trials were held there), which they recognized as a distance learning institution. On the whole, though, participants were given little information on the VPLab itself. First, they were told of its general purpose, that is, "to teach experimental physics." In order to reassure recruits that the subject matter was not too difficult, I also revealed that the prototype featured an experiment in the domain of classical mechanics, and suggested that they had probably dealt with much of the underlying theory in their previous physics courses.

I must point out, however, that the environment's 'realism principle' was *not* mentioned at all. I wanted to start by studying the VPLab's verisimilitude on its own merits (i.e., its intrinsic capacity to appear to be real); it would therefore not have been appropriate to notify participants that the environment had been designed following strong 'realism guidelines'.

4.3.2 Steps of the Data-Gathering Method

The method used to collect data can be roughly separated into three steps: (1) pre-interaction questionnaires/interviews, (2) interaction with the VPLab, and (3) debriefing interview. The total duration of sessions ranged from two to three hours.

4.3.2.1 Pre-interaction Questionnaires and Interviews

In the first step, I used both written questionnaires and verbal interviews in an attempt to detect elements that could influence verisimilitude judgments, but which would do so, in large measure, regardless of the VPLab's specific features. I set out to identify preconceptions that seemed most likely to affect judgments concerning a broad class of simulation-based learning environments. Specifically, I tried to ascertain participants' expectations of what a lab course should involve as well as their preconceived ideas about simulation.[85] Additionally, I gathered background information such as data relating to participants' use of computers (prior experience with video games, in particular), as well as data on general attitudes toward computers.

---

[85] I also attempted to detect *a priori* attitudes toward the Télé-université and its faculty. During the first few interviews however, I surmised that the method I had chosen for doing so was inadequate and consequently, I abandoned this effort early on in the course of the study.

Table II lists the types of information discussed above and the methods through which it was gathered. Regarding my choice of methods at this phase, I used questionnaires and structured interviews with close-ended questions when seeking factual information related to participants' backgrounds (e.g., courses taken in physics), and a semi structured, more open-ended style of verbal interview to probe for opinions and expectations of what a lab course should involve.[86]

Table II: Participant information and methods used for collection

Type of information	Method used to collect data	Appendix containing data-gathering tool
Courses taken in physics and/or courses taken with scientific experimentation-based activities	Telephone interview (structured)	Appendix A: Items 1 to 6
Prior experience with computers, in general	- Telephone interview (structured)	Appendix A: Items 7 and 8
	- Written questionnaire (close-ended)	Appendix B: Question 1
Prior experience with *simulation* and *multi-media applications* that have characteristics similar to those of the VPLab	- *Simulation:* Question asked during the debriefing interview (open-ended question)	Appendix E: Item 5
	- *Multi-media applications:* Written questionnaire (close-ended)	Appendix B: Question 2
Self-assessed computer expertise, and self-reported use of advanced operating system functions	- Telephone interview (structured)	Appendix A: Item 10
	- Written questionnaire (close-ended)	Appendix B: Questions 3 and 4
Self-reported attitudes toward use of computers, in general	Telephone interview (structured)	Appendix A: Item 9
A priori attitudes toward simulation as an educational medium	Written questionnaire (close-ended)	Appendix B: Questions M5 to M10
Expectations of what a lab course should involve	Semi-structured verbal interview (open-ended)	Appendix C: All items

4.3.2.2 Interaction Activities

The second step in my method consisted in allowing subjects to interact with the VPLab. First, a script was read to participants providing them with a general idea of what they would be expected to do, and reassuring them that they would not be evaluated in any way (see Appendix D). At this time, participants were also handed a signed document stipulating: (1) that their identity would be kept confidential; (2) that they would be granted access to any unpublished reports (or references to

---

[86] For expositional motives, the questionnaire pertaining to *a priori* attitudes toward simulation as an educational medium will be discussed in detail, along with collected data, in a further section.

published ones) presenting results based on data collected during sessions; and (3) that all collected data would only be used by VPLab team members, and only for the purposes of the research project (which were plainly stated therein).[87]

Next, subjects were given an example of the 'think-aloud' procedure (which consists in verbalizing one's thoughts and describing one's own actions while performing tasks) and were told how to navigate from one workspace to the other. They then engaged in a series of activities representative of those that novice users would actually perform during an experiment. Many of the activities were exploration-based because of an assumption that novice users working autonomously would mostly use exploration first, as a means of discovering different features of the environment. Also included were typical experimental tasks such as evaluation of uncertainty in measurements.

Below is a summary of the activities that participants were asked to carry out. In a few sessions, latter ones had to be skipped due to lack of time.

Activity 1. Free exploration of workspaces in the air-table experiment: Participants were free to explore the experiment's available workspaces, namely, the Manipulation and Analysis simulation workspaces, as well as the Presentation and Explanation multimedia documents.

Activity 2. Viewing the multimedia Presentation: Subjects were asked to focus on the multimedia Presentation document, which introduces the simulated set-up (viz., the merry-go-round, the air-table, its pump, and the disc) and explains how to control it. If participants had not already done so, they were also told to view the video clip depicting the real experimental setup.[88]

Activity 3. Free exploration of the Manipulation Workspace: Subjects were allowed to explore the Manipulation workspace freely, as they tried to identify what they were seeing.

[For practical reasons, participants were then given a *minimal* description of what the Manipulation workspace simulation was intended to represent, so that any participant who had gross misunderstandings at this point could move on to the next activities without having to overcome too many obstacles. (In hindsight, it seems that very few participants – perhaps only one – actually had such gross misunderstandings.)]

Activity 4. Launching the disk at various speeds: Participants were told to turn on the air-table pump and launch the disk as fast as they could (in some cases the merry-go-round was rotating at this time, and in other cases it was not). Next, subjects were instructed to stop the merry-go-round if it was rotating, to launch the disk as slow as possible, and then to describe its motion.

---

[87] See Appendix F.

[88] In the video clip, a man is shown launching a disk on an air-table placed in a rotating merry-go-round. The trajectory of the disk is seen from both the inside and the outside of the merry-go-round. Among other things, the audio narration identifies both views and mentions reduced friction on the air-table. (In the Presentation document text, information is given to the effect that this video footage was shot at the Palais de la Découverte, located in Paris.)

Activity 5. Recording a sequence of the disk's motion: After having been informed of the possibility of recording a sequence of the disk's motion in the Manipulation workspace, subjects were asked to guess how such a recording could be carried out. If participants failed to determine that it required use of the virtual camcorder, their attention was then directed toward this device (without mentioning the word 'camcorder'). Subjects were then instructed to launch the disk diagonally across the table surface and record a 30-second sequence of motion (while the merry-go-round was not rotating).

Activity 6. Free exploration of the Analysis workspace: Participants were allowed to explore the Analysis workspace freely. They were instructed to describe the things they saw, as well as the activities and actions they thought could be accomplished within this workspace.

Activity 7. Measuring the recorded image of the scale marker in the Analysis workspace: Working on the image that they had previously recorded (and which was now being displayed on the virtual monitor), participants attempted to measure the length of a tile on the merry-go-round's floor, by using the ruler also provided in the Analysis workspace.[89] (Subjects were also instructed to register this measurement in the virtual lab notebook, bearing in mind that it would be required for further calculations.) In order to study their interpretation of the main metaphor, participants were then asked to guess: **(1)** why "20cm" had been inscribed there, in the first place (see detailed explanations on this subject in the box on next page), and **(2)** what the Analysis workspace was meant to represent.[90] Note that the virtual monitor was not labeled.

Activity 8. Anticipating how to measure mean velocities: Subjects were directed to go back to the very first frame of the recorded sequence. Next, they were informed of a device that would allow them to superimpose traces of the disk's trajectory over the currently displayed image frame (as shown in Fig. 1.2). Participants were asked to guess how to activate this device, and were shown the Trace Controller if they had not guessed correctly. They were then directed to *describe* how one could measure the magnitude and direction of the disk's mean velocity (i.e., speed) between two specified positions marked by superimposed traces along its trajectory.

Activity 9. Measuring distances between various positions along the disk's trajectory: Participants were asked to measure the distance between the disk's current position and the position marked by the first superimposed trace. The next directive was to register this measurement in the lab notebook. Participants were then asked to do the same for the next four traces. Their instructions were to proceed as though these data would later be included in a table or graph within a graded lab report, and to bear also in mind that these data could be used in further calculations.

---

[89] The terms "marker," "floor of the merry-go-round," and "virtual monitor's image" were *not* actually used in instructions given to subjects. Instead, they were simply told to "measure the distance between the purple arrows" (see Fig. 4.1).

[90] This is an excellent example of the type of exercise that could be included in a tutorial intended to familiarize novice users with the VPLab's interface. It is thus representative of the hurdles that first-time users would need to jump in order to understand how to perform an experiment.

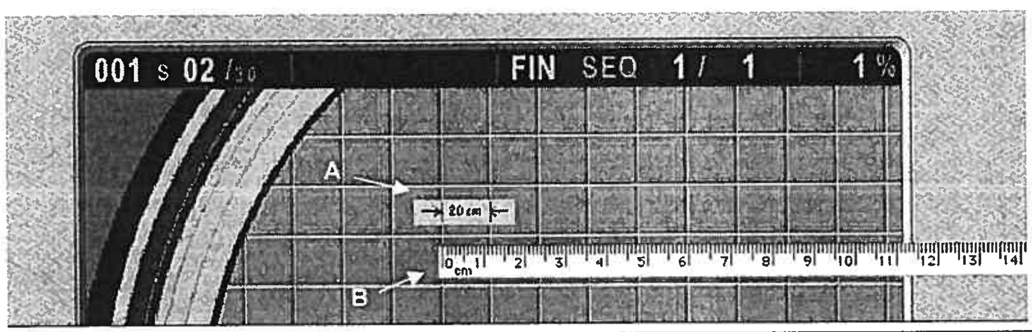
Activity 10 Evaluating the magnitude and direction of the mean velocity vector: As a reminder, subjects were shown the formula for mean velocity, which was explained when necessary. They were also told that the displayed image frames had 1/15 s duration, and that the superimposed traces represented the next consecutive frames when the Trace Interval Indicator was set accordingly (by means of the Trace Controller). Participants were then asked to evaluate both the magnitude and direction of the disk's mean velocity, between its current position and another specified position (i.e. trace) along its trajectory. Finally, subjects were instructed to register the data in the lab notebook as though it would later be included in a graded lab report.

Activity 11 Assessing uncertainty of the mean velocity: Participants were asked to assess the uncertainty of the mean velocity that they had just determined.

Relationship between scale of simulation and scale of measuring instruments (Activity 7)

The merry-go-round floor is made of tiles. As shown in figure 4.1(A), one of these tiles has an inscription ("20cm") which refers to its actual length in the real world. The experimenter can measure the length of the tile's *image*, as displayed on the Analysis workspace virtual monitor, by using the ruler also provided in this workspace: see Fig. 4.1(B). The correct scale ratio of the image, with respect to the real world, may then be inferred by associating "20cm," with the measurement obtained according to the scale of the virtual ruler (1.1cm).[91] (This method is just meant to correspond to the type of real-world procedure that could be used – optical aberrations notwithstanding – to evaluate the scale of the image on a flat TV screen when the physical size of at least one of the filmed objects is already known.)[92] In short, comparing the measurement of the image on the ruler's scale (1.1cm) to the inscription on the tile (20cm) provides the scale ratio of the image displayed on the virtual monitor.

Figure 4.1 A) The (20cm) scale marker; B) The ruler being used (on top of the virtual monitor screen) to measure the image of a tile.



[91] Technically, this is only valid because the simulations are accurately scaled representations of physical phenomena (like topographical maps, design specs, etc.). By including the correct scale marker, the simulations on the one hand, and the measuring tools on the other, are *reciprocally* scaled by designers so that the virtual ruler and tape measure can yield physically meaningful measurements. Even when properly explained, this technical point is somewhat difficult to grasp without direct experience with the VPLab.

[92] Since I wished to study how potential users might interpret and understand the VPLab's main metaphor, none of this was explained to subjects before the debriefing period, and then mostly not before the very end.

Step by step instructions were given *verbally* for all activities described above, with the exception of activities **9** and **10**, for which participants were given somewhat more complex written directives. Participants were also routinely encouraged to 'think aloud' and discuss anything they perceived as either 'strange' or 'familiar'. At this stage, this simple suggestion seemed the most appropriate way of having subjects express judgments of verisimilitude. When participants mentioned an aspect related to credibility, they were sometimes probed on-the-spot (albeit shortly) in order to further understand their thinking.

Before the activities period began, I had warned participants that, apart from initial instructions, I would volunteer very little additional information or help. True, subjects in difficulty were sometimes given clues or minimal explanations, but only to prevent humiliation or excessive frustration, as is ethically required in user trials (cf. Rubin, 1994).

4.3.2.3 Debriefing Interview

The third and last step in the data-gathering method was to debrief participants in order to have them discuss any issues that could not be addressed while they were performing tasks. Given that noteworthy events occurring during the activities period could differ significantly from one participant to the other, and that the exploratory nature of the investigation needed to be accommodated, the debriefing procedure required a fair degree of flexibility. I therefore opted for a semistructured interview style, with themes and questions prepared in advance (see Appendix E), but room for variation and follow-up queries when useful.

The first questions were quite general and open-ended. For instance, I asked subjects how they felt about the VPLab in general, and what they thought of using the environment, in comparison to previous lab work. Participants then answered questions targeting specific dimensions of verisimilitude judgments (e.g., possibility and plausibility) applied to various aspects of their experience with the VPLab (e.g., actions they had performed or objects they had seen and used).

4.4 USER SAMPLE

In qualitative and descriptive investigations with *exploratory* objectives, the user sample does not necessarily have to be very large. Contrary to experimental or correlational research, the idea here is to consider a small number of cases and to look for observations that are essential to each case;[93] one then postulates that, because these observations are essential, they may apply to other similar cases in reality (cf. Pires, 1997).

In forming the sample for such a study, the researcher does not necessarily seek statistical representativeness of populations (generalization is therefore not accomplished through statistical

[93] Though essential to each case, there is no telling at the outset whether such observations will be similar or different from case to case.

inference warranted by a probabilistic sample): rather, he or she may aim for an acceptable degree of diversity with respect to chosen parameters.[94] I shall now give a general description of the present sample, followed by a more detailed one, which will further allow the reader to appreciate the level of diversity achieved.

4.4.1 General Description

As shown in table III, the sample consisted of thirteen undergraduate students majoring, or specializing, in chemistry (5 students), mechanical engineering (4 students), or physics (4 students) at different universities in the Montreal area.[95]

Table III: Major of participants

Discipline	Chemistry					Mechanical engineering				Physics			
Participants	AN	BO	CP	DQ	ER	FS	GT	HU	IV	JW	KX	LY	MZ

All but one participant (subject JW) were first-year students. All subjects volunteered (and were remunerated) for participation in the study. Participants had had no prior contact with either the VPLab or Télé-université.

All participants had previously conducted physics experiments in school laboratories at university level, and had attended lab-based physics courses during the current or previous term. Subject matter knowledge was not assessed through formal means, but some participants did exhibit more knowledge than others about the specific subject matter relevant to the experiment chosen for this study, i.e. forces in rotating frames of reference. Understandably, the physics students had taken more physics courses than the other participants. A number of subjects had previously encountered real air-tables in an experimental context but some of those set-ups were significantly different from the air-table which served as referent for the VPLab's simulation.

Attitudes and expectations toward experimental work were fairly diverse. While some participants claimed to enjoy performing physics experiments, others stated that they did not take pleasure in doing so for two main reasons: lack of theoretical (or technical) knowledge relating to particular experiments, and preference for theoretically oriented activities. Educational benefits expected from experimental work varied a good deal, and included: better assimilation of theory and abstract concepts; an opportunity to verify the validity of theory; gaining appreciation for precision in one's work; learning to be honest in reporting one's work; learning the scientific method, statistical analysis of results, or handling of apparatus; learning how to deal with uncertainty in general, as well as with errors caused by instruments.

---

[94] When a sample is composed of volunteers, due to circumstances surrounding the recruitment of participants, it may prove somewhat more difficult to reach a high level of diversity.

[95] To protect anonymity, each participant shall only be identified by two capital letters.

All participants reported much prior experience with computers and graphical user interfaces, but some were somewhat more confident about their computer abilities than others. There was also a broad spectrum of prior experience with simulation, as shall be shown below.

4.4.2 Detailed Description

In this section, I first present information about self-reported attitudes toward computer use. Next, I show data on self-assessed computer expertise and then display information concerning use of simulation as well as multimedia applications bearing similarities to the VPLab. Finally, I consider subjects' *a priori* attitudes toward simulation as an educational medium. Further information is available in Appendix G, which consists of fairly extensive subject profiles. Note that my purpose here is not to establish statistical correlations between these data and other variables.

4.4.2.1 Self-reported Attitudes toward Use of Computers

Computer-related attitudes are considered factors affecting "both the extent and the manner in which students use computers" (Levine & Donitsa-Schmidt, 1998). The context of this study made it impossible to use a lengthy, valid, and reliable questionnaire just to assess these attitudes. I cannot therefore claim to have *measured* them.

Nevertheless, I did acquire data of a similar yet distinct nature, which helps describe the profiles of participants. Information in table IV was obtained by asking subjects to rate use of computers, in general, on the following 5-point scales:[96]

A)	1- Unpleasant	**to**	5 - Pleasant
B)	1- Useless	**to**	5 - Useful
C)	1- Difficult	**to**	5 - Easy

Table IV thus shows data relating to self-reported attitudes toward use of computers in terms of perceived *pleasantness of use* (A) and *usefulness of computers* (B). It also shows perceived *ease of use* (C) in the fourth column.[97] The meaning of symbols is explained in the area beside table IV.

It can be seen that the degree of diversity of these attitudes ranges from moderate (for perceived *pleasantness of use*) to low (for perceived *usefulness*). Observe that none of the participants gave the lowest rating ('1') on any of the scales and that ratings are relatively high for most subjects. This might be explained by the fact that participants were recruited on a voluntary basis within a population of individuals who use computers, most likely, for many hours a week (see table VIII).

---

[96] French versions of these scales, which are borrowed from De la Teja, Lundgren-Cayrol, and Paquin (1998), were used during the telephone interview.

[97] Levine and Donitsa-Schmidt (1998) suggested that such a construct as *perceived ease of use* (which these authors called *computer self-confidence*) should be treated separately from other computer-related attitudes. They could not definitely conclude, however, that computer attitudes and self-confidence were different psychological constructs.

Table IV: Self-reported attitudes toward use of computers.

Subjects	Perceived pleasantness of use	Perceived usefulness	Perceived ease of use
AN	■ ■	■ ■ ■	■ ■ ■
BO	■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■
CP	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■
DQ	■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■
ER	■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■
FS	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■
GT	■ ■	■ ■ ■ ■ ■	■ ■ ■
HU	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■
IV	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■
JW	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■
KX	■ ■ ■	■ ■ ■ ■	■ ■ ■ ■ ■
LY	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■
MZ	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■ ■

Meaning of symbols

Pleasantness

■ ==> ■ ■ ■ ■ ■
1-Unpleasant 5-Pleasant

Usefulness

■ ==> ■ ■ ■ ■ ■
1-Useless 5-Useful

Ease of use

■ ==> ■ ■ ■ ■ ■
1-Difficult 5-Easy

One way to explore this data judiciously is to look at extreme cases. With respect to this criterion, interesting cases include subjects CP, FS, HU, IV, LY, who gave the maximum rating ('5') on all three scales, as well as subject AN who gave relatively low ratings on all scales. Also worthy of mention is the case of subject GT, whose ratings vary most from one scale to the other, and the case of subject DQ, whose rating for perceived *ease of use* is somewhat lower than his ratings for perceived *pleasantness of use* and perceived *usefulness*.

4.4.2.2 Self-assessed Computer Expertise, and Use of Advanced Operating System Functions

Initially, I had hoped to gather information on subjects' computer expertise with respect to abilities relevant to use of the VPLab. However, obtaining objective information on computer expertise can be a complex and lengthy process. Ideally, one would have subjects perform several tasks representative of the relevant task domains in order to assess their performance.

Since I could not implement such an assessment method in the present context, I gathered data of a different nature, not necessarily tied to actual computer expertise, and having more to do with how a user *perceives* his or her own expertise.[98] Table V thus shows self-assessed expertise relating to computer use in general, and common computer applications.

Information in the second column was acquired during the preliminary telephone interview, by asking subjects to assess their own expertise with respect to use of computers, in general. Information in all other columns was obtained through the pre-interaction questionnaire: participants were asked to assess their own expertise with respect to use of window-based operating

[98] Whether this relates directly to the aforementioned construct of *self-confidence*, as described by Levine and Donitsa-Schmidt (1998), is debatable.

systems (e.g., Windows 95, Mac OS), word processors, browsers, e-mail, and graphics creation or image editing software (e.g., Illustrator, Corel Draw, Photoshop).

The following scale was used: [99]

1 – very weak 2 – rudimentary 3 – intermediate 4 – good 5 – expert

The meaning of symbols in table V is as follows:

■ : very weak ■ ■ : rudimentary ■ ■ ■ : intermediate ■ ■ ■ ■ : good ■ ■ ■ ■ ■ : expert

Table V: Self-assessed expertise relating to computer use in general and to common applications

Subjects	In general	Window-based OS	Word processing	Browsers	E-mail	Graphics creation or image editing software
AN	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
BO	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■	■ ■	■ ■
CP	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■
DQ	■ ■ ■	■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■
ER	■ ■ ■	■ ■ ■	■ ■ ■ ■	■ ■ ■	■ ■ ■	■
FS	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
GT	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■	■ ■	■ ■ ■ ■
HU	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■
IV	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■
JW	■ ■ ■	■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■
KX	■ ■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■ ■	■ ■ ■	■
LY	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■
MZ	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■

Again, it is sensible to look at extreme cases. These include participants with a relatively high 'general' self-rating who also rated themselves fairly high in regards to most types of applications (CP, FS, HU, IV, LY [100]), as well as those with a relatively low 'general' self-rating, who also rated themselves relatively low in regards to most types of applications (AN, ER).

The degree of diversity among participants is fairly high for self-assessed expertise relating to use of e-mail and graphics creation/image editing software; it is lower for 'general' and window-based OS expertise (notice that these two ratings are the same for nearly all of the participants – the exception being subject KX [101] – which might mean that the latter is highly representative of the former); the diversity is even lower for word processing and browser expertise.

---

[99] For self-assessment of expertise pertaining to computer use 'in general', the term "weak" was mistakenly used instead of "rudimentary".

[100] Observe that these are the exact same subjects who gave the maximum rating on all three scales pertaining to *self-reported attitudes toward computers* (see table IV).

[101] KX was following a curriculum that featured more programming courses, which translates to spending more time using programming interfaces.

In the questionnaire, participants were also asked to indicate how often they used four 'advanced' functions of windows-based operating systems (creation of shortcuts on the desktop; use of shortcut keys; drag and drop; software customizing functionalities like macros or changing default options). The following scale was used:

1 – very often 2 – often 3 – occasionally 4 – rarely 5 – almost never

I judged that subjects had not reported considerable use of advanced functions if they answered either **"rarely"** or **"almost never"**. Table VI thus shows the number of functions that each subject reported using, when counted this way. The degree of diversity, here, is low. Still, it is of interest that AN, ER, GT and JW did not use all four advanced functions; there might be a relation between AN's and ER's lower self-assessments shown in table IV and their reports of less frequent use of advanced functions in window-based operating systems. This seems to point to a lower level of expertise on their part.

Table VI: Use of 'advanced functions' in window-based operating systems (self-reported)

Subjects	Number of advanced functions used 'very often', 'often', or 'occasionally'
AN	■ ■
BO	■ ■ ■ ■
CP	■ ■ ■ ■
DQ	■ ■ ■ ■
ER	■ ■ ■
FS	■ ■ ■ ■
GT	■ ■ ■
HU	■ ■ ■ ■
IV	■ ■ ■ ■
JW	■ ■ ■
KX	■ ■ ■ ■
LY	■ ■ ■ ■
MZ	■ ■ ■ ■

4.4.2.3 Prior Use of Simulation and Multi-media Applications Bearing Similarities with the VPLab

In order to have an indication of predispositions to perceiving the VPLab as strange or novel, I sought to find out if participants had previously encountered applications bearing similarities to it. Table VII lists simulation applications previously used by subjects. There was a wide range of prior experience with simulation: for instance, AN reported having no prior experience whatsoever with simulation, whereas IV had tried out industrial flight simulators.

Table VII: Prior experience with use of simulation (self-reported)

Subjects	Prior experience with simulations
AN	No prior experience
BO	Realistic video games; Social science simulations
CP	Realistic video games (but no experience with simulation in an educational context)
DQ	SimCity *
ER	SimCity; Small educational programs in physics
FS	Realistic video games; Numerical (non-visual) simulation with MAPLE software; Design of mechanical component simulations, using Computer Assisted Design (CAD) software
GT	Realistic video games; Design of mechanical component simulations, using CAD software
HU	Realistic video games; Design of mechanical component simulations, using CAD software
IV	Industrial flight simulators; Design of mechanical component simulations, using CAD software
JW	Small physics simulation
KX	Realistic video games (no experience with simulation in an educational context)
LY	SimCity; Highly realistic video games; Much experience with MAPLE software
MZ	Little experience except for software simulating motion of stars

* SimCity, a popular video game, is basically a simulation of a city and its problems. The player acts as mayor. This game has been praised for its realism and has sometimes even been used in educational contexts.

Elsewhere, participants were also asked to indicate, on the scale below, how often they used the following multimedia applications:

– video games;
– graphics creation or image editing software (e.g., Illustrator, Photoshop, Coreldraw);
– animation software (e.g., Director, 3D studio);
– web sites containing video or animation.

1 – very often **2 – often** **3 – occasionally** **4 – rarely** **5 – almost never**

Table VIII presents reported use of these types of multimedia applications. I assigned **very often / often / occasionally** to a category named '*More*' and **rarely / almost never** to a category named '*Less*'. The last column displays total weekly use of computers.

Table VIII: Use of multi-media applications bearing similarities to the VPLab (self-reported)

Subjects	**Video games**	**Graphics creation or image editing software**	**Web sites containing video or animation**	**Animation software**	Self-reported weekly use of computers, in general (hours)
AN	*Less*	*Less*	*Less*	*Less*	6 to 12 hrs.
BO	*More*	*Less*	*Less*	*Less*	6 to 12 hrs.
CP	*More*	*More*	*More*	*Less*	more than 12 hrs.
DQ	*Less*	*Less*	*Less*	*Less*	more than 12 hrs.
ER	*Less*	*Less*	*Less*	*Less*	more than 12 hrs.
FS	*More*	*Less*	*More*	*More*	more than 12 hrs.
GT	*More*	*More*	*More*	*Less*	6 to 12 hrs.
HU	*Less* *	*More*	*Less*	*More*	more than 12 hrs.
IV	*Less*	*Less*	*More*	*Less*	6 to 12 hrs.
JW	*Less*	*Less*	*Less*	*Less*	1 to 5 hrs.
KX	*More*	*Less*	*Less*	*Less*	more than 12 hrs.
LY	*Less* *	*More*	*More*	*Less*	more than 12 hrs.
MZ	*Less*	*More*	*Less*	*More*	more than 12 hrs.

The diversity among participants is high for video game use, slightly lower for use of graphics creation/image editing software and web sites containing video or animation, and lower still for use of animation software.

Looking at extreme cases, it can be seen that AN, DQ, ER and JW reported '*less*' frequent use of all four applications (with JW reporting less weekly use of computers in general), whereas CP, FS and GT reported '*more*' frequent use of three out of four applications (with CP and FS reporting greater weekly use of computers in general).

* During their debriefing interviews, subjects HU and LY mentioned that they had played realistic video games, as shown in table VII. Their answers to the questionnaire might just indicate that they had not played video games very often *during a relatively short period preceding their participation in the study.*

4.4.2.4 A priori Attitudes toward Simulation as an Educational Medium

Because I felt that users' preconceived ideas concerning simulation could serve as bases for credibility judgments, I set out to investigate these beliefs. To this end, I developed a novel method with which to evaluate participants' *a priori* attitudes toward simulation (as an educational medium), and more specifically the degree to which these attitudes were either *favorable* or *unfavorable*.

This procedure involved questions containing descriptions of various pedagogical situations, each accompanied by 5-point scale items (see Appendix B: Questions M5 to M10). Through these questions, participants were first asked to express confidence levels toward *simulation* in these situations, and then shortly thereafter, they were asked to express confidence levels toward *other alternative educational media* (video clips or training equipment) in those *exact same situations*. I made comparisons within pairs of near-identical questions involving simulation on the one hand, and the alternative medium on the other hand.

Tables IX and X present classifications of the participants according to the results of the process just described (see Appendix H for details). This information allows me to evaluate how credible simulation was to participants, as an educational medium, even before they inspected the VPLab.[104]

Both tables show a moderate degree of diversity amongst participants, with regard to these preconceptions. Note that it is more prudent to consider tables IX and X separately because these classifications are based upon two sets of indicators involving distinct baselines– participants' attitudes toward *video clips* were used for the first set, and their attitudes toward *fairly rudimentary training equipment* were used for the second. I strove to establish baselines appropriate for each type of pedagogical situation presented in the questionnaire (convincing students during a lecture, and training operators for various tasks). The two categorizations are wholly meaningful in their own right, insofar as the specific baselines are deemed adequate for each type of situation.

Table IX thus presents a classification of participants according to their *a priori* attitudes toward simulation **in comparison to *video*, when used to illustrate physics concepts**. This classification was derived from answers to questions involving situations wherein a teacher would try to convince skeptical students of the validity of a counterintuitive physics concept during a lecture.

---

[104] I had originally intended to verify that the questionnaire answers (and the resulting indicators contained in Appendix H) could be considered reliable, by discussing them with participants during the debriefing period. Such discussions did take place, but I subsequently realized that two shortcomings would invalidate this 'triangulation' process. First, because I was forced to discuss these questions at the very end of the debriefing period in order to prevent influencing other judgments, there was a significant probability that participants' reactions to their own questionnaire responses would themselves be influenced by prior events. Second, I realized, after the fact, that readjusting or correcting questionnaire responses (on numerical scales) by drawing on participants' discourse exclusively, would be unfeasible. Nevertheless, the very idea of using such a questionnaire as a pretext for discussing these attitudes remains interesting. To illustrate this process, excerpts of debriefing discussions about questionnaire responses were included in Appendix G (see footnotes 4, 7, 11, 14, 17, 20, 21, and 22). Again, it is important to stress that, for reasons just given, these cannot be used to validate or readjust questionnaire answers in the present case.

Table IX: ***A priori*** **attitudes toward simulation (in comparison to video) when used to convince skeptical students of the validity of counterintuitive concepts**

A priori **attitude toward simulation**		
Unfavorable	**Neutral**	**Favorable**
DQ, ER, FS, GT, HU, IV, KX, MZ	AN, BO, JW	CP, LY

Table X presents a classification of participants according to their *a priori* attitudes toward simulation **in comparison to use of training equipment** (i.e., real equipment, though more rudimentary than that needed for the actual task), **for skill training**. This classification was derived from answers to questions involving the expression of confidence in operators training for various tasks.

Table X: ***A priori*** **attitudes toward simulation (in comparison to real, albeit simple equipment) when used for training**

A priori **attitude toward simulation**		
Unfavorable	**Neutral**	**Favorable**
DQ, HU	AN, GT, JW, MZ	BO, CP, ER, FS, IV, KX, LY

Let me reiterate that the two types of attitude were evaluated with reference to different baselines. In light of this fact, if one wishes to consider both types, interesting cases can be specified as follows:

- participants *unfavorable* to simulation in *at least one* of the two cases (DQ, ER, FS, GT, HU, IV, KX, MZ).
- participants *unfavorable* to simulation in *both* cases (DQ, HU)
- participants *favorable* to simulation in *at least one* of the two cases (BO, CP, ER, FS, IV, KX, LY)
- participants *favorable* to simulation in *both* cases (CP, LY)

Evidently, it would be interesting to further investigate such attitudes with larger user samples. In regards to credibility, some might expect students to be generally unfavorable, a priori, to simulation as an educational medium. To my knowledge, no study has specifically examined this issue although, in a fairly recent paper, Cartwright (1998) anecdotally reports:

> *[...] students knew that the data were computer-generated, and perhaps because of this, they always seemed to perceive such data as being less "real" than anything that came out of the back of a spectrometer.*

Indeed, I did find students who exhibited such unfavorable *a priori* attitudes toward simulation (e.g., DQ and HU), but I also encountered favorable *a priori* attitudes (e.g., CP and LY).

4.5 ANALYTICAL METHODS

4.5.1 Recordings and Transcripts

Two simultaneous recordings of sessions were made. A camera taped video and audio tracks of participants seated at the computer and engaging in activities or discussing with the interviewer. At the same time, a VCR also recorded a direct video feed from the computer, thus capturing a full screen view of what subjects saw and did within the VPLab while performing tasks during the activities period.[105]

Verbatim transcripts of the recordings were produced, including copious descriptions of both video tracks (which were integrated, within brackets, to the transcribed speech). The transcribed text files were loaded into Atlas Ti™, a software package used for advanced qualitative analysis, but employed here only for indexing purposes (i.e., to gain faster access to interesting excerpts); no analytical processing of coded excerpts was performed with the package.

4.5.2 Analytical Process

A crucial element of this study's analytical approach is that each participant was first treated as an autonomous case. I initially examined each transcript in isolation – as though it constituted material for an individual case study – locating all excerpts pertaining to verisimilitude. This yielded results on a first level: based on a majority of these excerpts, I wrote fairly thorough accounts of each session wherein I attempted to reconstruct the judgment processes of subjects. Those individual accounts, contained in Appendix I, are very instructive because they offer a focused view of specific credibility concerns for each of the 13 participants;[106] such treatment is highly congruent with the aforementioned principle of searching for elements essential to each case.

Throughout this initial analysis, I also flagged judgments and cues as 'more important' or 'less important': that is, I tried to identify elements that had made the most impact on verisimilitude for each of the participants. Such a process was admittedly subjective; this is not to say, however, that I had no criteria for gauging the importance of these items. To some extent, I looked for issues and cues that had been *spontaneously* evoked by participants during the session, as well as those mentioned when subjects were asked general questions relating to overall credibility of the VPLab. Importance of issues and cues was also sometimes discussed explicitly during the sessions. Tables XI and XII, presented in the next chapter, display a significant sample of the results of this process.

---

[105] A redundant audio track was recorded for synchronization purposes.

[106] With this exposition, judgments are presented in their original context, when possible, thereby conveying added detail and nuance. In addition to Chapter 5, interested readers should consult these accounts to get an idea of how various verisimilitude judgments and cues relate to each other within individual sessions, and to obtain further information concerning specific judgments.

The second analysis phase consisted in qualitative comparison of judgments, based on material in both the individual accounts and the original transcripts. To create subtitles within the individual accounts, I had previously identified sections of text with labels corresponding to aspects of participant/VPLab interaction relevant to the various judgments considered; I thus simply regrouped elements from different accounts that had been placed under similar headings, and proceeded to compare them, sometimes going back to the original transcripts for additional material. In this analysis, I confronted both similar and diverging judgments to one another (seemingly favorable judgments to unfavorable ones, for instance), essentially identifying and contrasting their various bases.

4.6 LOOKING BACK

In this chapter, I have covered the methodological elements of my exploratory study, detailing its context, general approach, user sample, data-gathering techniques, and analytical processes. In the next chapter I shall expose, interpret, and discuss my observations.

Chapter 5. Results

I have organized the discussion of results around important issues linked with various aspects of the VPLab. In keeping with the study's exploratory aim, I endeavored to tackle a wide diversity of themes and to present a detailed exposition of observed differences between various cases.

Compared to the individual accounts in Appendix I, the following exposition allows a more general and contrasting view of verisimilitude judgments expressed by all participants. On the whole, I have found that verisimilitude judgments can be quite complex. These judgments (and the cues involved) may vary considerably from one subject to the other. Concerns that appear to be crucial for some participants do not stand out for others. Even when participants show the same concerns, it is not uncommon for their judgments to be contradictory or to involve significant nuances relating to other preoccupations.

This idiosyncrasy has been observed several times and for a variety of issues. Individual traits of participants (e.g., interests; attitudes; aptitudes; experience with lab work, computers and simulation; knowledge of subject matter; etc.) appear to have been important factors influencing verisimilitude judgments. In what follows, I have tried, whenever possible, to describe individual traits that seem to matter in specific verisimilitude judgments expressed by participants. Among different types of individual traits, *a priori* attitudes toward simulation, prior experience of lab work, and prior use of certain computer applications figure prominently.

In the course of my investigation, I encountered credibility concerns that had little or nothing to do with specific characteristics of the environment. One such matter dealt with the feeling of *presence* (or tangibility) in the simulated environment; because the general subject of presence in virtual environments has been studied to a fair extent in the past, I will not address this concern here. Another such issue was rather related to user judgments based on the VPLab's ontological status as a simulated environment– i.e., the environment's very nature. I discuss this topic first.

I then go on to examine a host of important issues concerned with verisimilitude judgments that involve specific cues which emerged from the VPLab environment itself. These issues relate to video-clips of real experimental set-ups, to the behavior of simulated apparatus, to the VPLab's main metaphor, to graphical attributes and visual presentation of the environment, to measuring instruments and their precision, to perceived freedom and control within the environment, to discursive cues present in the environment, and to user anticipation of relevant pedagogical objectives.

5.1 ONTOLOGICAL STATUS OF SIMULATIONS

In this section, I describe observed expressions of *lack* of credibility specifically linked with the VPLab's ontological status as a simulation environment. These judgments involve the *constructedness* criterion of modality judgments; they cannot be associated with any particular cue emerging from the environment, but are instead inherently tied to the VPLab's very nature.

I suggest that such lack of credibility can vary across a spectrum which ranges from the least radical to the most radical. One example of the least radical type was expressed by subject LY:[107]

> *[...] you'll always have limitations: is this really representative of the theoretical model? What's behind this [simulation] to make [the disk] move like that? Did [the programmer] take a formula and simplify it to allow for nice motion? [...] That's what bothers me: you have this software but you can have it do anything you want. [...]*
>
> *Of course, you tell yourself that [the teachers] are teaching a class so they won't hand you any old thing. Even so, they always tell you to act as if [what is being taught] isn't true until they prove it to you [...] they say that you should always ask yourself questions concerning what the teacher is saying: maybe he's saying nonsense. With [the VPLab], you can't really question things because there's an [intrinsic] limit in using the program itself: if you start to question things at home like that, you lose the whole principle of using the software.*
>
> *You don't know [in the case of the simulation] if the programmer has taken the time to include everything – to really consider all the theoretical aspects and do the correct calculations – or if he just shoved the whole thing, and said: "Here, this is what it'll do". [Maybe] a whole table has already been written up so that when such or such thing happens, [the disk] automatically goes the other way... Or, does it really work with a formula, with all values truly changing according to reality?*
>
> [citation 1]

Through his[108] comments here, subject LY addresses the issue of the underlying model's design, in relation to his own tendency to scrutinize what teachers expose in class. He asks a crucial question: If students should always start by being skeptical of what teachers expose, then why *should* they blindly trust instructional simulations at face value? In my opinion, this participant is just manifesting a 'healthy' skepticism toward simulation models. It seems to me that students, such as LY, who have computer science knowledge, might be inclined to display such attitudes.

Another case of the *least* radical types of judgment is exemplified by subject BO's attitude. This participant spoke of "the software taboo": he believed that the most important obstacle to the success of the VPLab would be a lack of credibility that could occur if users felt that they were "just pawns in a game" and that everything within the VPLab had been pre-programmed to react in a determinate way when users followed a pre-determined path. Since this apprehension seemed to be successfully countered, in BO's case, by the presence of video clips "showing the experiment done

[107] Participant citations were translated from French. The original citations, referenced by a number between brackets (for instance, *[citation 1]* in the above quote), are listed in Appendix J.

[108] Masculine pronouns and adjectives are used throughout for both male and female participants. As a precaution, I have chosen to conceal gender in order to inhibit unwarranted associations between certain attitudes and gender.

with real objects" and by the possibility of free interaction with the simulated apparatus, I believe that his ontologically-related judgment was of the least radical type. BO thus stated:

There is programming but it respects what happens in real life.[109] [citation 2]

At the other end of the spectrum, I found the most radical judgments, one of which was expressed by subject DQ. It can be interpreted as a claim that there is an (undetermined) alteration caused by mediation of the experiment through the simulated environment:

***DQ**: [...] When you're on a computer, it's not real. I think that's the biggest difference between the two.* [...]

***Interviewer**: What would you think of a [virtual reality] lab where you could manipulate things using gloves? There would be objects... and there are gloves that give you tactile sensations. I was wondering if the problem [with the VPLab] was that you were working with a mouse and a keyboard or if it would be the same [problem] for you with a helmet and gloves?*

***DQ**: It would be the same. It remains imaginary... well, imaginary, in a way of speaking. It's not imaginary but it's not real.* [citations 3 and 4]

Another variety of radical-type judgment was expressed by JW. He brought up the question of simulation being vulnerable to tampering. There was also a link with the question of tangibility:

JW**: [...] I think that there are some things which, even if you see them here [in the VPLab], you'll have the impression that they could be fully tampered with. For instance, when we watched the disk move in the video clip, you could see that it was real, but [...] it seems less real in the computer, when it's not a video clip. When you do it in a lab, you see it with your own eyes. Here [with the VPLab], you see it [...] **but it's a machine that has done it all.

***Interviewer**: So it's the medium itself?*

***JW**: Yes, it's the fact that I don't do things with my own hands – that I don't really look upon it...* [citation 5]

Somewhere in the middle of the spectrum of ontologically-related judgments are conceptions like the ones displayed by ER, GT, IV, and KX. These participants exhibited *expectancy of ideal conditions* within the VPLab. For instance, subject ER expected that physical factors (a piece of pencil lead on the air-table, for example) which could cause experimental results to stray dramatically from theoretical predictions, would be absent from the VPLab simulation:[110]

[...] maybe such and such physical factor should be taken into account. I don't know... the window was open and a draft blew over my setup; but here [in the VPLab], you won't find that. [...] It's a computer, [so] everything goes well... [citation 6]

One may ask if there is a connection between unfavorable *a priori* attitudes toward simulation as an educational medium (see tables IX and X) and the occurrence or the radicalism of negative judgments based on a simulated environment's ontological status.

---

[109] Notice that subject BO *fully acknowledges* the role of technology (programming), but *still* considers the environment as verisimilar. The existence of such judgments is the reason why Lombard's criterion of 'illusion of non-mediation' (see Chapter 3), as included in his definition of *social realism* (Lombard, 2000), cannot be used in a valid operational definition of verisimilitude.

[110] Rather than the term 'absent', ER used the word 'impossible'.

To examine this question, let us start by considering the aforementioned cases of subjects DQ and JW, both of whom expressed the *most* radical kinds of (negative) ontologically-related judgments. On the one hand, subject DQ was one of two participants (HU is the other) who had exhibited unfavorable *a priori* attitudes toward simulation with respect to *both* of the situations presented in the preliminary questionnaire (convincing students in a classroom, and operator training). Hence, DQ's case supports the hypothesis of a connection between unfavorable *a priori* attitudes and negative ontologically-related judgments. On the other hand, subject JW's *a priori* attitudes toward simulation were *neutral* with respect to both of the questionnaire situations, so his case does not lend credence to the hypothesis (although its significance is somewhat mitigated since JW's *a priori* attitudes are neutral rather than favorable).

Next, let us discuss BO's and LY's statements classified as the *least* radical kind of ontologically-related judgment. Since these judgments were not radical at all, one would expect BO and LY to present *a priori* attitudes tending toward neutrality, if not approval, and indeed such is the case (see tables IX and X). LY even counts as one of two participants (the other being CP) who exhibited *favorable* attitudes with respect to *both* of the situations presented in the preliminary questionnaire.

Finally, consider the statements of subjects ER, GT, IV and KX who expected ideal experimental conditions within the VPLab (recall that those statements were classified somewhere between the least radical type of ontologically-related judgments and the most radical type). Observe that all of these participants displayed unfavorable *a priori* attitudes toward simulation with respect to one of the situations presented in the preliminary questionnaire (convincing students in a classroom), but not the other (operator training). I see two valid, albeit opposite, ways to view these facts: either (a) these cases do not support the hypothesis of a connection between these types of judgments and *a priori* attitudes toward simulation, or (b) they do support this hypothesis and, if so, one must suppose that the unfavorable *a priori* attitudes toward simulation with respect to the first situation matter most in such instances. Proposition (b) becomes more plausible when the following additional case is considered: as I mentioned, subject CP displayed *favorable* attitudes toward simulation with respect to *both* of the situations presented in the preliminary questionnaire and, contrary to the participants mentioned above (ER, GT, IV, KX), it so happens that he expected to encounter ***non***-ideal experimental conditions within the VPLab.

In view of the majority of the cases stated above, I believe that there may be a link between the expression of negative judgments based on a virtual environment's ontological status and the presence of unfavorable *a priori* attitudes toward simulation. An important and more general conclusion suggested by the data would be that preconceived ideas influence credibility judgments, and that this influence seems to be somewhat independent of concerns linked with cues emerging from the simulated environment. Related to this is the finding that students (e.g., subjects BO and LY) may make judgments of constructedness and still find a virtual environment credible.

I must also mention that some participants (e.g., FS, JW) predicted that simulations like those of the VPLab would be more vulnerable to disbelief in situations where the simulated apparatus' behavior is strange or counter-intuitive. I can, however, point to a significant counter-example through a specific account concerning subject HU.

In the Analysis workspace, HU examined the disk's motion by measuring distances between successive positions in the disk's trajectory (which corresponded to successive time indexes). During this exercise, a very interesting event occurred: HU obtained a measurement that *ran counter to his expectations*. He then rationalized the existence of this seemingly anomalous result by saying that it was *normal to encounter it* since he was involved in "*practical work*".

Insofar as subject HU had exhibited unfavorable *a priori* attitudes toward simulation with respect to both of the situations presented in the preliminary questionnaire, it is fairly significant that he would *not* blame the VPLab's simulation for this seemingly anomalous result. What's more, during the debriefing interview, HU even went so far as to say that it was he, and not the simulation, who would be at fault if he were to obtain final experimental results radically straying from theoretical predictions (he also asserted that he was usually at fault when this happened in an actual lab). He claimed that he would *not* expect the computer to make mistakes.

Subject HU's statements may thus indicate that it is possible for students having unfavorable preconceptions of simulation, to be 'won over' by simulated environments, eventually regarding them as credible.

5.2 AN OVERVIEW OF IMPORTANT CUES AFFECTING OVERALL VERISIMILITUDE

Below, tables XI and XII present an overview of verisimilitude-related concerns for which I found relations to specific cues emerging from the simulated environment. In preparing these tables, I tried to identify the cues that had made the most impact on verisimilitude for each of the participants (criteria for gauging importance of cues were given in the previous chapter). Most of the cues and themes presented here are analyzed in greater detail later; other ones not included below will also be tackled. My first finding here is a simple one: different cues and aspects of the simulated environment matter more or less to different individuals. In considering these results, bear in mind that they merely represent a sample (albeit, a significant one) of my observations.

Table XI presents cues connected to positive verisimilitude judgments, whereas table XII (on page 101) presents cues connected to negative ones. Observe that descriptions found in the last column reflect *the judgments of subjects* and not those of the author. It is also essential to note that a given cue may have had a positive effect for some subjects, but a negative effect for others. For instance, one subject (GT) complained about the lack of precision that was induced by having to visually align instruments onto graphical objects, since he was expecting a CAD-like 'snap' function to fix instruments very precisely onto objects being measured (see table XII, under the theme *Instruments*). By contrast, another subject (LY) felt that the absence of such an automatic function was favorable– he appreciated that the user could "do things himself" and that an uncertainty factor would subsist when making measurements (see table XI, under the theme *Freedom and Control over the simulation and the experimental process / Uncertainty assessment*).

Table XI: Important cues affecting verisimilitude judgments *positively*

'Positive' cues	Subjects concerned	Description of typical judgments relative to cue
***Theme:** Behavior of the Manipulation Workspace simulation (Disk motion on the air-table, in the merry-go-round)*		
Unpredictability of the disk's motion	AN	The disk's motion is unpredictable and therefore similar to an actual disk's motion.
The disk's slow and uniform deceleration (when the pump is activated)	BO, CP, FS, GT, HU, JW, LY, MZ	Deceleration is an indication that air friction working against the disk's motion has been included in the simulation (**CP, FS, HU, JW, LY, MZ**), or that repeated collisions gradually affect the disk's speed (**BO, GT**).
Angles of collision between the disk and the table's sides	BO, GT	Angles of collision between the disk and the sides of the table are similar to those on a billiards table (angle after collision is "opposite" to angle before collision).
Rapid cessation of movement when pump is deactivated	GT	It is normal that the disk should stop rapidly when the pump is deactivated (that is, when there is no air cushion to reduce friction).
Rotation of the disk about its center	GT, MZ	The disk's rotation about its own center, or spin, indicates that friction between the table's sides and the disk (at the point of impact) has been included in the collision model.
Potential cues that would allow detection or awareness of experimental conditions involving randomness, anomalies and the possibility of making errors	KX	Experimental conditions that would involve randomness, anomalies, and the possibility of making errors, would be advantageous, as these would help the VPLab become the *"model of a real situation"*.
***Theme:** The video clip in the Presentation multimedia document and Discursive cues in the multimedia documents*		
The video clip	BO, FS	The video clip "shows the experiment done with real objects." (subject **BO**) When the simulated disk's motion is compared to that of the disk depicted in the video clip, it is extremely similar. Therefore, the VPLab offers much potential for physics experiments (subject **FS**).
Discursive cues, concerning the simulation's complexity, found in: (1) The Presentation multimedia document (2) Theoretical explanations contained in the Explanation multimedia document	LY	The Presentation multimedia document describes (or should describe) how complex the simulation is compared to reality and why there are deviations from reality, if any. This makes the simulation's behavior meaningful. The theoretical explanations (in the Explanations multimedia document), which contain animations of disk motion (including vectors), will promote trust in the simulation.
***Theme:** Freedom and Control over the simulation and the experimental process / Uncertainty assessment*		
Free interaction and freedom to choose methods	BO, HU	The freedom not to follow a (tutorial-like) pre-established path (**BO**), and the freedom to choose measurement methods and calculating methods (**HU**), are favorable for credibility.

High degree of control over objects / Direct manipulation conventions / Affordance of errors on measurements	BO, GT, HU, FS, LY	'Direct manipulation' conventions: using the hand-shaped cursor and mouse to directly handle the apparatus in a variety of ways (**BO**) is favorable; not having to enter parameters with the keyboard to get feedback in return (**FS, GT**) is also favorable. It is the user who performs the measurements, and *not* the computer (**HU**), so that the situation is "really experimental." The *absence* of a CAD-like 'snap' function (allowing the user to fix the protractor very precisely on the object being measured and automatically obtain a measurement) is favorable (**LY**). The absence of such a function allows an uncertainty factor to subsist when making measurements. Users can do things for themselves.
***Theme:** Virtual instruments, operations performed, data collected*		
Types of instrument	CP, IV, KX	The types of instruments used are likely to be the same as in an actual lab (**CP**). In a broad sense, data is collected the same way as in a real lab (**KX, IV**).
Instruments look like they can be handled with one's hands	GT	The instruments look like they can be handled with one's hands– this is a "realistic" aspect found in video games.
Some instruments can be handled as expected (e.g., the virtual tape-measure)	IV	Use of the virtual tape measure is enjoyable and its "way of functioning" is the same as for a "real tape measure."
Objects being measured and quantities derived from measurements	CP, IV	Objects being measured – distances between traces (dots), angles, etc. – are the same as in an actual lab experiment (**CP, IV**). Quantities derived from measurements, such as disk velocity, are also likely to be the same (**CP**).

Table XII: Important cues affecting verisimilitude judgments *negatively*

'Negative' cues	Subjects concerned	Description of typical judgments relative to cue
***Theme:** The Main metaphor (The virtual camcorder and the virtual monitor with Trace and Zoom functions)*		
The metaphor itself and its task allocation	MZ	It feels artificial and "unrealistic" to film objects and take measurements on the recorded images, rather than doing it on the objects themselves. Also, there are drawbacks in terms of pedagogical effectiveness because the metaphor's allocation of tasks is not conducive to thinking ahead about the methods one should use (*planning ahead*).
The requirement of having to perform scale conversions of measurements	CP	Performing scale conversions of measurements does not correspond to anything that is part of actual lab work.
Too many steps in the process of measuring lengths / Using the Zoom function	HU, CP	Performing measurements within the VPLab is more fastidious than in a real lab (**HU**). There is no need for a *Zoom* function in a real lab (**HU, CP**).
Traces 'moving along' ahead of the object in motion	CP, ER	When comparing to carbon paper markings, it seems strange and impossible that there should be traces ahead of the object in motion (the disk's image, during playback).

Adding and removing traces in the Analysis workspace	DQ	It is very difficult to imagine how one could add and remove traces at will so easily in the context of a real experiment.
Lack of precision resulting from degraded graphical quality after zooming in on the recorded image	MZ	The uncertainty of measurement which results from zooming in on the image is an unnecessary consequence of poor visual rendering. In an actual lab, there would be easy solutions allowing an experimenter to obtain much more precision.
Theme: General visual presentation and graphical attributes		
The colors and textures of the apparatus depictions in the Manipulation and Analysis workspaces / Game-like graphical attributes	ER, FS	Lower visual fidelity: the color schemes emphasize the fact that the images of the apparatus are drawings (**ER**). The Manipulation and Analysis workspaces' graphical attributes are "attractive" and "game-like" and, as such, create expectations of lower complexity in simulation behavior (**FS**). Moreover, the images are not photo-realistic, its textures could be improved, and the colors could "look more real".
Seeing the apparatus in a narrow space	ER	Seeing the apparatus in a narrow space is annoying and it would be preferable to see the whole air-table in large.
Theme: Instruments		
Appearance of the instruments / "Unreal" instruments (calculator and tape measure) / A 'gadgety' interface	ER	The calculator and tape measure do not seem "real": the VPLab tape measure and calculator are not similar to those encountered in the real world. The interface has many gadgets– this is distracting.
Measuring instruments that cannot be handled as expected or are less intuitive than in the real world	ER, IV, LY	Some instruments – like the virtual tape measure – should be as intuitive to use as their real counterparts (**LY**). The tape measure does not behave like real ones (**ER**). The virtual ruler and protractor do not allow for arbitrary rotations: they are restricted to 90-degree turns (**IV**). It would be more 'realistic' and satisfactory to be able to smoothly spin these instruments just by continuously 'dragging' a corner in a circular motion.
Perceived lack of precision when visually aligning instruments with graphical objects / Impossibility of "snapping" instruments onto graphical objects being measured	CP, GT	There is an unwarranted lack of precision when visually aligning instruments onto graphical objects (**CP, GT**). It should be possible to use a CAD-like 'snap' function to fix instruments very precisely onto the object being measured and thus automatically obtain precise measurements (**GT**).
Theme: Control		
Feeling a lack of control over objects / Impossibility of handling objects with one's hands	DQ, JW	A feeling of lack of control over objects is experienced. It is impossible to control objects with one's hands (**DQ**). Working with a mouse instead of manipulating apparatus and instruments with one's own hands is detrimental to comprehension (**JW**).
Lack of precision when launching the disk	GT, KX	It would be preferable to be able to control disk velocity and direction more accurately. Use of the mouse is to be blamed for this lack of precision (**KX**). In a real lab, one could know what force has been applied when launching the disk with the elastics that line the table's sides. In the VPLab simulation, one cannot set the initial position of the disk as precisely as in an actual lab. Additionally, one would be able to launch the disk faster in an actual lab (**GT**).

5.3 THE MAIN METAPHOR

(The virtual camcorder and the virtual monitor with its Trace and Zoom functions)

Below, I examine cues and issues that directly concern the VPLab's main metaphor. As mentioned before, I observed that verisimilitude judgments could be very idiosyncratic. Some of this idiosyncrasy is vested in – and also seems to result from – the specific ways in which individuals interpreted the metaphor. In other words, participants interpreted the main metaphor in their own way and this, in turn, seemed to affect verisimilitude judgments concerning the metaphor itself and related aspects of the environment.

Table XIII presents a sample of participants' interpretations of the Analysis workspace main display (virtual monitor) and virtual camcorder. These are ordered by degree of similarity to the meaning that designers intended to convey. I have also enumerated cues quoted by participants as contributing to their interpretations.[111]

Cues marked by an asterisk (*) had not been included in an earlier version of the VPLab, which I had usability tested with six other students (this work was mentioned in section 4.2.2.1 [p. 76]); at the time, five of them had *not* understood that the Analysis workspace represented a display device and the remaining subject was not totally convinced that this was so.

Table XIII: Interpretations of the main metaphor

Subjects	Interpretations	Degree of similarity between interpretations and the intended meaning	Cues involved
FS	The Analysis workspace's main display is a flat video screen which faces upwards. It is connected to the camcorder. Measurements are performed on the screen itself. Instruments can be set on the side of the screen. In the Manipulation workspace, there is uncertainty as to whether the camcorder is placed inside the merry-go-round or outside of it.	Extremely similar	-- The monitor frame * -- The fact that instruments and panels outside the playback area (outside the virtual monitor's frame) remain in place and do not expand or contract after zooming in or out (only the image inside the screen's frame varies in size) * -- Scale correspondence between Analysis workspace and Manipulation workspace
IV	The Analysis workspace's main display is like an oscilloscope: it is a flat screen on which you can perform measurements directly.	Very similar	-- Time display on monitor (which was very similar to the virtual camcorder's time display) * -- The blue screen preceding the first image of each 'filmed' sequence (this made IV realize that the camcorder's small monitor and the main monitor were both displaying the same images) * -- The colors (blues, violets and greens) used for the image displayed on the

[111] Other cues might also have mattered without subjects being aware of their effect.

			virtual monitor -- Grid-like pattern formed by the tiles on the virtual merry-go-round's floor (which, for IV, was indicative of scale correspondence)
MZ	The Analysis workspace's main display is a television screen allowing measurement of the recorded video image.	Very Similar	-- Scale correspondence between Analysis workspace and Manipulation workspace
LY	The Analysis workspace's main display is a device (screen) that allows viewing a replay of things recorded.	Similar	-- The monitor's time display * -- The different color schemes used in the Manipulation and Analysis workspaces
BO	1- The Analysis workspace's main display is a *workbench* used to perform measurements. Similar to recording an experiment with a camera and then watching the replay. Yet, writing on the display surface with a freehand-type function should be allowed. (2- BO also referred to a rapid photography rig with a phosphorescent marker to record successive positions, and an overhead projector for display purposes.)	Similar	-- The blue screen preceding the first image of each 'filmed' sequence (this made BO realize that the camcorder's small monitor and the main monitor were both displaying the same images) *
HU	The Analysis workspace's main display is a camcorder (HU first expected that objects depicted on the main display should have the same scale as that of the measuring instruments).	Less similar	-- The monitor's time display * -- Scale correspondence between the Analysis workspace and the Manipulation workspace -- The effects of performing a zoom-in. -- Grid-like pattern formed by the tiles on the virtual merry-go-round's floor
KX	*At first*: The displayed image does not really seem like a recorded video sequence, as such. *When KX was asked specifically to interpret the metaphor*: The Analysis workspace's main display is a camera. *Later*: The Analysis workspace's main display is a board that presents results in an animated way.	Less similar	-- Scale correspondence between Analysis workspace and Manipulation workspace -- The different color schemes used in the Manipulation and Analysis workspaces -- The impossibility of manipulating graphical objects which had previously been movable in the Manipulation workspace's simulation
ER	The Analysis workspace's main display is like nothing that really exists; it is like a video game. (Difficulty in interpreting the metaphor.)	No similarity to intended meaning	(The control panels for the Trace and Zoom functions seemed to be cues for this interpretation.)
GT	Great difficulty in interpreting the metaphor in a functional way. The displayed image should behave like objects in a CAD package.	N/A	

When these results are compared with reactions to the earlier prototype, there is an indication that a more tangible representation[112] of the metaphor helps users better understand its intended meaning. Many subjects now equate the Analysis workspace's features with those of a display device, whereas none had done so when testing the previous version of the VPLab.

Concerning the camcorder's verisimilitude, many participants judged that it was possible to use a camcorder in an actual student lab, but that it was not very probable due to considerations of cost. As far as the virtual monitor is concerned, it is interesting to observe that some cues which designers thought would contribute to verisimilitude, were actually conducive to unfavorable judgments for certain participants. For example, CP and ER found that having to perform scale conversions (of measurements) was bothersome and they felt that it did not correspond to anything which actually occurs in real labs. In other cases, however, participants (e.g., FS, IV, KX) were not at all annoyed by this requirement– in fact, it might have actually helped them interpret the metaphor.

Another such example concerns the degraded graphical quality that results from zooming-in on the displayed image in the Analysis workspace. When certain participants (e.g., BO, LY, MZ) observed that magnified super-imposed traces were not identical and that overall definition of the image had degraded, they saw these characteristics as unintentional computer artifacts, which they perceived as "artificial" or "reminding one that one was working on a computer."

The distortion that caused differences among magnified traces was in fact intentionally included in the display by designers to simulate the limited resolution of existing camcorders and, at the same time, to promote uncertainty assessment. It is of great interest to note that such features included by designers, in part to allow students to gain knowledge of certain experimental procedures, may sometimes not yield greater verisimilitude and may even lead to lesser verisimilitude.

It must be said that the VPLab still incorporates some characteristics which make it stray at least slightly from a perfectly *literal* interface (Smith, 1987), even by the designers' standards. For instance, the virtual instruments in the Manipulation workspace appear to float above the simulated scene (considering that the user, in this experiment, has a bird's eye view of the simulated apparatus) without them being tied to, or constrained by, anything. In a perfectly literal representation, however, the effects of gravity on the virtual stopwatch, the camcorder and the calculator should have been simulated in the Manipulation workspace and therefore these instruments should 'fall into' the simulated scene.[113]

---

[112] That is, representing the monitor as a display area surrounded by solid, opaque borders containing a time display, and adding a small camcorder screen, which bears striking similarities to the main monitor (see Fig. 1.2).

[113] Additionally, users who recognize the main display in the Analysis workspace as a monitor or a television could suppose, contrary to what the designers wished to depict, that the screen's surface is perpendicular to the (virtual) ground – because monitors and televisions usually are in everyday life – and then infer that simulated gravity, here too, should take effect on the virtual instruments (since these are found on a 'layer above' the monitor).

However, these gravity-related considerations did not appear to be issues in the verisimilitude judgments expressed by participants. Either they did not analyze the metaphor in such detail or they took for granted that some things were different in a virtual environment and that these things did not matter.[114]

Nevertheless, some participants (e.g., FS, HU, MZ) did speak of another such issue, namely the view of the simulated scene afforded by the camcorder; for instance, subjects asked where the camcorder was located with respect to the merry-go-round. Perhaps these students raised issues of this ilk because they sensed that the question of the observer's point of view was important when considering an experiment dealing with rotating frames of reference. I also speculate, in this matter, that a metaphor capable of presenting multiple points of view would have yielded greater verisimilitude. Not only might such a metaphor help improve visual perception of the simulated phenomenon, but it would also simulate the real-world capability of moving a camera around in the lab. Moreover, if users were allowed to inspect apparatus more closely (by changing their view-point) in order to detect potential quirks, the practice of including anomalies or defects in experimental set-ups might seem less artificial or unfair. Indeed, some participants (e.g., CP, ER, MZ) claimed that inclusion of anomalies would be unfair to unwarned users, as such anomalies would be extremely difficult to detect– the fact that the user is confined to a very limited point of view was blamed among other factors.

5.3.1 Straying from Familiar Real-world Experiences Commonly Shared by Users

The metaphor's design aims to allow students to carry out operations analogous to those performed in actual labs. However, I can infer from my data that most participants were unfamiliar with at least some of the specific methods and technical processes which designers sought to replicate through this metaphor– i.e., video analysis of recorded physical phenomena.[115]

In view of my observations, I propose that a virtual laboratory metaphor like the VPLab's, which somewhat strays from representations shared by most potential users, is conducive to diverging judgments within the user population. This divergence seems much more likely to occur in situations where there exists little discourse (e.g., explanations) or social interaction to stabilize the meaning and verisimilitude of such a metaphor (i.e., when the user is 'left more to his own devices', as in this study).

Said divergence may result of processes taking place, conceptually, on two separate levels. On a first level, initial *interpretation* of a metaphor may be more or less problematic, leading different

[114] This would be consistent with a metaphorical interpretation of the main representational feature (see chapter 1); Alty et al. (2000) stated that human beings are very used to the metaphor concept and, as such, are not troubled by mismatches between metaphor and reality since they expect to encounter these.

[115] A possible exception to this was subject FS.

individuals to ascribe various meanings, functions, uses and values to this metaphor. Differences in interpretation may arise, for example, as objects and events depicted through the metaphor are more or less familiar to users, in the relevant context (in the present case, lab work).

One can appreciate, for instance, how different subject FS's interpretation is from ER's (see table XIII). The interpretation made by FS is extremely close to the metaphor's intended meaning and involves association of the VPLab's devices with real 'advanced' analysis technologies, whereas ER's interpretation ("nothing that really exists" ; "like in a video game") lies at the opposite end of the interpretative spectrum. Subject FS's greater technological knowledge, enthusiasm for technology, and use of video games might be factors that were conducive to a match between his interpretation of the metaphor and its intended meaning.[116] In any case, taking into account the basic difference between the interpretations made by these two participants, I may go on to observe that FS's construal involving more 'advanced' analysis technologies probably had positive effects on verisimilitude judgments concerning specific elements of the metaphor: contrary to ER, subject FS felt that the Analysis workspace's digital Trace function[117] was somewhat plausible because he associated it with video devices encountered elsewhere (special effects used in hockey broadcasts).

On a second level, differences in individual traits – including interests, attitudes, aptitudes, and familiarity with recognized metaphor objects and events – may give rise to diverging judgments, even when different users have *similar* and acceptable understandings of what designers wish to represent through the metaphor.

Illustrating this divergence are the differences among verisimilitude judgments expressed by subjects MZ and LY who made *similar interpretations* of the metaphor. Near the end of the debriefing interview, subject LY was asked to estimate the probability of finding real-lab equivalents of the main metaphor's functions (recording an image sequence, viewing it, and using a trace function). LY answered that finding devices replicating these functions in an actual lab was probable– that is, in a new school or one which kept up to date with recent technologies. Also, during the session, LY compared the Trace function to the carbon paper tracing system that he had used for an experiment conducted in college. LY appreciated the fact that the Trace function (like

---

[116] However, other hypothetical differences between ER and FS might also explain the difference of interpretation. The critical difference between FS and ER might simply be that FS had a greater capacity to associate the VPLab's devices with objects and processes which would seem to be foreign (from a user's point of view) to the context of a physics experiment. Or, at a much more basic level, it might be that FS had a greater capacity or tendency to imagine possible three-dimensional referents for uncommon two-dimensional depictions presenting a certain measure of 'ambiguity' (in the present case, one single 2-D depiction corresponding to a bird's eye view of the Analysis monitor, with no additional views of this device's 'other sides').

[117] It is essential to point out that the choice of experiment (one with an air-table) bears consequences for judgments regarding the metaphor, and especially for those judgments which concern the Analysis workspace's Trace function. In educational labs, air-tables are often used in conjunction with a tracing system that works by repeatedly shooting electrical discharges on carbon paper. Students analyze object trajectories thus recorded on carbon paper *as a series of dots*. Had I chosen a different experiment for this study – one that was not traditionally linked with such a tracing system – verisimilitude judgments of the Trace function might have been very different (although not necessarily more negative). Note, however, that the experiment was not chosen with this in mind.

the carbon paper system) did *not instantaneously* provide needed information to the experimenter, but instead required him to do further work in order to obtain this information.

MZ's attitude stands in sharp contrast to LY's. During the session, MZ criticized the way that the metaphor structured tasks in the experiment. He felt it was strange that the experimenter had to make length measurements on "a television image" in the Analysis workspace instead of making them while handling the apparatus (in the Manipulation workspace). Also, even though he noted great similarities between the Analysis workspace's *Trace* function and a carbon paper tracing system he had previously used, he thought it peculiar that it was not left to the experimenter to decide if traces are to be drawn as the disk moves on the air-table. Considerations of pedagogical value, which seemed important to the previous participant, were manifest in MZ's judgment:

> *[...] even from a* ***pedagogical standpoint****, I think it's good that one should be required, while performing the experiment, to plan ahead and say: "I'm going to have to leave traces [of the trajectory] to be able to make measurements."*
>
> *Whereas here [i.e., with the VPLab], it's like we don't really care: we move the disk around, then we go to the Analysis [workspace] where we can do anything we want. For this aspect, maybe it's not very realistic.* [citation 7]

During the debriefing interview, MZ further expressed negative judgments concerning the metaphor as a whole. He said that it felt artificial and that he could not imagine, as far as the specific air-table experiment was concerned, how replicating its functions in an actual lab could be advantageous. I surmise that MZ's abilities and interests in experimental design were conducive to him expressing these types of judgments.

Leaving aside the question of divergence for now, one could say that verisimilitude judgments would probably tend to be more positive if individuals were faced with a metaphor based on more familiar devices or processes (in this instance, a system similar to the carbon-paper tracing system to which several participants referred[118]).

Subject BO's case supports this hypothesis. This participant had had prior experience working with an actual air-table in an experimental context. The functionality of the rig he had then used to collect data, if more rudimentary, was in many ways analogous to VPLab functionality. It involved rapid photography and a phosphorescent marker to record successive positions of the disk; analysis was then performed by developing the film and projecting the pictures on a screen. It is true that BO found salient differences between this device and the VPLab's analysis system. Nevertheless, based on comments he made, I surmised that these differences had a negligible negative impact on credibility because the basic functions provided by the VPLab's devices *were the same as the ones provided by the rig he had previously used*, so that the structure of the experimental methods were somewhat similar.

---

[118] Of course, there are practical issues that can hinder the implementation of such a metaphor, not the least of which is the issue of long-term usability (cf. Alty et al., 2000) as well as the problem of designing an environment suitable for several different types of experiments and not just those that would involve a carbon paper tracing system.

Ultimately, this issue should be investigated further, as I suspect that a hypothesized counter-phenomenon (dubbed 'latency of favorable verisimilitude judgments') could impede the expression of positive verisimilitude judgments in such cases. This hypothesis is examined in the final chapter.

5.4 THE VIDEO CLIP AS A BASIS FOR VERISIMILITUDE JUDGMENTS

As expected, a number of participants (e.g., AN, BO, CP, FS, GT, IV) manifestly used the video clip (viewed in the multimedia *Presentation* document) as a basis for judgments concerning simulated objects and events. In most cases, the video clip favored greater verisimilitude of the simulation or of the experimenter's role in the simulated environment. For instance, subject BO attributed great importance to viewing the video before working with the simulation:

> ***Interviewer**: So this [video clip] is important?*
>
> ***BO:** Yes... You know, skeptical people will say: "Well this is all pre-arranged. It's software so it'll work just so – all I have to do is click and follow the path." With the video clip, they see that it's not just software – it's not just a simulation where you click and it responds like so. [The video clip] shows you the experience done with real objects.*
>
> *[...] That's why it's useful to see the video clip beforehand. It provides an introduction so that someone who comes here [in the Manipulation workspace] and starts the merry-go-round will not be surprised of the disk's curved trajectory.*
>
> ***Interviewer**: Because otherwise you would be surprised?*
>
> ***BO**: Well novices would be surprised, not people who are used to it. [...]*
>
> ***Interviewer**: Does the curved trajectory seem...*
>
> ***BO**: No, it seems normal in comparison to the video clip that was shown earlier.*
>
> [citations 8 and 9]

One should note that the simulation and the video clip offered the same bird's eye view of the set-up. Comparison (albeit from memory) between the clip and the simulation was thus facilitated, a situation which probably favored verisimilitude further.

Participants appeared to use the video clip to judge different aspects of the environment: AN and IV referred to the video clip when considering their own roles in the experiment; BO used the clip to judge the experiment, as a whole, and also to assess the simulated disk's trajectory on the air-table; CP referred to the video clip to back up his claim that it was possible to find an actual merry-go-round in a lab; FS and GT referred to the video clip to assess the disk's motion and the scale of the simulated objects; HU tried to use the video clip to assess the disk's motion but had a hard time doing so because the simulation did not offer a view of the air-table from outside the merry-go-round (as did the video clip, though very briefly).

Participants who referred to the video clip to assess the simulated disk's motion focused on various aspects of this phenomenon: BO and FS considered the disk's behavior, in general; GT focused on collisions between the disk and the table's sides (more specifically: the question of conservation of energy); IV was mainly concerned by the relation between the disk's trajectory and the merry-go-round's speed.

Despite the video clip's usefulness, however, participants often had to rely upon other cues in order to assess disk motion, as certain behaviors (e.g., the disk's slow deceleration after having been launched; back and forth motion across the table on one straight path; the disk getting stuck in a corner of the table, etc.) were not ostensibly displayed in the video sequence.

I can offer an example where behavior *not* shown in the video clip seemed dubious to one of the participants. Subject IV felt it was strange, when the merry-go-round's speed was high, that the disk would sometimes become stuck in one corner of the air-table after having moved around a lot. "But maybe it is normal," he concluded, showing that he was not totally convinced either way. In contrast though, another participant (FS) found this behavior quite normal, as he explained that it was the result of centrifugal force.

From the preceding considerations, three important inferences can be drawn about the role of video clips. First, clips depicting actual apparatus may enhance verisimilitude of simulations for certain individuals, in situations where the simulation and the video clip allow for close comparison. Secondly, different individuals may use the same video clip in different ways to judge various aspects of a simulation. Thirdly, for certain individuals (as for subject IV), video may not be sufficient to secure credibility of all behaviors depicted by a simulation.

Finally, it should be pointed out that there were *no direct indications* that any of the participants who were physics majors used the video clip as a basis for verisimilitude judgments. This may suggest that knowledge pertaining to the phenomena depicted by the simulation was an important factor influencing use (or non-use) of video clips as a basis for judgments. I also observed that only a subset (subjects FS, GT, IV) of those individuals who had displayed unfavorable *a priori* attitudes toward simulation *in comparison to video* tended to use the video clip as a basis for verisimilitude judgments concerning the disk's motion. Contrary to what would be expected, other participants (DQ, HU, KX) who seemed to have exhibited strongly unfavorable *a priori* attitudes did not refer to the video clip in such judgments. All of these issues merit further investigation.

5.5 BEHAVIOR OF THE MANIPULATION WORKSPACE SIMULATION
(Disk motion on the air-table, in the merry-go-round)

Assessment of disk motion seems to have been relatively important with respect to the VPLab's overall credibility. Recall that one of the session's activities (activity 4) was specifically designed to expose participants to the disk's behavior and observe what judgments they would express. Nevertheless, by no means does this fully explain why there were so many noteworthy judgments relating to the simulation's behavior: indeed, several participants (e.g., BO, FS, HU, IV, KX) also expressed opinions concerning the simulation's verisimilitude during the preliminary exploration-based tasks for which no specific goals had been set (except to explore, of course) and some of these judgments were unprompted. Yet, the significance of the simulation's behavior, with respect to overall credibility, is not very perplexing after all because, as a surrogate for the real setup, it is the focus of attention in the experiment.

In any event, there were various types of bases for verisimilitude judgments concerning the simulation's behavior. As shown in the preceding section, the video clip was one such basis. Others included prior experience with similar phenomena in the real world (i.e., objects moving on air-tables), and information drawn from explanations provided in the multimedia *Presentation* document.

Again, in judgments concerning the simulation's behavior, different cues were important to different participants, and assessments of the simulation's verisimilitude may have diverged depending on the cues perceived or taken into account by different individuals. Such divergence can be observed by comparing comments made by subjects AN and LY. In AN's case, the primary cue for overall verisimilitude was the *unpredictability* of the disk's motion. This was probably related to AN's observation of the disk after he had launched it in such a way that its motion, initially back-and-forth, became irregular after a short while. Conversely, subject LY observed the disk repeatedly travel back and forth across the table, never deviating from a single straight path. This indicated to LY that he could launch the disk at a perfect 90 degree angle (to the table's side), and that the table's surface and sides "were perfect"; the subject claimed that "the conditions were perfect" and that the disk would "totally react [according] to theory" (which is tantamount to attributing *predictability* to the disk's behavior, in opposition with AN's judgment). This comparison suggests that different observations of the very same simulation, corresponding to different sets of initial conditions, may lead to opposite conclusions as to its verisimilitude.

5.5.1 Deceleration of the Disk

One of the cues used by participants – namely, the disk's slow deceleration (caused by residual friction between the disk and the table, and by air friction) – deserves in-depth analysis for two reasons. The first is to check the designers' assumption that this cue would lead to favorable judgments in terms of the VPLab's overall credibility. A second reason is that the investigation of perceptions regarding simulated friction (the cause of the disk's deceleration) could be insightful in studying how the simulation of a broad range of behaviors described by classical mechanics might be perceived by students, insofar as friction is an important phenomenon within this field.

At the outset, I had expected all participants to say that the mere occurrence of deceleration was an indication that the simulation took into account friction working against the disk's motion. I was thus very surprised to observe that one participant (DQ) attributed the disk's deceleration to the merry-go-round's continuous rotation, while stating that the air cushion was not to blame because it was always stable (I am not too certain of what he meant). Another participant (GT) attributed the deceleration to a "loss of energy" for which he did not specify a cause, while making comments which would indicate that he was not aware of the existence of friction.

All the other participants associated disk deceleration with non-zero friction, as I had expected. It is true that the textual explanations in the multimedia Presentation document (consulted by most participants before they made their judgment regarding the deceleration) mentioned "a surface with very little friction," which indeed suggested the inclusion of friction in the simulation. However, one participant (KX) did link the deceleration to air friction even *before* he viewed the Presentation document, while another (FS), after having consulted the document, still did not expect friction to be present. Hence, the textual explanations cannot be held completely responsible for the effectiveness of this cue, in all circumstances.

Turning to another aspect of this issue, I observed that the apparent *magnitiude* of deceleration was detrimental to verisimilitude for one participant (ER). Although ER did acknowledge the presence of friction, he felt that the disk was not slowing down fast enough. This led him to believe that air friction had been included in the simulation, but that residual friction with the table itself had not. Subject ER's prior experience of launching a metal disk on an air-table (as opposed to the much lighter plastic disk depicted in the video clip and simulation) must have been an important factor contributing to his judgment. On the other hand, another participant (CP), who had also had prior experience launching such a disk, did not find fault with the magnitude of the simulated disk's deceleration; contrary to the previous subject, he was very aware of the difference between the two set-ups, and suggested that it explained the difference in the disks' behaviors:

> ***Interviewer:*** *So it's normal to see this deceleration?*
>
> ***CP:*** *Yes and it corroborates what would happen in a lab. But in a lab, you have* ***steel disks so they slow down faster****.* [citation 10]

Overall, I may draw several conclusions from how participants judged the disk's deceleration. The first is that a simulated behavior, for which designers have high expectations in terms of contribution to verisimilitude, may indeed be effective for several individuals. Others, however, might not react favorably. In these cases, real-world experience might help explain opposite reactions but it also may not constitute a sufficiently discriminating factor, as demonstrated by CP's judgment compared to ER's.

Another conclusion would be that even when an aspect of a simulation's behavior is considered to be 'normal' or 'realistic' by various users, different individuals might come up with different explanations for the same 'normal' behavior (at least, during their first contacts with a simulation). This is demonstrated by the surprising reactions of the two participants (DQ and GT) who did not seem to associate the deceleration of the disk with the inclusion of residual friction in the simulation.

Yet another conclusion would be that some individuals may make expected inferences between a given simulated behavior (the deceleration) and its intended cause (friction) without any prior explicit notice of the cause, as shown by the case of subject KX who linked the deceleration to friction even before he had read the Presentation document wherein friction was mentioned.

5.5.2 Random Fluctuations

Random fluctuations of the merry-go-round's angular velocity (rotational speed), as well as the effects of vibrations of the merry-go-round's structure, had been included in the simulation model in order to enhance its fidelity to the actual apparatus. As these elements were not detectable, I cannot say whether they would favor verisimilitude, but I can say that they were not expected by participants. Nonetheless, it is possible that knowledge of the inclusion of such fluctuations could promote credibility. This supposition will be discussed in a further section.

5.6 GENERAL VISUAL PRESENTATION AND GRAPHICAL ATTRIBUTES

In this section, I examine judgments regarding the simulation's general visual presentation and graphical attributes. To begin, I address an issue closely related to the topic of the simulation's behavior, which was just discussed.

5.6.1 Connections between Judgments Concerning Graphical Attributes and Those Regarding Simulation Behavior

One of my findings in this area is that a number of participants (e.g., AN, ER, LY, MZ) could easily discern visual presentation of the disk's motion, from its underlying model. One type of judgment expressed by two of these participants illustrates this capacity very well. It concerned the disk's motion, which was somewhat jerky at extremely low velocity, an effect related to the finite pixel dimension of the computer display. Observing this effect, both subjects AN and ER proposed that the software did not allow for smooth presentation of motion and that the jerky movement was in fact representing low velocity. Subject AN added that this was just a detail which did not bother him. I consider this account to be very significant, as it describes circumstances where visual fidelity (and, more importantly, *perceived* visual fidelity) was poor but *where credibility was in fact preserved.*

Another very important concern in this area is the question of whether a simulation's graphical attributes (or graphical complexity) create expectations as to its behavioral fidelity (or underlying model complexity). Once more, I found that different individuals had expressed conflicting judgments.

Subject FS who, we recall, had thought that residual friction would not be included at all in the simulation, was led to this expectation by the Manipulation workspace's graphical attributes, which he considered "attractive" and "game-like". Here, his perception of the graphical attributes (as attractive) probably lead him to imagine appropriate target users (beginners), and then to anticipate the simulation's level of complexity (simple). For the same reasons, FS also seemed to feel less involved in some tasks like uncertainty assessment.

Both subjects LY and BO displayed an opposite attitude. LY thought that there "wasn't really a relation between content" and graphical quality. Later, he also declared:

> *[The VPLab] is somewhat like SimCity [the video game]* ***where everything is accounted for.*** *These are software for which the graphical interface is not realistic – [but] you look at what happens [i.e., the content] and it's very realistic.* [citation 12]

As for subject BO, though the simulation's graphics also reminded him of video games (like subject FS), he did not seem to think any less of the VPLab– quite the contrary, in fact:

> ***BO:*** *The graphics aren't dull. Sometimes, because it's physics, [teachers] think that they have to make it boring. When you get textbooks and videos from the fifties in class, it's usually physics.*
>
> ***Interviewer****: So does [the VPLab] look* ***less serious*** *to you?*
>
> ***BO:*** *No. On the contrary, I think it opens some doors. It doesn't have to be ugly to be serious. It doesn't have to be boring for you to learn something.* [citation 13]

BO later added that possible lack of credibility didn't have much to do with graphical attributes. Both the statements of LY and BO, as opposed to those of FS, seem to indicate that it is possible for individuals to remain relatively uninfluenced by a simulation's 'simpler' visual presentation.

5.6.2 Other Verisimilitude Judgments Concerning Graphical Attributes and Visual Presentation

While subjects like BO and CP praised the prototype's visual presentation, others displayed a more negative reaction (e.g., AN, ER, FS). Subject ER was the most displeased with the VPLab's visual presentation. Apparently, it made the experience of witnessing the disk's motion less convincing for him than seeing it in a real lab. He felt that the simulation's unusual colors [119] emphasized the fact that the images were actually drawings. To this, he added that the disk did not have the appearance of a real puck. Finally, he mentioned that seeing the apparatus in a narrow space was annoying and that it would be preferable to see the whole table in large. I conclude, from ER's reactions, that lower *visual fidelity* (through the cues described above) can be associated with lower verisimilitude.

For his part, subject AN believed that the VPLab's visual presentation could be improved if designers were aiming to impart a greater sensation of "palpability". Subject FS also expressed a

[119] The simulations in both the Manipulation and Analysis workspaces use specific color schemes comprised of vivid hues: 'warm' colors (i.e., red, yellow, orange) for the Manipulation workspace simulation and 'cool' colors (i.e., colors towards the blue/violet end of the spectrum) for the images displayed on the Analysis workspace monitor.

negative judgment concerning the VPLab's graphical attributes. During the debriefing interview, FS proposed that photo-realistic images – including elements such as "a nicer texture", as well as instruments and colors that "look more real" – might help provide "a greater impression that [the environment] is real." I must note, however, that this student praised the VPLab for its "attractive" graphics – in comparison to non-commercial software – and said that these graphical attributes would help foster beginning experimenters' interest in working with the environment.

I believe that there are two types of attitudes at work here and that they are not mutually exclusive. It seems that some individuals (e.g., BO, CP, FS) find graphics like those of the VPLab attractive compared to the visual presentation of educational products (viz., textbooks, software, etc.) that they usually encounter in science classes. However, some of these same individuals (e.g., FS), or others (e.g., AN, ER, JW), may feel that those graphical attributes could or should still be improved in order to further promote presence or credibility. It would be interesting to verify whether these types of negative judgments concerning graphical attributes similar to those of the VPLab arise from comparing software like the VPLab to more graphically complex computer applications (e.g., highly realistic video games). Neither AN, ER, nor JW reported playing realistic video games (only FS reported having done so), but most of these participants had *seen* such video games before.

5.7 OBJECTS, OPERATIONS, AND DATA

In this section, I analyze judgments pertaining to the kinds of objects that are present in the VPLab environment, focusing on its tools and instruments, on operations performed with these, and on the type of data that can be collected. Additionally, I discuss how participants perceived the handling and behavior of measuring instruments.

5.7.1 Virtual Instruments, Operations Performed, Data Collected

A number of subjects (e.g., CP, IV, KX) felt that the same kind of data could be collected within the VPLab as in a real lab.[120] For instance, subject IV stated:

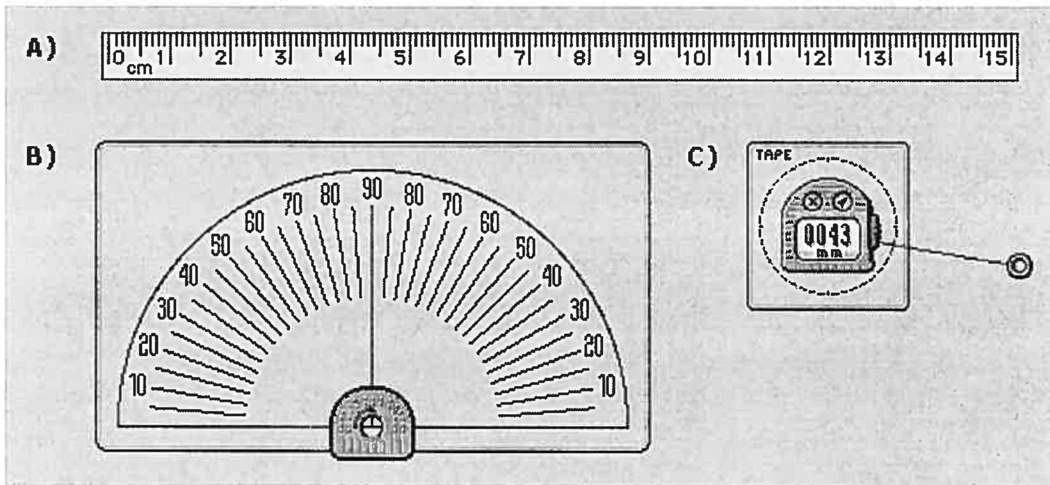
> *[...] all the elements are present to make it as if I were in a lab. All the instruments are provided so that I can obtain the same data as I would have wanted to obtain in a lab – that's what's important, I think.* [citation 14]

Some of the instruments – particularly, the virtual ruler and protractor (Fig. 5.1 A , B) – seem to have been perceived by many participants as objects that could be found in a lab. Other instruments with less 'conventional' appearance, especially the virtual tape measure (Fig. 5.1C), were perceived more negatively by a number of participants (e.g., AN, ER, MZ). In the case of the tape measure, the digital display and the red 'tape' (which actually looks very much like a string) were judged

[120] Furthermore, using traces of the disk – specifically in the form of *dots* – as data was a cue that gave rise to verisimilitude for several participants (e.g., BO, CP, ER, LY, MZ).

'unrealistic' by some.[121] Furthermore, certain participants (e.g., IV, MZ) mentioned that in an actual lab, it would be more practical to use a ruler or another type of tool to measure lengths, rather than a tape measure.

Figure 5.1 Measuring tools used in the VPLab's Analysis space: A) ruler; B) protractor; C) digital tape measure.



For one participant (ER), verisimilitude was considerably affected by the presence of certain instruments in the environment. This participant was really bothered by the fact that instruments which he perceived as "real" (the stopwatch, protractor and ruler) shared the environment with others which he perceived as "unreal" (the calculator[122] and tape measure). Apparently, objects that were similar to those the subject had seen, appeared more real to him than those that weren't, and dissonance or lack of coherence occurred because both types of instruments were present in the same space. What's more, this participant further complained that "all the gadgets" were distracting him from what he really should be doing– that is, from studying the real phenomenon.

Another participant (GT) stated that the type of instruments available, as well as the way they looked and the way they were controlled, made the VPLab look and feel like a video game. For this subject, however, "looking like a video game" had the connotation of "being very realistic":

> *In video games, we often see this – a logbook or a camera. [The VPLab's camcorder] is designed in a very real... very realistic way: you can almost manipulate it... with your fingers. You click on a button with the finger [i.e., hand-shaped cursor] and it closes [the camcorder's screen] automatically. So it's very realistic, it's gadgety [...] You don't enter functions with the keyboard – it's almost always done with the mouse and a hand [i.e., hand-shaped cursor] on the screen.* [citation 15]

---

[121] Also, the tape measure's 'inner workings' seemed very difficult to explain. One reason is that the measurement starts at a red circle drawn on the tape measure's plexi-glass casing (see Fig. 1.3); some participants (e.g., AN, MZ) said that they could not figure out how the measurement would be processed by the tape measure if it were faithfully replicated in reality. In addition, its tape "seemed to come out of nowhere."

[122] The simulated calculator is rectangular but, contrary to most pocket calculators, its width is twice as long as its height. Moreover, it does not have buttons: mathematical expressions are entered using the computer keyboard.

5.7.2 Handling and Behavior of the Measuring Instruments

Some participants felt that the measuring instruments could not be handled as expected or that they behaved in a strange fashion. For example, a number of subjects (e.g., IV, ER) were considerably displeased that the virtual ruler and protractor did not allow for arbitrary rotations, but were restricted to 90-degree turns. It would have been more "realistic" and satisfactory for these participants if they had been able to smoothly rotate these tools just by continuously 'dragging' a corner in a circular motion.[123]

Judgments toward the tape measure's behavior were not the same for all participants and appeared to be very complex. Some participants (e.g., ER) felt that this tool's components behaved quite differently from their real counterparts. For one subject (LY), an important which led to lesser verisimilitude was his perception that the tape measure was not as intuitive to use as its real counterpart. This participant had not been able to find the device's reference points for the beginning and the end of the measurement.

Nevertheless, other participants (e.g. FS, IV) had a more positive view of the tape measure. In particular, subject IV elaborated at length on this topic, revealing just how complex judgments toward certain instruments can be.

At a basic level, IV judged that the virtual tape measure provided the same type of data that he expected to obtain in an actual lab. At another level, and in contrast to other participants (e.g., ER, LY), subject IV enjoyed using the virtual tape measure and said that its "way of functioning" was the same as for "a real tape measure." This was probably because mappings of mouse-driven actions to hand-driven actions (those possibly performed with one's hands when manipulating an actual tape measure) were thought to be satisfactory– i.e., manipulating the same types of components seemed to produce the same types of effects.

At yet another level, IV said he would never use the virtual tape measure's real-world counterpart in an actual lab because it could never be manipulated with as much precision as what was provided through mouse-driven actions in a 2D space. However, the subject also stated that *some* imprecision remained despite the 'excess in precision', and this preserved verisimilitude, to some extent.

Thus, IV's case suggests that there can be more than one dimension to verisimilitude judgments concerning virtual objects like the tape measure. As in the case of the VPLab's main metaphor, the divergence of judgments regarding such virtual objects as the tape measure is linked, in my opinion,

[123] At the time of the study, this feature was not feasible due to software limitations, but it has since been implemented.

to the fact that common experience or awareness of their intended referents (or of very similar objects) was not shared by subjects.[124]

5.8 THE CRITERION OF PRECISION AND THE ASSESSMENT OF UNCERTAINTY OF MEASUREMENT

For several participants (e.g., CP, GT, HU, IV, KX, MZ), precision was an important criterion when making verisimilitude judgments concerning various elements of the VPLab. *A priori*, participants seemed to regard precision of manipulations and precision of tools as crucial elements of experimental work: during the preliminary interview, certain participants (e.g., CP, DQ) said that they expected accuracy from their school's lab apparatus and that a lack of precision could become a source of frustration. Others (e.g., DQ, FS, GT) mentioned that they usually strove to achieve precise measurements.

I believe that the 'quest for precision', as a value, is cultivated through lab work or any activity involving repeated use of precise instruments. Most participants were familiar with both lab work and precise tools, and among them, engineering students probably had had the most contact with high-precision instruments. It is prudent to bear in mind that precision might be of lesser importance for other individuals who would not have as much experience with laboratory instruments and practices.

5.8.1 Precision of the Virtual Instrument vs. Precision of the Object it Appears to Represent

Sometimes, an instrument's precision was judged with reference to the actual physical object that the simulated tool was meant to represent. For instance, a number of participants (e.g., HU, LY, KX) felt that the virtual protractor was *less* precise than its real-world counterpart; this had a considerable impact on its verisimilitude. The following excerpt is an excellent illustration. During the debriefing interview, subject HU rated the probability of finding the VPLab's protractor in a physics lab at 2 on a scale of 1 to 5 (with '1' meaning a very low probability and '5' meaning a very high probability). He gave the following explanation for this rating:

> *The protractors that I've used before had a calibration that was [detailed] to the one-degree mark. We would really see the one-degree mark... so the level of precision [of those protractors] is a bit higher [than that of the VPLab's protractor]. So this one may not be precise enough. I would say "2" - a low probability [...] because it's not precise enough for a physics lab.* [citation 17]

Demonstrating an opposite reaction, some participants (e.g., LY, IV) felt that another tool – the virtual tape measure – could yield *greater precision* than the object which they perceived as being

---

[124] It is interesting to note that tape measures with digital displays do exist and are sold commercially but are less common than the older models that most people use at home. In any case, the virtual tape measure's digital display is not the only feature that a number of participants felt was different.

its real-world referent. Subject LY, for instance, could not imagine himself measuring a short distance with sufficient precision (in an actual lab) with what appeared to be a string (the virtual tape measure's 'tape').

5.8.2 Precision of the Virtual Instrument vs. Precision of an Object Other than that which it Appears to Represent

An instrument's accuracy could also be judged by reference to the level of precision that a user expected to obtain for the *type of data* provided, or by reference to other types of real-world instruments providing the same data. For instance, subject DQ judged that the tape measure was precise enough because it seemed to provide the same level of precision as a ruler. Judgments may not always go the same way when this type of criterion is applied however: contrary to DQ, subject HU felt that the measurements would have been more precise, had he been able to use a ruler for all measurements, instead of the tape measure.

In a slightly different assessment, one participant (ER) expected more precision from the tape measure than it could yield because he had a vague recollection of being able to obtain 'more decimals' for length measurements (in similar experiments). For this subject, however, another factor was of influence: the tape measure's digital display (see Fig. 5.1 C) seemed to create expectations for a very precise reading. This is quite interesting, as many participants referred solely to other devices with digital displays (e.g., voltmeters) when assessing uncertainty of length measurements performed with the tape measure. Indeed, users can associate a virtual object with a different real-world object that they have encountered (in this case, a voltmeter), on account of one salient – yet, in some regards, superficial – likeness to that object (presence of a digital display, in the present case).

5.8.3 Precision of Virtual Instruments vs. Precision of Software Tools, and Other Concerns Regarding Uncertainty of Measurements

When discussing the precision of the virtual instruments or the assessment of uncertainty of measurements, participants sometimes referred to other computer software with which they had previously worked (e.g., Computer Aided Design [CAD] packages, Graphics creation software).

In one case, subject GT complained about the lack of precision associated with visual alignment of VPLab instruments onto graphical objects. He contrasted this way of working to the use of CAD-like functions which, had they been available in the VPLab, would have allowed him to fix tools very precisely onto objects being measured, or to otherwise obtain extremely precise measurements automatically:

> *[... in the VPLab] I have to rely on a screen with a zoom, with a [different] scale, and with pixels. It's really approximate, and I can't be sure that [the instruments] are aligned or... visually, it's hard to tell.* [citation 18]

This subject's reaction is understandable, insofar as the act of measuring had always implied great precision for him– precision and methods available with software tools he had frequently used, and precision which had been required of him in the course of his past employment as a parts inspector in the field of aeronautics.

Some participants, like subjects CP and ER, showed mixed reactions when asked whether it was surprising to be required to assess uncertainty of measurement while working with the VPLab. For CP, dissonance resulted from working on "*physics* software" like the VPLab, which allows for much less precision than that which is usually available in most computer-assisted tasks. This student also felt he couldn't get as close to the measuring instrument (the ruler) as wished, because being too close to the screen was not optically comfortable. So, for both subject CP and subject GT, there was a negative aspect associated with the visual alignment of tools on objects being measured. CP did acknowledge, however, that uncertainty assessment was a normal part of physics experimentation.

For subject ER, their was an even more important tension between usual 'computer precision' and measurement uncertainty, specifically related to the virtual tape measure. Dissonance was created because, on the one hand, it was necessary to align the tape measure's components with the object that was being measured, and on the other hand, the reading of the measurement was obtained on a digital display within a computerized environment:

> *Well, it's because [the tape measure] is between... Because, given the fact that [the VPLab] is a computerized system, you tell yourself that it is going to measure precisely– direct, precise, real values. But this is rather somewhere between taking precise values and taking values that refer to something that would be collected manually. So, because it's between the two, I'm having a bit of difficulty...*[125] [citation 19]

Other participants (e.g., HU, IV, KX, LY) exhibited more approving reactions with respect to measurement uncertainty. For instance LY, contrary to subject GT, commented favorably on the absence of a CAD-like 'snap' function, which would have allowed the user to fix the protractor very precisely on the vertices of the angle being measured. LY said that the absence of such a function allowed an uncertainty factor to subsist when making measurements. Later, when he was required to perform uncertainty assessment of measurements obtained with another tool – the tape measure – LY proceeded to do so with no hesitation. Afterwards, LY stated that the method he had applied to assess uncertainty was the same as the one he would have applied in an actual lab. Apparently, it felt quite natural, for this participant, to assess uncertainty of measurement within the VPLab, even when it came to measurements obtained with the tape measure; this is in direct opposition to ER's attitude toward the tape measure.

[125] This excerpt also goes to show that some individuals like ER give the impression, through their judgments, of being in a 'state of limbo', as they are 'caught between' aspects of the virtual environment that seem real to them, and other aspects that seem unreal or artificial.

I also have reason to believe that the act of *requiring* the user to perform uncertainty assessment was itself a positive verisimilitude cue, in some cases. For instance, subject AN said:

> *[...] If you didn't ask me, I would surely say that [the data] is precise. But [uncertainty] is always there; they want to make reality more a part of it [the VPLab] [...] they want it to be closer to reality so they ask us to assess uncertainty so that we will really be working...* [citation 20]

This issue does not actually involve a verisimilitude cue that is inherent to the VPLab environment itself, but instead one which is brought about by a potential task (uncertainty assessment) that a teacher might ask a student to perform. Of course, the very fact that uncertainty assessment is possible can also be taken as a cue favoring verisimilitude: it only makes sense to require students to assess uncertainty if the interface, and more specifically the measuring instruments, afford it. As a matter of fact, at least two participants (HU, KX) spoke directly or indirectly of uncertainty *even before* they were required to assess it. Subject HU had this to say about the process of measuring distances within the VPLab:

> *[...] it's really experimental in the sense that it is I [and not the computer] who measures the distance between dots. If ten people measured [a distance], there could be ten different results.* [citation 21]

Some judgments involving the criterion of precision had nothing to do with the virtual measuring instruments, per se. For instance, subject MZ felt that the VPLab's instruments were precise enough but that the metaphor itself (and its Trace function) did not provide adequate precision:

> *[...] if you're going to film [the experiment], you might as well arrange it so you can get good resolution; you'd get a close-up of the table in order to obtain a better image, for instance ... You'd arrange to fix a grid on the table's surface so it would be easier to evaluate distances. It seems to me that these are things you think of almost naturally when you're doing it for real, whereas in [the VPLab], there are big limitations.* [citation 22]

This sensation of lack of precision occurred, as mentioned before, when MZ realized that the recorded image's quality degraded as he zoomed-in to measure distances between traces more precisely. He judged this apparent lack of precision in terms of the accuracy that was usually available when using computers, and thus regarded the resulting uncertainty of measurement as an unnecessary consequence of poor visual rendering. MZ perceived uncertainty as being artificial in this context:

> *I'm aware that this aims to simulate the manipulation [of instruments] but... I know that the computer is powerful enough to give me dots [i.e., position of traces] which are much more precise than this. So, this is a kind of false uncertainty. It's just that the dots are too big... In reality, I'm certain that the computer knew very, very precisely where the dots were when it made them.* [citation 23]

The above discussion (and the beginning of the next section) shows that precision and uncertainty were important concerns relating to the verisimilitude of various aspects of the VPLab. This is interesting insofar as it suggests that some credibility concerns can be relatively common among members of the same population. Drawing another general conclusion, I may say that the credibility of limitations imposed by an interface (e.g., precision or lack thereof) can be assessed, as expected, in direct reference to real-world conditions (e.g., lab work), but it can *also* be assessed with reference to the capabilities of other computer applications (e.g., CAD packages).

5.9 FREEDOM/CONTROL WITHIN THE SIMULATED ENVIRONMENT

Precision was important, as well, to a number of participants who made judgments in regards to manipulation of the disk on the air-table. As we recall, users could only launch the disk 'manually' – by dragging and releasing it with the hand-shaped cursor – in much the same way as in the real-world experiment.

One participant (FS) did make comments indicating that this method allowed for sufficient precision in launching the disk, when compared to working with the real set-up. By contrast, several others (e.g., BO, GT, HU, IV, KX, MZ) spontaneously complained about a lack of accuracy. For instance, subject GT claimed that in a real lab, one could know what force had been applied when launching the disk with the "elastics" that line the table's sides. This is something that he had not been able to do with the VPLab. GT also seemed to say that the initial position of the disk before its launch would not be as precise in the VPLab simulation as in an actual lab.

Precision notwithstanding, some of those same participants and others (e.g., BO, HU, FS) were satisfied with the general level of interaction provided through 'direct manipulation' with the mouse and hand-shaped cursor (e.g., drag and drop of objects and apparatus components). For those participants, 'free interaction' with objects (i.e., almost as free as in an actual lab) and freedom to choose methods, coupled with 'direct manipulation', promoted overall credibility of the environment. For instance, free interaction was a most important verisimilitude cue in the case of subject BO who, as we recall, had expressed apprehension of being "just a pawn in a game" and *a priori* suspicions (apparently related to use of science tutorial software) that everything would be pre-programmed to react in a determinate way as one followed a pre-determined path. Interacting freely with the simulated apparatus alleviated these concerns:

> *[If] you do not have control over anything, then you might say: "It's programmed to do that." Whereas if you have control – to be able to move and touch everything that you desire, to throw and have fun with the disk for 15 minutes – you see that it's not really programmed... there is programming but it respects what happens in real life.* [citation 2]

For subject HU, the most important element that contributed to the VPLab's verisimilitude was probably the freedom to choose work methods. This is linked, in my view, to the degree of control that one has over actions. As HU said:

> *I do everything, basically. See here: I determine the number of dots [i.e., traces] and the interval [between them] myself, as I want... For instance, I can take five different measurements, with a tolerance of 1 or 2 millimeters, and calculate their average to obtain a more precise distance: [the computer] does not do it for me. It is I who chooses the measurement methods and the calculating methods [...] I choose my own way of proceeding.* [citation 24]

In light of the foregoing examples, it appears that perceived control over objects and perceived limitations in regards to interaction constitute significant issues with respect to verisimilitude.

5.10 ANTICIPATED PEDAGOGICAL OBJECTIVES AS FRAMEWORKS FOR CREDIBILITY JUDGMENTS

An interesting yet somewhat unexpected finding of this study is that participants sometimes tended to use potential pedagogical objectives – those which they anticipated as being eventually set for students using the VPLab – as general frameworks for credibility judgments.

One example of this process involves subject LY. Previously, I mentioned that this participant commented favorably on the absence of a function which would have allowed the user to fix the protractor very precisely onto a graphical object and automatically obtain a measurement. He argued that such an automatic function would be detrimental to students in a context where learning how to conduct a lab experiment is more important than getting excellent results. LY's main impression was that performing measurements oneself without the help of an automatic function was favorable in that context.

Another important issue in this area deals with the question of the type of target users that were anticipated by participants. I observed that some participants (e.g., FS, MZ) judged that the VPLab was destined to be used by students of lower grade levels than their own; occasionally, this seemed to have an impact on their credibility judgments: for one participant (FS), lower simulation fidelity was *expected* and deemed adequate for *less advanced students*. Another participant (KX) felt that the VPLab would serve as a very good surrogate *only* for students who do not have access to an actual lab. He argued that students would understand and learn more if they had the possibility of performing experiments "concretely" in an actual school lab.

The cases discussed above strongly suggest that users who only know about the VPLab's general purpose (i.e., to teach experimental physics) can form relatively specific representations of designers' goals when working in the simulation-based environment which they created (and when following very basic task scenarios, admittedly exogenous to the environment itself, yet consistent with the designers' vision); my observations indicate that these representations can then serve as frameworks or criteria for credibility judgments. Indeed, the anticipated context of use seems to underlie credibility judgments in meaningful ways.

5.11 POTENTIAL ANOMALIES AND USE OF DISCURSIVE CUES (I.E., EXPLANATIONS)

As discussed in a previous section (*Ontological status of simulations*), a number of participants (e.g., ER, GT, IV, KX) expected ideal or optimal experimental conditions within the VPLab. Many associated computers, in general, with 'perfection' and with 'consistent' behavior, and did not expect computer programs to spontaneously generate errors. Hence, many also did not expect simulated experiments to present anomalies or degraded experimental conditions similar to those which can show up in school-lab experimental set-ups (e.g., a gust of wind blowing on the disk, dirt on the air-table's surface).

Additionally, some participants (e.g., CP, LY, MZ) also felt that it was impossible, when handling the simulated apparatus, to commit serious errors which would radically affect experimental outcomes (e.g., launching the disk too abruptly and damaging it).

When participants were eventually told that it would be possible to simulate the types of degraded conditions or random fluctuations discussed above, some (e.g., CP, ER, MZ) said that it would not be possible to detect these, even if they did exist in the simulation.[126] Others (e.g., IV, HU) questioned the usefulness or pertinence of simulating such elements. For instance, subject HU claimed that simulated anomalies were unwarranted, as the goal of the experiment was really to study and understand disk motion (read 'normal' motion), and not to be confronted to 'tricky' situations. Furthermore, he felt that some of the potential anomalies and random fluctuations of real experimental set-ups could be avoided by manufacturers of apparatus (and sometimes even by students), if they really wished to do so. For this subject, credibility was rather linked to the replication of as many conditions as are *'inescapable'* and *'useful'* in reality.

In slight contrast, other participants (e.g., BO, JW, KX, LY) said right away that the inclusion of anomalies would improve the simulation. For example, when subject KX was made aware (by the interviewer) that experimental conditions could involve randomness, anomalies and the possibility of committing serious handling errors, he stated that this would be very good as it would truly be the "model of a real situation." The crucial point here is that these participants (as well as others) also mentioned that users *should be warned* of the inclusion of such anomalies. Hence, it seems that discourse – in this case, explanations regarding the simulation's model – would play an important role with respect to verisimilitude judgments in this context. For some students like subject KX, potential cues that would allow awareness of random fluctuations of parameters or anomalies in the simulated apparatus may give rise to enhanced verisimilitude.

There are already a few indications that *discursive* cues can matter when it comes to credibility judgments concerning the simulation's complexity. Recall that I previously discussed the importance, for credibility, of viewing the video clip, which included verbal discourse. In addition, I can point to other cases involving the textual and graphical explanations in the multimedia Presentation and Explanation documents.

---

[126] Subject MZ also said that since it did not seem possible to make adjustments required to correct such defects, students should not be expected to anticipate them.

The most convincing of these cases concerns subject LY. During the session, this participant did not seem to mind that one of the simulation's behaviors he observed (slow deceleration of the disk due to presence of residual friction on the table's floor) pointed to greater complexity of the simulation, while another observed behavior pointed to lesser complexity in the collision model (he had deemed that the sides of the table were perfectly uniform). For LY, this contradiction – if ever there actually was one – had been resolved by the multimedia Presentation document, which made everything coherent: the subject had noticed that '*minimized friction* on the table's surface' was mentioned in the Presentation document, whereas no reference had been made regarding the table's sides. Hence, in the subject's opinion, designers had no obligation to make the table's sides 'less than perfect'.

So, the multimedia presentation of the experiment seemed to set the tone for LY's expectations of complexity, and this was linked to prior experiences in situations where teachers had announced, before specific experiments, that certain aspects of the physical phenomenon under study would not be taken into account.[127]

Still in LY's case, yet another discursive cue could eventually give rise to greater credibility: extensive mathematical and theoretical information accompanying the simulation. LY felt that greater disclosure of the 'inner workings' of the simulation (in the form of mathematical and theoretical information) was warranted. During the debriefing period, he was shown theoretical explanations (in the Explanations multimedia document), which contained animations of disk motion (featuring items such as vectors), and he stated that this type of information would promote credibility of the Manipulation workspace simulation.

I believe that LY's expectations in regards to mathematical and theoretical descriptions of the simulation's behavior were conditioned by his prior experience with simulations created with MAPLE ™ software: it seems that these visual simulations had been accompanied by real-time exposition of the formulas and calculations used to render them. This case suggests that disclosing the method through which a simulation model is constructed could, in some cases, enhance credibility of simulated environments (to the extent, of course, that the method would be perceived as valid).

As a concluding note, let me add that I did *not* observe any judgments involving a lack of credibility of information (Tseng and Fogg, 1999a, 1999b) contained in the multi-media documents– i.e., the video clips, the textual information, and the animations. It is entirely possible that *this* type of information will not be subject to substantial doubt, or so at least when users assume that it is provided by authority figures like teachers and domain experts.

[127] LY probably associated the act of neglecting these aspects at the time of analysis (in order to simplify the process), with the act of neglecting these aspects when designing the simulation itself.

Chapter 6. Conclusions

To conclude, I will review the theoretical and empirical developments of this project, expose its limitations and offer leads for future research. In closing, I will tackle ethical implications of simulation credibility research and development.

6.1 THEORETICAL DEVELOPMENTS

One of the theoretical contributions of this thesis is the proposition that any proper conceptualization of simulation credibility must focus on the discourse of actors who use, analyze, or otherwise deal with simulation, and more notably, that key discourse is formed of *judgments*. Another contribution is the elaboration of a model that helps define, categorize, and extensively describe judgments according to who expresses them, what they focus on, which criteria they are based upon, and which competencies and resources are involved in rendering them. In addition to this model, a distinction between first-order and second-order judgments (those involving meta-assessment prior to their final expression) was pivotal in contrasting expert judgment-types with other kinds of assessments relating the perceptions of media users.

Within this framework, I outlined a partial typology of judgments including simulator realism/fidelity assessments of experts, as well as psychological realism/fidelity, television modality, and computer credibility judgments expressed by media users as the primary judges. Of course, the development of this typology was influenced by an interest in the credibility concerns of users, leading to the development of a verisimilitude judgment construct. In defining this construct, I asserted that, like modality but contrary to fidelity and psychological fidelity, verisimilitude is not necessarily characterized by reference to very specific and agreed-upon systems or situations; indeed, there are no assurances as to the exact referents that may be involved in verisimilitude judgments. This is congruent with the idea that the central principles of verisimilitude assessments are those of modality (viz., constructedness, recognition of absence, possibility, plausibility, existence, perceived utility, genre and consistency within the genre), which go far beyond *similitude*, the underlying principle of fidelity.

I also theorized that verisimilitude judgment bases – aside from the individual competencies of judges – could be associated with categories of credibility (viz., presumed credibility, reputed credibility, surface credibility, experienced credibility) and with types of modality criteria (viz., internal and external). More concretely, I reasoned that non-experts usually draw upon resources that are readily available to them, making informal judgments based, for instance, on cues emerging from their interaction with the environment, on their own limited knowledge and experience of whatever they think is represented by the simulation, or even on its very nature as a computerized construct.

Borrowing from computer credibility research, I put forward that the potential scope of verisimilitude assessments is quite broad (including targets such as software and hardware interface features, specific events and objects presented by the simulation, interaction scenarios, etc.) and that it is perhaps best conceived as being defined by users themselves. Moreover, I asserted that the notion of trustworthiness, which captures the perceived goodness or intent of the source of a product, represents important common ground between computer credibility and simulation verisimilitude.

I subsequently disentangled the verisimilitude judgment construct thus defined, from notions of presence and willful suspension of disbelief (the latter, I argued, should be replaced by a Goffmanian concept of engrossment, thereby avoiding confusion with credibility). An important realization was that presence and suspension of disbelief describe phenomena that operate *in situ,* if at all, while verisimilitude judgments can be both expressed and studied post hoc. It follows, incidentally, that a verisimilitude framework is appropriate to explore the impressions that users *retain* from interaction with simulation (what they come away with).

This not withstanding, I should now point out a limitation in my general approach, namely a failure to fully take into account behavior *not* involving verbal expression or discourse. It seems indisputable that credibility does manifest itself through actions, in addition to discourse. Fuller consideration of relevant activity-related behavior should therefore eventually enter the verisimilitude equation– for one thing, even sincere users may not always act as they claim, nor adequately account for how they have acted.

6.2 EMPIRICAL DEVELOPMENTS

For the empirical part of this project, I used the verisimilitude judgment construct as a general theme in the exploration of potential users' discourse. To this end, I developed a qualitative and descriptive method involving thirteen university students who tried out the VPLab prototype.

This approach has allowed for the gathering and in-depth analysis of a wide variety of judgments. Overall, my results indicate that user verisimilitude judgments pertaining to simulation can be very complex and specific. In particular, I observed that given cues could play different, even contradictory, roles in the formation of judgments. I also found that, in some instances, *unfavorable* assessments could be promoted by cues which designers initially expected to *favor* verisimilitude, and vice-versa. Furthermore, my descriptive approach allowed me to suggest that individual traits, such as certain attitudes and prior experiences, can play significant roles in the expression of particular judgments.

As far as this study's participants were concerned, some of the prevalent individual traits of which I have just spoken included *a priori* attitudes toward simulation, prior use of certain computer applications, knowledge/experience of specific apparatus and related subject matter, and knowledge/experience of lab work in general. Indeed, it is especially noteworthy that some verisimilitude judgments seem to be at least partially based on preconceived ideas or prior experience pertaining to the medium of simulation itself.

As mentioned above, the question of presumed credibility, which is linked with *a priori* trust in simulation as a medium, may be of particular interest to researchers and practitioners. First, the present data indicate that students' *a priori* attitudes toward simulation as a medium can be unfavorable, neutral, or even favorable. Second, I found indications that unfavorable *a priori* attitudes may influence verisimilitude judgments related to the constructed/virtual nature of synthetic environments. I have established, however, that some users who make these types of judgments may *still* express other types of judgments *in favor* of overall credibility.

With regard to interactivity, I may conclude that an interface which allows direct manipulation of simulated objects, and freedom to choose work methods, will be favorable to verisimilitude for certain users. The credibility of *limitations* imposed by the interface (e.g., precision of measurements or lack thereof) can be evaluated, as expected, with reference to real-world conditions, but can also be assessed with reference to the capabilities of *other computer applications* of a completely different nature.

One of the most important findings relating specifically to virtual labs concerns the perception of the simulation's behavior. I found indications that cues which point to inclusion of real-word constraints (e.g., a moving object's deceleration signifying inclusion of friction) often lead to favorable credibility judgments (although this is not always strictly the case).

In a related area, I found that video clips showing the actual phenomena replicated by simulations were valuable assets in terms of credibility. However, my findings indicate that designers cannot necessarily expect meaning and verisimilitude of simulations to be completely circumscribed just by providing users with common 'referents' in the form of video data. Nevertheless, I suggest that future studies should test whether an even tighter coupling of simulation with video data could further promote credibility. For instance, one could provide users with video footage of strange or potentially unexpected behavior in real phenomena, and then later show participants that such behavior can indeed be observed in the simulations replicating these phenomena.

Other discursive cues, namely textual/graphical presentations and theoretical explanations of the simulation, also seemed to influence verisimilitude judgments expressed by certain participants. Future investigations in this area could explore the consequences of disclosing information to users concerning the 'inner workings' of simulation models (an act which some might regard as more ethically correct– see below). For example, a longitudinal study could be conducted wherein virtual lab users would be called upon to perform several experiments; after each experiment, these participants would be made aware of simulation modeling methods and informed of unapparent similarities or differences between the simulation and the actual apparatus. The idea would be to verify whether credibility of a virtual lab can be progressively enhanced, from one simulated experiment to the next, by showing users how designers "have done their homework."[128]

Further issues were closely related to the VPLab's main metaphor. Some of the technical processes and objects represented by the metaphor were unfamiliar to participants (with respect to their experience in laboratory contexts), and this may have caused certain user interpretations of the metaphor to stray from its intended meaning; in some cases, such interpretations apparently lead to negative effects on verisimilitude. I proposed that more 'familiar' metaphors could possibly give rise to less divergent and more positive verisimilitude judgments. However, I briefly mentioned an additional hypothesis (dubbed 'latency of favorable judgments'), which postulates that the expression of positive verisimilitude judgments could be impeded in such cases. I discuss this hypothesis in more detail, just below.

6.3 OUTLINES FOR FUTURE RESEARCH

I suggest that when a *high-fidelity* virtual environment is being used in everyday life (or in an ethnographic-like study which aims to observe use of virtual environments in everyday conditions), users' positive attitudes relative to verisimilitude may tend to remain latent, as elements that favor verisimilitude are taken for granted.[129] That is what I call 'latency of favorable judgments'.

Let me expand upon this: I am proposing that in everyday use, the more a virtual environment feels 'natural' to an individual (either by conforming to what he/she expects, or by seeming very similar to possible real-world environments, or else by being internally coherent and consistently stimulating perceptual mechanisms as accurately as real environments), the more the elements which contribute to this feeling of naturalness are taken for granted by that individual. As a side

[128] A similar test could be conducted for virtual lab metaphors by informing users of relationships between metaphors and analogous experimental methods used in real labs.

[129] This could also be the case when some kind of metaphor is involved, say one that is based on very familiar objects, events and processes.

effect, the remaining *perceived* differences between the virtual environment and the real world might 'stick out', which (combined to an awareness of ontological status) may lead to the expression of negative verisimilitude judgments.[130] In other terms, for a user habitually engaged in such a seemingly 'natural' virtual environment, it is 'business as usual' unless some feature promotes disengagement from the mediated experience.

In the course of this study, I sometimes did get a sense that perceived deviations from reality (or rather, from the participants' experience of reality) actually did 'stick out', but I cannot demonstrate this ostensibly with the present data, since the methods I used were not designed to do so. It is also my belief that certain 'positive' aspects of the VPLab's metaphor, by and large, were taken for granted or ignored.

One such aspect would be the 'first-person' perspective afforded by the interface. With the VPLab, the user's actions are not mediated by an on-screen anthropomorphic character that represents him as the experimenter (like in third-person video games). Instead, the user directly interacts with the instruments and apparatus via a cursor shaped like a hand and meant to represent the user's own hand. In this way, users may feel that they are 'personally' conducting experiments. This characteristic was hardly mentioned by participants as contributing to verisimilitude.[131]

In my opinion, the importance of such an aspect would be more likely to emerge paradigmatically (cf. Barker, 1988) – in this instance, if users (either directly or mentally) compared various *potential* metaphors which could be alternatively implemented for the same virtual environment. This, however, was not part of the study's design.[132]

Notice that it would also be possible to test a similar hypothesis with other media. For example, one could observe if spectators having recently viewed films that are considered more or less 'realistic' by subject matter specialists and movie critics (i.e., experts), would naturally tend to discuss amongst themselves elements which give rise to greater verisimilitude or, on the contrary, elements that are unfavorable with respect to verisimilitude. My hypothesis entails that

---

[130] Of course, if the user does not *perceive* any further differences between the virtual environment and the real world, then he might well be led to judge (perhaps even falsely) that the environment is extremely verisimilar, possibly despite considerable lack of fidelity.

[131] Subject AN did mention that it was interesting to be "the master" of the situation and subject GT mentioned that the instruments were designed realistically, giving the impression that one could "handle them with one's own hands." Nevertheless, I do not believe that these comments reflect the specificity of 'first-person perspective', nor do they adequately convey its potential importance for verisimilitude.

[132] I believe that failure by participants of this study to specifically acknowledge the verisimilitude of the first-person perspective could eventually serve as first evidence of 'latency', that is, if another study using such a comparative method as described above, could demonstrate that this aspect can, in fact, favor verisimilitude. In a more descriptive/anthropological study, attitudes like subject BO's concerning the metaphor would rather tend to infirm this latency if they could be *spontaneously expressed during the use* of a virtual environment in a context as close to everyday use as possible.

the latter would tend to happen. In regards to virtual environments, let me also put forward the idea that unfavorable *a priori* attitudes toward simulation could exacerbate this hypothesized propensity for negative elements to 'stick out'.

Regardless of the details, my first underlying premise is that – within given cultures, including ours – there is an asymmetry in verisimilitude judgments regarding certain mediated experiences (e.g., films, simulated environments). My second premise is that this asymmetry, in some ways, favors the expression of *negative judgments* (this is not to say, however, that there will necessarily be more negative assessments than positive ones in a given context). If this hypothesis can be somehow verified, it might constitute an important issue relating specifically to how verisimilitude judgments are investigated, but it may also be one which addresses the very nature of everyday verisimilitude judgments themselves. One could consider that this latency or asymmetry is itself part and parcel of the problem of designing credible virtual environments.

As other starting points for future investigations, I propose three straightforward questions, which are likely to represent particularly salient preoccupations for individuals faced with simulations. The first may emerge immediately for users: How real does this simulation seem? The second could come after additional thought about, or contact with a simulation: *How far* should I trust it? The third involves motivation or justification: *Why* should I trust it? Although there are several other important issues, perceptions relating to these questions are assuredly of fundamental interest.

At this juncture, I should recall that the study described in this thesis was conducted in a research facility rather than in users' normal work-settings (i.e., in school or at home). The extent to which this influences credibility judgments is unknown. It would be useful if at least some future studies were to be conducted in more 'natural' conditions. When dealing with students for instance, efforts should be made to observe verisimilitude judgments in class (or at home, in the case of distance education). In so doing, it is likely that investigators will not just be assessing the verisimilitude of simulation software as such, but also the credibility of whole units (e.g., learning units, training units) which, in addition to the simulation-based environment, also include external elements involved in its use, such as prescribed tasks, support materials, etc. It should be paramount to include *context* of simulation use into some types of credibility studies.

Attitudes resulting from prolonged use of simulation-based environments should be given very special attention in order to investigate the full realm of *experienced* credibility. For practitioners, it is crucial that the value of simulation as a credible medium be assessed not only by taking into account the initial reactions of users, but also by considering their attitudes when sufficient experience of use has been acquired. We also need to find out how perceptions of verisimilitude affect user motivation, performance, and achievement of goals (e.g., transfer of skills, instructional effectiveness).

I have observed that verisimilitude judgments can often be complex. As such, future studies should ideally involve both rich qualitative descriptions of individual judgments pertaining to specific elements of virtual environments, as well as reliable quantitative measurements of overall credibility. Studies with large representative samples of users, working with a *variety* of simulation-based environments,[133] are required to confirm and go beyond the findings of this exploratory study.

The present work did not aim to establish the existence of statistically valid and consistent causal relationships between verisimilitude judgments and individual traits; certainly, this should be the topic of future studies. Nevertheless, I believe that my observations can serve as excellent basis for such investigations involving simulation-based science laboratories. Such studies could focus on the following types of user characteristics:[134]

– interests, attitudes, aptitudes, and experience pertaining to lab work in general;
– knowledge of subject matter pertaining to specific simulations;
– exposure to computers, multimedia applications and simulation;
– *a priori* attitudes toward simulation and computers in general;
– 'computer confidence', computer expertise, and knowledge pertaining to computers and simulation.

Another promising but as yet unexplored area for research deals with possible links between simulation credibility and the level of *attention* given to relevant cues. For instance, it could be useful to test whether users who pay much attention to cues thought to favor verisimilitude (relevant discursive cues, for example) find simulations more credible than others who do not. Once verified, this hypothesis would have interesting implications: should there be a strong link between attention to cues and credibility, a designer's power to influence credibility would then be somewhat more limited than could otherwise be expected, insofar as user attention is difficult to control in everyday conditions.

Due to the context of this study, social aspects of verisimilitude could not be properly addressed.[135] These too should be tackled in future investigations. Obviously, in reality, simulation users are not 'confined to a closed box': they interact with others and are influenced

---

[133] The fact that the present work deals with only one simulation within a single environment constitutes a limitation. On the other hand, I have taken the trouble of extensively describing both the VPLab environment and the user sample so that researchers considering the findings of future in-depth studies similar to this one might be better equipped to compare outcomes, when possible.

[134] Some of these items are inspired by a review of user variables relevant to general computer credibility (Tseng and Fogg, 1999a, 1999b): namely, *user familiarity with subject matter*, *user understanding of the computer system*, and *user need for information*.

[135] The expression 'social aspects' might be seen as misleading, if it is held that verisimilitude is *intrinsically* social.

by their peers (e.g., classmates, instructors) and by information from other sources (e.g., television, movies). Additionally, the credibility of a simulation might be affected to some extent by the credibility attributed to the product's designer, to an affiliated institution, or to a third party (an instructor, for example) who suggests or imposes the use of that simulation (cf. Tseng & Fogg, 1999a).

Looking even further beyond the individual bases of judgments to their social context, investigators should consider Hodge and Tripp's hypothesis that general social relations influence modality in significant ways; these authors suggested, for instance, that:

> *Modality relations (both in television content and in response to television) will often serve to express something about the social relations of the viewer. Over-emphasis on the reality of television content expresses a sense of social isolation, a rejection of general social relations in the lived world in favor of those experienced via television. Over-emphasis on the unreality expresses the opposite: a rejection of the world as mediated by television in favor of lived experience.*
>
> (Hodge and Tripp, 1986, p. 136)

Television, the focus of Hodge and Tripp's research, is much more a part of our social fabric than simulation is. Transferring such hypotheses to the context of simulation use might therefore seem risky. With the proliferation of video games and educational software, however, simulation has been introduced to a wider public, such that there may already exist situations in which hypotheses like these would carry pragmatic implications.

In the same spirit, I would draw attention to the fact that my empirical investigation constitutes a case study, or 'micro-study', of verisimilitude; at a later stage, researchers might consider conducting macro-studies, for instance, analyses of simulation verisimilitude as it variously relates to diverse cultures or sub-cultures. Such work could lead to a much broader vision of the field.

6.4 ETHICAL CONSIDERATIONS

As a final note, I will briefly address another theme which must not be overlooked by members of the research and development community: ethics in the promotion of verisimilitude and credibility. First off, it should be established, for obvious reasons, that a certain measure of caution toward simulation is a commendable, even a highly desirable, trait. Some may argue, incidentally, that for *certain* users, *a priori* distrust of simulation goes beyond that which can be deemed 'healthy skepticism'. Still, in the case of simulated lab work, one could question the very notion that something truly unique is going on when students are skeptical of such simulations. As Hennessy and O'Shea (1993, p. 130) put it: "It must be recognized that the same concern regarding simulation credibility can be applied to laboratory work [...] After all, the science laboratory is another idealized situation." This suggests that the credibility of the simulation's referent *itself* should also be pondered.

In any event, when dealing with credibility of media, it is appropriate to consider the means through which knowledge and beliefs might be influenced. For instance, one may feel that using video footage of real apparatus, with the *sole* purpose of promoting credibility of simulated experiments, would not be an ethically correct solution as it would rest, at least to some extent, on the premise that students should trust video data without much reserve.[136]

More generally, it is obviously unethical to try to make non-recreational simulations appear to unsuspecting users as being more accurate than experts would judge. Nevertheless, designers and practitioners should still strive to make simulations with lesser fidelity seem credible, when those simulations can be deemed sufficiently valid and useful by their peers and by domain experts. However, promotion of credibility should *never* come to the detriment of users. In instructional simulations, *voluntary* departures from elevated levels of fidelity can be very beneficial (Alessi, 1988) – when such is the case, it can be explained to users easily enough. In addition to this, I strongly insist that designers should strive to uncover any significant *involuntary* departures from high fidelity, as well as barriers to the achievement of desirable objectives which may be pursued by users. What's more, it is imperative that this information be disclosed to users themselves, even if one should do so only after they have finished using a simulation. People should never come away with a false impression that, in the course of using a simulation, they have acquired specific knowledge or skills, or attained particular objectives, when that is actually not the case.

I will go even a step further and propose that, as a general rule, users must also be provided with as much information as possible concerning the workings of underlying models and modeling methods. Turkle (1997, p. 82) was of the same opinion when she argued that people should be taught to demand greater transparency in simulations and to ask that "the games we [*sic*] play (particularly the ones we use to make real-life decisions) make their underlying models more accessible." Her premise was that simulations "enable us to abdicate authority [...]; they give us permission to accept the opacity of the model that plays itself out on our screens" (p. 81). Turkle's characterization of simulations in general, as "opaque", is justified. Moreover, by reading the rest of her discussion, it is also understood that some people might not passively

---

[136] As such, I recommend that practitioners who use video clips allow users the opportunity of evaluating the trustworthiness of the video footage itself by providing them with at least some of the following items, while stressing their relevance: the opportunity of verifying the video producer's credentials; information about when and where the footage was shot; a detailed description of the objects depicted in the video footage; a description of any special circumstances that significantly affect the behavior of apparatus, but are not obvious in the video clip; information regarding manipulation or special editing of the footage; other video footage from different sources. (Note that enhancing credibility is *not* the sole purpose of including video clips in the VPLab. Among other reasons, excerpts of professionally produced science videos are used because they contain well presented theoretical explanations and real-life applications of phenomena involved in the VPLab's experiments.)

accept “the authority” of simulations without reserve. That much seems clear from my study, too. However, let me suggest that Turkle’s excellent recommendations, stated above, should not apply solely to simulation use. Indeed, musn’t greater efforts be deployed in teaching literacy and critical thinking, not only with respect to simulation, but also in regards to all media, and to visual media in particular? I certainly agree with educators and thinkers who believe, for a host of reasons, that this would be extremely beneficial. From then on, added meaning and purpose is conferred upon empirical credibility research: that of ensuring the adequacy and quality of this education. I can only hope that this thesis will stand as a contribution, however modest, to such efforts.

References

Alessi, S.M. (1988). Fidelity in the design of instructional simulations, *Journal of Computer-Based Instruction*, 15 (2), 40-47.

Alessi, S.M., & Trollip, S.R. (1991). *Computer-based instruction: Methods and development*. Englewood Cliffs: Prentice-Hall.

Alluisi, E.A. (1978). A discussion of psychological fidelity in simulated work environments. *Psychological fidelity in simulated work environments: Proceedings of a Symposium at the Annual Meeting of the American Psychological Association, Toronto, Canada, Research Problem 78-26* (pp. 57-65). Alexandria, VA: U.S. Army Research Institute.

Alty, J.L., Knott, R.P., Anderson, B., & Smyth, M. (2000). A framework for engineering metaphor at the user interface, *Interacting with Computers*, 13, 301-322.

Bardini, T. (1997). Bridging the gulfs: From hypertext to cyberspace, *Journal of Computer Mediated Communication*, 3 (2). Retrieved September 2, 1999, from http://www.ascusc.org/jcmc/vol3/issue2/bardini.html

Bardini, T. (1996). Changement et réseaux socio-techniques : de l'inscription à l'affordance, *Réseaux*, 76, 125-155.

Barker, D. (1988). "It's Been Real": Forms of television representation, *Critical Studies in Mass Communication*, 5, 42-56.

Baum, D.R., Smith, D.A., Klein, G.A., Hirshfeld, S.F., Swezey, R.W., & Hays, R.T. (1982). *Specification of training simulator fidelity: A research plan* (ARI Technical Report 558). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

Bell, H.H., & Waag, W.L. (1998). Evaluating the effectiveness of flight simulators for training combat skills: A review, *The International Journal of Aviation Psychology*, 8 (3), 223-242.

Bowman, D.A. (1999). *Interaction techniques for common tasks in immersive virtual environments: Design, evaluation and application.* Doctoral dissertation, Georgia Institute of Technology.

Bunyard, D. (2000). *Notes on semiotics: Modality*. Retrieved February 31, 2002, from King Alfred's University, Education Studies Web Site: http://www.wkac.ac.uk/edstudies/courses/derek/ssmodality.htm

Caird, J.K. (1993). The perception of visually simulated environements. In E.J. Haug (Ed.), *Concurrent engineering: Tools and technologies for mechanical system design* (pp. 971-977). Berlin Heidelberg: Springer-Verlag.

Carr, K. (1995). Introduction. In K. Carr & R. England (Eds.), *Simulated and virtual realities* (pp.1-10). Bristol, PA: Taylor & Francis.

Cartwright, H.M. (1998). Remote control: How science students can learn using internet-based experiments. *New Networked-Based Media in Education, Proceedings of the International CoLoS Conference, Maribor, Slovenia* (pp. 51-59). Maribor: University of Maribor.

Chandler, D. (1997). *Children's understanding of what is 'real' on television: A review of the literature*. Retrieved May 24, 1999, from University of Wales, Aberystwyth, Media and Communication Studies Web site: http://www.aber.ac.uk/media/Documents/short/realrev.html

Chandler, D. (1994). *Semiotics for beginners*. Retrieved December 6, 2001, from University of Wales, Aberystwyth, Media and Communication Studies Web site: http://www.aber.ac.uk/media/Documents/S4B/semiotic.html

Christou, C., & Parker, A. (1995). Visual realism and virtual reality. In K. Carr & R. England (Eds.), *Simulated and virtual realities* (pp. 53-84). Bristol, PA: Taylor and Francis.

Compagnon, A. (1999). *Brisacier, ou la suspension d'incrédulité*. Paper presented at the Colloque "Frontières de la fiction" virtual conference. Retrieved March 27, 2002, from http://www.fabula.org/forum/colloque99/222.php

Cooper, M. (2000). The Challenge of practical work in an eUniversity - real, virtual and remote experiments. *IST 2000 The Information Society for All, Nice, France*. Retrieved April 28, 2002, from http://kmi.open.ac.uk/projects/pearl/publications/pearl-1.rtf

De la Teja, I., Lundgren-Cayrol, K., & Paquin, C. (1998). *Campus virtuel. Rapport de la mise à l'essai du prototype global*. (Technical Report no LICEF 98R148). Montréal: Centre de recherche LICEF.

Dittrich, J.E. (1977). Realism in business games: A three-game comparison, *Simulation & Games*, 8 (2), 201-210.

Dowling, C. (1997). Simulations: New "worlds" for learning, *Journal of Educational Multimedia and Hypermedia*, 6 (3-4), 321-337.

Dubey, G. (1997). Technologies virtuelles : entre dogme et croyance. La formation par simulateur dans l'aéronautique civile, *Cahiers internationaux de Sociologie*, 103, 373-398.

Edward, N.S. (1997). An evaluation of student perceptions of screen presentations in computer-based laboratory simulations, *European Journal of Engineering Education*, 22, 143-152.

Elliot, W.R., Rudd, R., & Good, L. (1983). *Measuring the perceived reality of television: Perceived plausibility, perceived superficiality and the degree of personal utility*. Paper presented at the Annual Meeting of the Association for Education in Journalism and Mass Communication, Corvalis, OR. (ERIC Document Reproduction Service No. ED236612).

Ellis, S. (1995). Virtual environments and environmental instruments. In K. Carr & R. England (Eds.), *Simulated and virtual realities* (pp.11-51). Bristol, PA: Taylor & Francis.

Fang, D.L. (1996). A study of trainees' learning attitudes towards shiphandling simulator training. *Marine Simulation and Ship Manoeuvrability, Proceedings of the International Conference MARSIM '96, Copenhagen, Denmark* (pp. 97-107). Rotterdam: A.A. Balkema.

Fisette, J. (1990). *Introduction à la sémiotique de C.S. Peirce*. Montréal: XYZ éditeur (Collection "Études et Documents").

Fiske, J. (1990). *Introduction to communication studies*. New York: Routledge.

Francis, A., & Couture, M. (2002). *Credibility of a computer simulation-based science laboratory: An exploratory study of learners' verisimilitude judgments* (Technical Report LICEF02RR01). Montréal: Centre de recherche LICEF.

Friedman, T. (1999). Semiotics of SimCity, *First Monday*, 4 (4). Retrieved January 15, 2002, from http://www.firstmonday.org/issues/issue4_4/friedman/index.html#author

Gibson, J.J. (1966). *The senses considered as perceptual systems.* Boston, MA: Houghton Mifflin.

Goffman, E. (1974). *Frame analysis.* Cambridge, MA: Harvard University Press.

Greenlee, D. (1973). *Peirce's concept of sign*. The Hague: Mouton.

Hatzipanagos, S. (1995). Fidelity and complexity: Dimensions in the study of reality and abstraction in computer simulations. *Proceedings of ICCE 95: International Conference on Computers in Education, Singapore* (pp.105-110). Charlottesville, VA: AACE.

Hays, R.T., & Singer, M.J. (1989). *Simulation fidelity in training system design: Bridging the gap between reality and training*. New-York: Springer-Verlag.

Heim, M. (1993). *The metaphysics of virtual reality*. New-York: Oxford University Press.

Hennessy, S., & O'Shea, T. (1993). Learner perceptions of realism and magic in computer simulations, *British Journal of Educational Technology*, 24 (2), 125-138.

Hodge, R., & Kress, G. (1988). *Social semiotics*. Ithaca, NY: Cornell University Press.

Hodge, R., & Tripp, D. (1986). *Children and television: A semiotic approach*. Stanford, CA: Stanford University Press.

Hoopes, J. (Ed.). (1991). *Peirce on signs: Writings on semiotic by Charles Sanders Peirce.* Chapel Hill: The University of North Carolina Press.

Hopkins, C.O. (1975). How much should you pay for that box?, *Human Factors*, 17 (6), 533-541.

Jentsch, F., & Bowers, C.A. (1998). Evidence for the validity of PC-based simulations in studying aircrew coordination, *The International Journal of Aviation Psychology*, 8 (3), 243-260.

Kay, A. (1990). User interface: A personal view. In B. Laurel (Ed.), *The art of human computer interface design* (pp. 191-207). Reading, MA: Addison-Wesley.

Kay, A. (1984). Computer Software, *Scientific American,* 251 (3), 53-59.

Kernal, H.K. (1999). Effects of computer/television convergence on users' perception of content, equipment and affect. *Proceedings of CHI'99, Pittsburgh* (pp. 248-249). New York: ACM Press.

Kiefer, F. (1998). Modality. In J. Vershchueren, J.-O. Östman, J. Blommaert, & C. Bulcaen (Eds.), *Handbook of pragmatics*. Amsterdam: John Benjamins Publ. Co.

Klein, J. (1992). *A developmental comparison of perceived reality in live theatre*. Paper presented at the Biennial Meeting of the Southwestern Society for Research in Human Development, Tempe, AZ. (ERIC Document Reproduction Service No. ED347600).

Laurel, B. (1991). *Computers as theater*. Reading, MA: Addison-Wesley.

Levine, T., & Donitsa-Schmidt, S. (1998). Computer use, confidence, attitudes and knowledge: A causal analysis, *Computers in Human Behavior*, 14 (1), 125-146.

Lombard, M. (2000). *Presence explication* (based on a discussion that took place via the Presence-l listserv, during the spring of 2000, among members of a community of scholars interested in the presence concept). Retrieved Septempber 13, 2001, from Temple University Nimbus Web site: http://nimbus.temple.edu/~mlombard/Presence/explicat.htm

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of telepresence, *Journal of Computer Mediated Communication*, 3 (2). Retrieved September 2, 1999, from http://www.ascusc.org/jcmc/vol3/issue2/lombard.html

Lombard, M., Ditton, T.B., Crane, D., Davis, B., Gil-Egui, G., Horvath, K., Rossman, J., & Park, S. (2000). *Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument*. Paper presented at the Third International Workshop on Presence, Delft, The Netherlands. Retrieved September 13, 2001, from Temple University Nimbus Web site: http://nimbus.temple.edu/~mlombard/P2000.htm

Martial, O. (1997). *Définition d'une interaction humain-ordinateur adaptée aux aveugles : les interfaces graphiques, un espoir*. Doctoral dissertation, Université de Montréal.

Matheny, W.G. (1978). The concept of performance equivalence in training systems. *Psychological fidelity in simulated work environments: Proceeding of a Symposium at the Annual Meeting of the American Psychological Association, Toronto, Canada, Research Problem 78-26* (pp. 3-16). Alexandria, VA: U.S. Army Research Institute.

Messaris, P. (1994). *Visual literacy: Image, mind, & reality*. Boulder, CO: Westview Press.

Nef, F. (1991). *Logique, langage et réalité*. Paris: Éditions Universitaires.

Peirce, C.S. (1991). Prolegomena to an apology for pragmaticism. In J. Hoopes (Ed.), *Peirce on signs: Writings on semiotic by Charles Sanders Peirce* (pp. 249-252). Chapel Hill: The University of North Carolina Press.

Peirce, C.S. (1998). What is a sign? In Peirce Edition Project & N. Houser (Eds.), *The Essential Pierce: Selected Philosophical Writings, Volume 2 (1893-1913),* (pp. 4-10). Bloomington: Indiana University Press. Retrieved June 10, 2002, from http://www.iupui.edu/~peirce/web/ep/ep2/ep2book/ch02/ep2ch2.htm

Peirce Edition Project, & Houser, N. (Eds.). (1998). *The Essential Pierce: Selected Philosophical Writings, Volume 2 (1893-1913).* Bloomington: Indiana University Press.

Pires, A.P. (1997). Échantillonnage et recherche qualitative : essai théorique et méthodologique. In J. Poupart et al. (Eds.), *La Recherche qualitative : enjeux épistémologiques et méthodologiques* (pp. 113-169). Boucherville: Gaetan Morin.

Potter, J.P. (1992). How do adolescents' perceptions of television reality change over time, *Journalism Quarterly*, 62 (2), 392-405.

Potter, J.P. (1988). Perceived reality in television effects research, *Journal of Broadcasting & Electronic Media*, 32 (1), 23-41.

Rubin, J. (1994). *Handbook of usability testing: how to plan, design, and conduct effective tests.* New-York: Wiley.

Schwartz, D.L. (1995). Reasoning about the referent of a picture versus reasoning about the picture as the referent: An effect of visual realism, *Memory & Cognition*, 23 (6), 709-722.

Smith, R.B. (1987). Experiences with the Alternate Reality Kit: An example of the tension between literalism and magic. *Proceedings of the CHI + GI '87 Conference on Human Factors in Computing Systems - IV and Graphics Interface, Toronto, Canada* (pp. 61-67). New-York: ACM.

Sonesson, G. (1999). *Pictorial semiotics: The state of the art at the beginning of the nineties.* Retrieved December 27, 2001, from Lund University, Department of Semiotics Web site: http://www.arthist.lu.se/kultsem/sonesson/pict_sem_3.html

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence, *Journal of Communication*, 42 (4), 73-93.

Stoffregen, T.A., Bardy, B.G., Smart, L.J., & Pagulayan, R.J. (In press). On the nature and evaluation of fidelity in virtual environments. In L.J. Hettinger & M.W. Haas (Eds.), *Psychological issues in the design and use of virtual environments*. Mahwah, NJ: Lawrence Erlbaum Associates.

Stuart, R. (1996). *The design of virtual environments*. New-York: McGraw-Hill.

Suchman, L. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge: Cambridge University Press.

Thévenot, L. (1990). L'action qui convient, *Raisons Pratiques*, 1, 39-69.

Tseng, S., & Fogg, B.J. (1999a). The elements of computer credibility. *Proceedings of CHI'99, Pittsburgh* (pp. 80-87). ACM Press: New York.

Tseng, S., & Fogg, B.J. (1999b). Credibility and Computing Technology, *Communications of the ACM*, 42 (5), 39-44.

Turkle, S. (1997). Seeing through computers: Education in a culture of simulation. *The American Prospect*, 31, 76-82.

Turkle, S. (1984). *The Second self: Computers and the human spirit*. Toronto: Granada.

U.S. Department of Defense. (1998). *DoD modeling and simulation (M&S) glossary.* Alexandria, VA: Defense Modeling and Simulation Office.

Wallace, R.E., & Schroeder, M.C. (1988). Analysis of billiard ball collisions in two dimensions, *American Journal of Physics*, 56 (9), 815-819.

Wetzel, C.D., Radtke, P.H., & Stern, H.W. (1994). *Instructional effectiveness of video media.* Hillsdale, NJ: Lawrence Erlbaum.

Williamson, T.W. (1995). Realism and anti-realism. In T. Hoderich (Ed.), *The Oxford companion to philosophy*. Oxford: University Press. Retrieved January 11, 2002, from http://www.xrefer.com/entry/553352

Wright, C. (1994). *Truth and objectivity*. Harvard: University Press.

Zeman, J. (1977). Peirce's theory of signs. In T. Sebeok (Ed.), *A perfusion of signs*. Bloomington: Indiana University Press. Retrieved December 27, 2001, from http://www.clas.ufl.edu/users/jzeman/peirces_theory_of_signs.htm

Appendix A: Questions Asked During the Telephone Interview

Subject ID:

Âge ….. ans

Scolarité –

- ☐ Cegep - programme(s) completé(s) ……………………………………………
- ☐ Université - programme(s) completé(s) ……………………………………
- ☐ Autre ……………………………………………………………………

---

1. **Avez-vous déjà suivi des cours de physique au niveau secondaire ?** ☐ oui ☐ non

   Si oui, combien de cours ? ……………………………………
   Avez vous réalisé des expériences de physique à l'occasion de certains de ces cours ?

   ☐ oui ☐ non

2. Avez-vous réalisé des expériences *dans d'autres domaines que la physique* au secondaire ?

   ☐ oui ☐ non

   Si oui, dans quels domaines ? ……………………………………

3. Avez-vous déjà suivi des cours de physique *au niveau collégial* ? ☐ oui ☐ non

   Si oui, combien de cours ? ……………………………………
   Avez-vous réalisé des expériences de physique à l'occasion de certains de ces cours ?

   ☐ oui ☐ non

4. Avez-vous réalisé des expériences dans *d'autres domaines que la physique* au niveau collégial ?

   ☐ oui ☐ non

   Si oui, dans quels domaines ? ……………………………

5. Avez-vous déjà suivi des cours de physique *au niveau universitaire* ? ☐ oui ☐ non

   Si oui, combien de cours ? ……………………………………

   Dans quel programme ? ……………………………………………

Avez-vous réalisé des expériences de physique à l'occasion de certains de ces cours ?

☐ oui ☐ non

6. Avez-vous réalisé des expériences *dans d'autres domaines que la physique* au niveau universitaire ?

☐ oui ☐ non

Si oui, dans quels domaines ? ....

7. Avez-vous de l'expérience avec des ordinateurs ? ☐ oui ☐ non

Si oui, quelle plate-forme avez-vous utilisé le **plus fréquemment** ?

☐ IBM/PC ☐ Macintosh ☐ Autre ....

8. Indiquez combien d'heures par semaine vous utilisez l'ordinateur (approximativement) ?

☐ 0 heures
☐ 1-5 heures
☐ 6-12 heures
☐ plus que 12 heures

9. Sur une échelle d'un à cinq -- en général, l'utilisation d'un ordinateur vous paraît :

Si **1** correspond à :	1	2	3	4	5	et **5** correspond à :
'Difficile'	☐	☐	☐	☐	☐	'Facile'
Désagréable	☐	☐	☐	☐	☐	Agréable
Inutile	☐	☐	☐	☐	☐	Utile

10. Indiquez le chiffre qui correspond à votre niveau de compétence quant à l'utilisation d'un ordinateur, en général.

1 - très faible ; **2** - faible ; **3** - intermédiaire ; **4** - bon ; **5** - expert

Appendix B: Pre-interaction Written Questionnaire

Nous aimerions connaître le profile des gens qui participent aux séances d'essai. Les questions qui suivent visent à recueillir de l'information sur l'utilisation que vous faite des ordinateurs.

1. Utilisez-vous un ordinateur à la maison ?

☐ oui ☐ non

Si oui, l'utilisez-vous en rapport avec vos travaux scolaires (par exemple : rédiger vos travaux, faire des graphiques ou des calculs pour ces travaux, chercher sur Internet, organiser votre temps d'étude, communiquer avec des coéquipiers, etc.) ?

☐ oui ☐ non

2. Indiquez par un X, la fréquence à laquelle vous utilisez les applications suivantes :

Application	Fréquence d'utilisation				
	Très souvent	**Souvent**	**Occasionnellement**	**Rarement**	**Presque jamais**
Jeux vidéos	☐	☐	☐	☐	☐
Logiciels de dessin ou de traitement d'image (Paintshop, Photoshop, Illustrator, Clarisworks, Coreldraw, Etc.)	☐	☐	☐	☐	☐
Sites WEB contenant des éléments vidéos ou d'animation	☐	☐	☐	☐	☐
Logiciels d'animation (Director, 3D studio, etc.)	☐	☐	☐	☐	☐

3. Utilisez-vous un système d'exploitation de style fenêtres (par exemple : Windows 3.1, Windows 95 ou 98 , Windows NT, Mac Os, XWindows, etc.) ?

☐ oui ☐ non

Si oui, le(s)quel(s) ……………………………………………………………..

Indiquez, par un **X**, la fréquence à laquelle vous utilisez les fonctions suivantes quand vous vous servez de ce(s) système(s) :

Fonction	Fréquence d'utilisation				
	Très souvent	**Souvent**	**Occasionnellement**	**Rarement**	**Presque jamais**
Création de raccourcis ou d'alias sur le bureau (desktop)	☐	☐	☐	☐	☐
Touches de raccourci	☐	☐	☐	☐	☐
Travail sur plusieurs applications simultanément dans des fenêtres multiples	☐	☐	☐	☐	☐
La fonction glisser-déplacer (drag and drop)	☐	☐	☐	☐	☐
Fonctions pour personnaliser les logiciels (changement des options par défaut, macros, etc.)	☐	☐	☐	☐	☐

4. Pour chaque type d'application, encerclez le chiffre qui correspond à votre niveau de compétence.

1 – très faible ; ***2 – rudimentaire ;*** ***3 – intermédiaire ;*** ***4 – bon ;*** ***5 – expert***

	très faible		intermédiaire		expert
Traitement de texte	1 ------------	2 ------------	3 ------------	4 ------------	5
Courrier électronique	1 ------------	2 ------------	3 ------------	4 ------------	5
Fureteurs (ex : Explorer, Netscape, etc.)	1 ------------	2 ------------	3 ------------	4 ------------	5
Sytêmes d'exploitation à fenêtres (ex : Windows 3.1 , 95, MacOs, etc.)	1 ------------	2 ------------	3 ------------	4 ------------	5
Logiciels de dessin ou de traitement d'image (Paintshop, Photoshop, Illustrator, Clarisworks, Coreldraw, etc.)	1 ------------	2 ------------	3 ------------	4 ------------	5
Autres ______________	1 ------------	2 ------------	3 ------------	4 ------------	5
	très faible		intermédiaire		expert

Il nous serait utile de connaître votre avis au sujet de différentes méthodes pédagogiques employées dans les cas suivants. Pour chacune des mises en situation veuillez répondre aux trois questions. *(Attention, il ne s'agit pas de résoudre les problèmes de physique qui sont décrits dans certaines de ces mises en situation ; d'ailleurs, la solution des problèmes est donnée. N'hésitez pas à me poser des questions en cas de besoin, je suis là pour ça !)*

M5. Vous faites partie d'un groupe d'étudiants qui prennent le cours de physique «Mécanique 101» (c'est un cours de dynamique). En début de classe, le professeur mentionne un fait qui paraît contre-intuitif aux yeux des étudiants. Plusieurs étudiants sont sceptiques. Le professeur décide donc d'illustrer le problème à l'aide d'une *simulation informatique*.

La *simulation informatique* montre un cube de bois qui flotte (en l'absence de gravité) dans la cabine de la navette spatiale en orbite autour de la terre. Une balle de tennis est lancée à deux reprises sur le cube de bois, dont une des faces a été recouverte de velcro.

Dans un premier cas, la balle de tennis est tirée sur la face du cube couverte de velcro, et la balle **colle** au cube après la collision.

Dans le deuxième cas, la balle est tirée sur une face du cube qui **n'est pas** couverte de velcro, et donc la balle **rebondit** après la collision. (Un appareil spécial permet de lancer la balle à la même vitesse dans les deux cas.)

On compare la vitesse du cube de bois après la collision dans les deux cas. Résultat : La vitesse du cube de bois est plus grande dans le cas où la balle **rebondit** sur la face du cube qui n'est pas couverte de velcro. La *simulation informatique* montre clairement ce résultat.

A) Estimez approximativement la proportion des étudiants sceptiques dans la classe qui, d'après vous, seraient complètement convaincu par cette simulation.

☐ 0% ☐ 10% ☐ 20% ☐ 30% ☐ 40% ☐ 50% ☐ 60% ☐ 70% ☐ 80% ☐ 90% ☐ 100%

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) Cette simulation me convaincrait si je faisais partie des étudiants sceptiques.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) Il existe de meilleures méthodes que la simulation pour convaincre les étudiants sceptiques dans ce cas.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

M6. Vous faites partie d'un groupe d'étudiants qui prennent un cours de physique moderne. En classe, le professeur mentionne un fait qui paraît contre-intuitif aux yeux des étudiants. Il s'agit de la dilatation du temps dans la théorie de la Relativité. Plusieurs étudiants sont sceptiques. Le professeur décide donc d'illustrer le problème à l'aide d'une simulation informatique.

Au début, la *simulation informatique* montre, côte à côte, trois horloges très précises et identiques. Les trois horloges sont exactement synchronisées. Ensuite, on voit que la première horloge fait le tour du monde à bord de l'avion à réaction qui détient le record mondial de vitesse et on voit que les deux autres horloges restent sur terre. Finalement, on réunit les horloges pour comparer le temps donné par chacune d'elles. Résultat : les horloges restées sur terre sont encore parfaitement synchronisées entre elles. Par contre celle qui a fait le tour du monde à grande vitesse indique un temps légèrement plus faible (il s'agit d'une différence infime). La simulation montre clairement ce résultat.

A) Estimez approximativement la proportion des étudiants sceptiques dans la classe qui, d'après vous, seraient complètement convaincu par cette simulation.

☐ 0% ☐ 10% ☐ 20% ☐ 30% ☐ 40% ☐ 50% ☐ 60% ☐ 70% ☐ 80% ☐ 90% ☐ 100%

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) Cette simulation me convaincrait si je faisais partie des étudiants sceptiques.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) Il existe de meilleures méthodes que la simulation pour convaincre les étudiants sceptiques dans ce cas.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

M7. Un employé d'une cour à ferraille doit opérer, pour la première fois, une grue mécanique spéciale. Cette grue spéciale sert à la fois à déplacer et à écraser des matériaux inutilisables, et ce, en une seule opération. Le *seul* entraînement qu'il subira avant d'opérer la grue spéciale se fera à l'aide d'une *simulation informatique* (simulation de cette grue mécanique spéciale et de divers matériaux inutilisables).

A) Indiquez le niveau de confiance qu'il faudrait accorder à cet employé, selon vous.

1- très faible 2 - faible 3 - modéré 4 - élevé 5 - très élevé

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) L'employé pourrait faire de graves erreurs dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) L'employé est bien préparé à affronter des difficultés de toutes sortes dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

----

M8. Un nouvel employé d'une centrale nucléaire remplace d'autres employés en grève. Sans l'aide de personne, il doit surveiller l'état du réacteur nucléaire et faire son diagnostique en cas de problème. C'est la première fois qu'il surveille un vrai réacteur nucléaire. Le *seul* entraînement qu'il a subi, a consisté à diagnostiquer et à surveiller une *simulation informatique* du réacteur de la centrale nucléaire en question.

A) Indiquez le niveau de confiance qu'il faudrait accorder à cet employé, selon vous.

1- très faible 2 - faible 3 - modéré 4 - élevé 5 - très élevé

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) L'employé pourrait faire de graves erreurs dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) L'employé est bien préparé à affronter des difficultés de toutes sortes dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

Nous aimerions également connaître votre avis au sujet des différentes méthodes pédagogiques employées dans les cas suivants. Pour chacune des mises en situation veuillez répondre aux trois questions. *(Attention, il ne s'agit pas de résoudre les problèmes de physique qui sont décrits dans certaines de ces mises en situation ; d'ailleurs, la solution des problèmes est donnée. N'hésitez pas à me poser des questions en cas de besoin, je suis là pour ça !)*

M9. Vous faites partie d'un groupe d'étudiants qui prennent un cours de physique moderne. En classe, le professeur mentionne un fait qui paraît contre-intuitif aux yeux des étudiants. Il s'agit de la dilatation du temps dans la théorie de la Relativité. Plusieurs étudiants sont sceptiques. Le professeur décide donc d'illustrer le problème à l'aide d'une ***séquence vidéo***.

Au début, *la séquence vidéo* montre, côte à côte, trois horloges très précises et identiques. Les trois horloges sont exactement synchronisées. Ensuite, on voit que la première horloge fait le tour du monde à bord de l'avion à réaction qui détient le record mondial de vitesse et on voit que les deux autres horloges restent sur terre. Finalement, on réunit les horloges pour comparer le temps donné par chacune d'elles. Résultat : les horloges restées sur terre sont encore parfaitement synchronisées entre elles. Par contre celle qui a fait le tour du monde à grande vitesse indique un temps légèrement plus faible (il s'agit d'une différence infime). La séquence vidéo montre clairement ce résultat.

A) Estimez approximativement la proportion des étudiants sceptiques dans la classe qui, d'après vous, seraient complètement convaincu par cette séquence vidéo.

☐ 0% ☐ 10% ☐ 20% ☐ 30% ☐ 40% ☐ 50% ☐ 60% ☐ 70% ☐ 80% ☐ 90% ☐ 100%

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) Cette séquence vidéo me convaincrait si je faisais partie des étudiants sceptiques.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) Il existe de meilleures méthodes qu'une séquence vidéo pour convaincre les étudiants sceptiques, dans ce cas.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

M10. Vous faites partie d'un groupe d'étudiants qui prennent le cours de physique «Mécanique 101» (c'est un cours de dynamique). En début de classe, le professeur mentionne un fait qui paraît contre-intuitif aux yeux des étudiants. Plusieurs étudiants sont sceptiques. Le professeur décide donc d'illustrer le problème à l'aide d'une ***séquence vidéo***.

La séquence vidéo montre un cube de bois qui flotte (en l'absence de gravité) dans la cabine de la navette spatiale en orbite autour de la terre. Une balle de tennis est lancée à deux reprises sur le cube de bois, dont une des faces a été recouverte de velcro.

Dans un premier cas, la balle de tennis est tirée sur la face du cube couverte de velcro, et la balle **colle** au cube après la collision.

Dans le deuxième cas, la balle est tirée sur une face du cube qui ***n'est pas*** couverte de velcro, et donc la balle **rebondit** après la collision. (Un appareil spécial permet de lancer la balle à la même vitesse dans les deux cas.)

On compare la vitesse du cube de bois après la collision dans les deux cas. Résultat : La vitesse du cube de bois est plus grande dans le cas où la balle **rebondit** sur la face du cube qui n'est pas couverte de velcro. La séquence vidéo montre clairement ce résultat.

A) Estimez approximativement la proportion des étudiants sceptiques dans la classe qui, d'après vous, seraient complètement convaincu par cette séquence vidéo.

☐ 0% ☐ 10% ☐ 20% ☐ 30% ☐ 40% ☐ 50% ☐ 60% ☐ 70% ☐ 80% ☐ 90% ☐ 100%

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) Cette séquence vidéo me convaincrait si je faisais partie des étudiants sceptiques.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) Il existe de meilleures méthodes qu'une séquence vidéo pour convaincre les étudiants sceptiques, dans ce cas.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

M11. Un employé d'une cour à ferraille doit opérer, pour la première fois, une grue mécanique spéciale. Cette grue spéciale sert à la fois à déplacer et à écraser des matériaux inutilisables, et ce, en une seule opération. Le *seul* entraînement qu'il subira avant d'opérer la grue spéciale *se fera en se servant d'une grue plus simple pour déplacer les matériaux et aussi d'un appareil différent qui écrase les matériaux de façon très semblable à la grue spéciale.*

A) Indiquez le niveau de confiance qu'il faudrait accorder à cet employé, selon vous.

1- très faible 2 - faible 3 - modéré 4 - élevé 5 - très élevé

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) L'employé pourrait faire de graves erreurs dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) L'employé est bien préparé à affronter des difficultés de toutes sortes dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

----

M12. Un nouvel employé d'une centrale nucléaire remplace d'autres employés en grève. Sans l'aide de personne, il doit surveiller l'état du réacteur nucléaire et faire son diagnostique en cas de problème. C'est la première fois qu'il surveille un vrai réacteur nucléaire. Le *seul* entraînement qu'il a subi, a consisté à diagnostiquer et à surveiller *d'autres appareils qui fonctionnent de manière très semblable au réacteur nucléaire en question.*

A) Indiquez le niveau de confiance qu'il faudrait accorder à cet employé, selon vous.

1- très faible 2 - faible 3 - modéré 4 - élevé 5 - très élevé

Encerclez le chiffre qui correspond à votre opinion au sujet des propositions suivantes :

B) L'employé pourrait faire de graves erreurs dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

C) L'employé est bien préparé à affronter des difficultés de toutes sortes dans l'exercice de son travail.

1- tout à fait en désaccord 2 - en désaccord 3 - incertain 4 - d'accord 5 - tout à fait d'accord

Appendix C: Items for the Pre-interaction Verbal Interview

1) J'aimerais savoir ce qui te plaît quand tu fais une expérience ?

2) Qu'est-ce qui te déplaît ?

3) Est-ce que tu trouves que le volet expérimental est essentiel à l'apprentissage de la physique ?

4) Est-ce que tu considères qu'il y a certaines choses qui sont nécessaires ou essentielles à un cours de physique expérimental ?

5) Est-ce qu'il y aurait certains éléments qui sont essentiels à un cours de physique expérimentale ?

– l'apprentissage de certaines notions ?

– l'apprentissage de certaines habiletés ?

– certaines conditions qui rendent l'apprentissage possible (par exemple, la présence de certaines personnes ou certains instruments essentiels) ?

– autres choses ?

6) Quels sont les principaux buts de l'expérimentation dans un cours de physique ?

Appendix D: Script Read to Subjects prior to Interaction with the VPLab

« Je vais te lire un texte qui présente la séance d'essai. La raison pour laquelle je lis un texte préparé d'avance est la suivante : il faut que je donne les mêmes informations à tous nos participants et je veux être certain de ne rien oublier.

Pendant les deux prochaines heures, si tu acceptes de nous aider, on va mettre le logiciel dont je t'ai parlé à l'épreuve; on va l'évaluer ensemble. Tu sais probablement déjà qu'il s'agit d'un environnement interactif pour l'apprentissage à distance de la physique expérimentale. Un peu plus tard, avec le logiciel, tu vas être appelé à faire certaines activités.

Par contre, il ne faut pas vraiment chercher un sens à tout ça, même si parfois on va faire des genres de mise en situations. Je tiens encore à te dire qu'il n'est aucunement question d'évaluer tes connaissances en physique aujourd'hui ni tes compétences en informatique. Tu peux donc te sentir très à l'aise s'il y a des termes ou des concepts qui ne sont pas clairs, ce n'est pas grave.

Pour le restant de la séance, je vais te demander ton opinion sur divers sujets. Premièrement, tu dois comprendre que je ne suis pas le concepteur du logiciel. Je collabore à son évaluation. Mon rôle ici, c'est d'essayer de l'évaluer avec toi. Ta franchise est une ressource très précieuse pour moi. En d'autres mots, plus tu es (franc ou franche) et tu me dis ce que tu penses pendant la séance, plus le prototype a des chances d'en bénéficier.

Je dois surtout insister sur la chose suivante : pour chacune des questions que je vais te poser, il n'y a pas de bonnes ou de mauvaises réponses. En bref, tu peux toujours, toujours te sentir à l'aise pour me dire ce que tu penses même quand cela implique que tu n'as pas de réponse à donner. Aujourd'hui, tu n'es certainement pas en classe ou devant un examen.

J'apprécie beaucoup, en passant, que tu te sois déplacé pour m'aider.

Tu as probablement remarqué la caméra vidéo. Avec ta permission, je vais enregistrer la séance de manière à pouvoir la visionner au cas je ne me rappellerais pas de certains détails. Je vais prendre quelques petites notes aussi. J'insiste sur le fait que ces enregistrements et ces notes ne seront jamais accessibles à d'autres gens que moi ou l'équipe de conception du logiciel. À cet effet, j'aimerais te remettre un formulaire que j'ai signé en tant que responsable des séances d'essai.

Ta participation est volontaire : on peut mettre fin à la séance en tout temps. Normalement, la séance entière devrait durer entre 2h et 2h30. Mais n'hésite pas à me dire quand tu voudras prendre une pause pour aller à la salle de bain, pour boire quelque chose ou simplement pour te reposer un peu. Les toilettes sont juste l'autre côté.

Est-ce qu'il y a des choses que tu voudrais que j'explique davantage ? Est-ce que tu acceptes de participer?

Je vais maintenant t'expliquer comment on va procéder pour la séance. Pour chaque étape de la séance, je vais te donner des directives énonçant des choses à faire. Parfois, les directives seront verbales et parfois, elles seront données par écrit. Ne te gènes pas pour poser des questions si ce n'est pas clair ou si tu as besoin de précisions sur les directives.

J'aimerais que tu te souviennes des 3 points suivants pendant toute la séance :

1er point important : Je t'encourage à poser des questions si tu as des difficultés : parfois je ne pourrai pas t'aider tout de suite parce qu'un des objectifs de la séance est de savoir si le logiciel permet aux gens de se débrouiller un peu tout seul à distance. Mais je t'encourage quand même à poser des questions parce que ça nous donne une idée des genres de problèmes qui sont éprouvés lors de l'utilisation.

2ème point important : Même si c'est un prototype avancé, le logiciel est encore au stade de prototype donc c'est normal qu'il y ait encore des choses à améliorer. Il ne faut pas que tu penses que c'est toi le problème.

3ème point important : Pendant que tu fais l'activité, essaie de verbaliser le plus possible tes pensées. Je te donne un exemple : [exemple du protocole « think aloud »]. Insiste surtout sur les choses que tu trouves familières ou à l'inverse, les choses que tu trouves étranges par rapport aux expériences de physique que tu as déjà faites.

Est-ce que ça va ? Est-ce que tu as des questions ? Je peux répéter les 3 points si tu veux.

Si non, on débute.

Appendix E: Debriefing Interview Items

1) En gros, que penses-tu du logiciel du Laboratoire virtuel de physique ?

2) Qu'en penses-tu par rapport à ce que tu as déjà fait en laboratoire ?

3) Comment appellerais-tu ce logiciel si tu devais le nommer ?

4a) D'après toi, jusqu'à quel point ce genre de chose là représente-t-il bien la réalité de faire une expérience en laboratoire ?

b) Pourrais-tu m'indiquer le potentiel de ce logiciel pour l'expérimentation, sur une échelle de 1 à 5, si '1' correspond à potentiel très faible et '5' correspond à potentiel très élevé.

----

5) Avant aujourd'hui, avais-tu déjà utilisé un logiciel qui comprenait une ou plusieurs simulations ?

(Les jeux vidéos semblables à Flight Simulator peuvent aussi être considérés comme des simulations.)

-- **Si oui,** dans quel contexte:

----

6) *(Quand l'utilisateur n'avait pas déjà abordé ces aspects, les questions suivantes lui ont été posées.)*

a) Quand tu faisais des expériences de physique, est-ce qu'on te demandait de tenir compte de l'incertitude sur les mesures ?

Si oui :

b) Comment faisais-tu pour tenir compte de l'incertitude, quand tu mesurais une longueur, par exemple ?

c) Et si on regarde comment ça se passe pour la règle à mesurer dans l'environnement, qu'en penses-tu ?

d) Pour le galon ?

----

7) Retour sur les faits marquants de la séance.

8a) Admettons que tu fais l'expérience au complet dans le labo virtuel et que tes résultats ne correspondent pas aux résultats théoriques. Pourtant t'es sûr et certain qu'il n'y a pas d'erreurs de mesure ou de calcul. Si tu refaisais l'expérience une deuxième fois, tu t'attendrais plutôt à quoi ?

b) Est-ce qu'il y a une raison particulière pour cela ?

c) Est-ce que ça représente bien la réalité d'un laboratoire ?

9) Si je te disais qu'on a pris les moyens pour introduire, une fois de temps en temps, des anomalies dans l'appareil expérimental, comme simuler des problèmes techniques avec la table ou les instruments de mesure (par exemple : la table serait collante ou la rotation du manège serait très inégale ou encore le galon serait mal calibré), est-ce que tu aurais soupçonné cela tout à l'heure, pendant la séance ? Qu'est-ce que tu penses de ça ?

(Pour des raisons d'éthique il convenait ensuite de dire à l'utilisateur que la question n'était qu'une mise en situation, mais que les situations décrites auraient été possibles.)

----

10) Dans ce que t'as vu et fait, est-ce qu'il y a des objets, des événements ou des actions qui seraient impossibles à reproduire dans les labos de mécanique ?

11a) Inversement, penses-tu qu'il y aurait des choses que tu as déjà faites dans un laboratoire de mécanique qui seraient vraiment impossibles à faire avec ce genre de logiciel ?

b) Y a-t-il des choses qui te sont arrivés en labo et qui ne pourraient pas se produire en utilisant ce genre de logiciel ?

(Facultatif)

12a) Peux-tu nommer les objets du logiciel qui existent sûrement dans certains labos de mécanique ?

b) Est-ce que ces objets (qui existent ailleurs) se comportent de la même manière ?

----

13) Y a-t-il des objets du logiciel qui n'existent certainement pas dans les labos de mécanique ou ailleurs ?

(Facultatif)

14) D'après toi, est-ce qu'il y a des éléments importants que l'on retrouve habituellement dans des labos de mécanique mais qui ne figurent pas dans le logiciel ?

----

15) Peux-tu évaluer la probabilité de retrouver, un jour, les éléments suivants en faisant une expérience de physique ?

L'échelle est la suivante :

1 – très peu probable   2 – peu probable   3 – incertain   4 – assez probable   5 – très probable

- **a)** ce galon à mesurer ; (certaines caractéristiques ?, l'objet en général ?)
- **b)** ce rapporteur d'angle ; (pourquoi ?)
- **c)** cette table à coussin d'air ; (pourquoi ?)
- **d)** ce cahier de laboratoire ; (pourquoi ?)
- **e)** l'écran table ; (pourquoi ?)
- **f)** une façon semblable de prendre des mesures ; (pourquoi ?)

----

16) Pour chaque outil que je vais te montrer, peux-tu m'indiquer jusqu'à quel point l'outil te semblait pouvoir être utilisé de façon semblable ou de façon différente aux types d'instruments disponibles dans les labos de physique.

L'utilisation est-elle :

1 – très différente   2 – différente   3 – incertain   4- semblable   5- très semblable

Pour les éléments suivants :

- **a)** La règle (pourquoi ?)
- **b)** Le galon à mesurer (pourquoi ?)
- **c)** Le système de traces (pourquoi ?)
- **d)** Le zoom (pourquoi ?)
- **e)** Le rapporteur d'angle (pourquoi ?)
- **f)** Le caméscope (pourquoi ?)

Appendix F: Ethics and Confidentiality Form

SÉANCE D'ESSAI DU PROTOTYPE

DE L'ENVIRONNEMENT D'APPRENTISSAGE DE LA PHYSIQUE

Formulaire de déontologie

Chère madame, cher monsieur,

Je soussigné Alexandre Francis, responsable des séances d'essai, vous remercie d'avoir accepté de participer.

Conformément aux règles de déontologie en recherche, voici quelques informations relatives à cette séance d'essai.

- Cette séance d'essai fait partie d'un projet dont le but est de développer des logiciels permettant de faire des activités expérimentales dans certains domaines de sciences et technologies.
- La séance d'essai à laquelle vous participez servira à alimenter une réflexion sur la pertinence de l'approche adoptée pour développer le logiciel visant à enseigner la physique expérimentale. Cette séance sert aussi à vérifier la pertinence de certains choix spécifiques en matière d'informatique.
- Les participants retenus pour les séances d'essai ont été choisis sur la base de l'adéquation de leur profil à celui de la clientèle à laquelle s'adressera le laboratoire, une fois développé.

En vertu des mêmes règles de déontologie, nous nous engageons, dans le cadre de toutes les activités liées à ce projet :

- à n'utiliser les informations que nous recueillerons que lorsqu'elles sont pertinentes aux objectifs du projet ;
- à maintenir confidentielle (dans la mesure permise par les règles de vérification financière) l'identité de tous les participants aux séances d'essai, notamment en ne fournissant, dans les textes présentant les résultats de la recherche ou fondés sur ceux-ci, aucun nom ou information susceptible de permettre leur identification ;
- à limiter l'accès au matériel recueilli aux seules personnes affectées à la recherche ;
- à vous fournir, sur demande, les rapports de recherche non publiés dans les revues spécialisées, ou les références, pour ceux qui l'auront été.

Nous espérons que ces informations sauront vous éclairer quant à la nature du projet et aux mesures que nous entendons prendre pour respecter les règles de l'intégrité scientifique dans le cadre de notre projet de recherche.

Veuillez agréer l'expression de mes meilleurs sentiments.

______________________________ ________________

responsable des séances d'essai | date

Appendix G: Subject Profiles

Below are participant profiles described in terms of educational background in physics and experimental work, self-assessed expertise with computers and positive attitudes toward them, *a priori* attitudes toward simulation as an educational medium, and prior experience with simulation and multimedia applications bearing similarities to the VPLab.

These profiles serve two purposes: (1) to expose a more thorough description of the user sample and (2) to expose data that will be useful for a deeper understanding of results found in Chapter 5 and individual accounts (see Appendix I).

G.1 SUBJECTS AN, BO, CP, DQ, ER: CHEMISTRY STUDENTS

Subjects AN through ER were enrolled in the same bachelor's degree program, specialized in chemistry (chemistry courses make up all of the curriculum, with few exceptions). At the time of the sessions, these participants were taking an experimental physics course for chemistry students.[1] All except one (AN) were taking or had taken two university-level theoretical physics courses for chemistry students. One of these theoretical courses dealt solely with content in classical mechanics and wave physics. Hereafter, I shall refer to these participants as 'chemistry subjects'.

Subject AN

At the time of his session, subject AN had resided in Quebec for the past 4 years. He[2] is originally from Zaire, where he was schooled up to high school level (lab equipment was scarce in Zaire). AN had the weakest physics background of the "chemistry subjects" (he had not taken any university-level theoretical physics courses).

AN seemed aware of statistical variation in experimental outcomes[3], but he still did not like the fact that he usually could not obtain experimental results exactly identical to those contained in text books and reference tables (for this, he blamed the quality of his material and the fact that he could only do the experiment once). He also seemed to think that manual dexterity was an important ability upon which to focus during an experimental physics course.

---

[1] This experimental physics course for chemistry students did not feature any classical mechanics experiments (the VPLab's air-table experiment illustrates theory in this field of physics).

[2] Masculine pronouns and adjectives are used throughout for both male and female subjects. As a precaution, I have chosen to conceal gender in order to inhibit unwarranted associations between certain attitudes and gender.

[3] 'Statistical variation of experimental outcomes' means that when experiments are repeated several times, varying results can be obtained from trial to trial (following a probabilistic function) and that reference values for known physical quantities are derived by repeating an experiment and by applying statistical methods in processing results of multiple trials.

AN is the only participant who gave relatively low ratings on all three scales pertaining to positive attitudes toward computers (see table IV). He also gave relatively low *computer expertise* self-ratings in regards to all of the common applications enumerated in the preliminary questionnaire (see table V), and these ratings might be correlated with his report of less frequent use of advanced functions in window-based operating systems (see table VI).

AN is the only participant with **no prior experience whatsoever of simulation use** (see table VII). He is also one of four participants who reported the *least* frequent overall use of four multi-media applications bearing similarities to the VPLab (see table VIII). This could predispose AN to perceiving the VPLab as being somewhat strange or novel. It is worth mentioning, however, that this subject also claimed to have watched many scientific documentaries on television and to have benefited very much from them; he thus supposed that content presented by way of multimedia may sometimes be more beneficial than content transmitted through conventional means (classrooms, textbooks, etc.).

A priori Attitude toward Simulation as an Educational Medium

AN exhibited neutral attitudes with respect to both of the situations presented in the preliminary questionnaire (simulation used to convince students in a classroom, and simulation used for operator training: see tables IX and X).[4]

Subject BO

This subject considered lab experiments to be somewhat akin to extra-curricular activities, given the fact that students are called upon to learn by handling apparatus (in contrast to the work required for lectures).

At his CEGEP (as a natural sciences student), BO had had prior experience with the use of an air-table in an experimental context. It is important to note that the functionality of the rig he used to collect data during this experiment, if more rudimentary, was somewhat analogous to the VPLab's functionality. It made use of rapid photography and a phosphorescent marker to record successive positions of the disc. Analysis was then performed by developing the film and projecting the pictures on a screen using an overhead projector. Also noteworthy is the fact that BO had never used a real camcorder. This could have some impact on his judgments concerning the VPLab's main metaphor.

---

[4] During debriefing, AN had this to say about answering the questionnaire:

> *I was a bit confused. It wasn't very clear in my mind that it was a computer simulation. I thought of it more as if it were a video. So… I could lower [my rating] a bit.* [citation 25]

Later, when contrasting video clips to simulations, he also stated: "When you see what really happened, it's a video." [citation 26]

This participant had made prior use of social science simulations and he had also played with very 'realistic' video games.

A priori Attitude toward Simulation as an Educational Medium

BO exhibited a neutral attitude toward simulation when used to convince skeptical students of counterintuitive concepts (see table IX), and a favorable attitude toward simulation when used for skill training (see table X).

Peer Influence

Analysis of data from the session with subject BO adds a very important dimension to potential findings: in the course of my interview with BO, it became obvious that at least one previous participant – subject CP – had spoken to subject BO about his experience prior to BO's session:[5]

> ***BO**: Well, one classmate told me that if [the VPLab] were available, he would get it. This friend who spoke to me doesn't like physics. And he told me: "It [the VPLab] helped me to understand things that I hadn't understood in class". [On the sole basis of] having done the test here, he said that [the VPLab] looked like it was really well designed and that – although he isn't a physics student – this would be the kind of software he would buy. But no, they [i.e. other participants] did not say anything of... I was not aware of...*
>
> ***Interviewer**: I'm just curious... Did they mention any of the questions [that you would be asked here today]?*
>
> ***BO**: No.* [citation 27][6]

One might be tempted to disqualify BO's data on this basis. On the contrary, I shall assert that, in reality, users are not confined to a closed box and can rather be influenced by third parties – in effect, that a product's credibility can usually be somewhat grounded in social interaction or affected by information acquired through other media. Hence, it is acceptable to include this kind of data in the study.

Subject CP

This subject felt that learning the scientific method was important in an experimental physics course. Let's note that CP disliked physics in general and also disliked the physics experiments he was performing at his university; he felt he didn't understand what he was being asked to do.

In the past, CP had usually obtained experimental results that came close to theoretical predictions and he thought that students would only rarely obtain results that were completely off. He seemed to feel that it was the experimenter's fault when this happened (which could indicate

---

[5] Subject CP, whom BO had spoken to prior to his session, was rather favorable to simulation as an educational medium (see tables IX and X).

[6] Participant citations were translated from French. The original citations, referenced by a number between brackets (for instance, *[citation 27]* in the above quote), are listed in Appendix J.

that he was not very aware that malfunctions, anomalies and inadequacies in an experimental set-up might affect the outcomes of an experiment).

This subject had prior experience with an air-table in an experimental context and also with a tracing system that worked by shooting electrical discharges on carbon paper.

In regards to positive attitudes toward computers (see table IV), CP is one of five participants who gave the maximum rating on all three scales used in the preliminary questionnaire (*perceived ease of use*, *perceived pleasantness of use*, *perceived usefulness*). He is also one of five participants who rated their own computer expertise relatively high in regards to most of the common applications enumerated in the preliminary questionnaire.

Although CP had made no prior use of simulations in an educational context, he did report playing realistic video games and using two other types of multi-media applications bearing similarities to the VPLab (see tables VII and VIII).

A priori Attitude toward Simulation as an Educational Medium

CP is one of two participants who exhibited *favorable* attitudes toward simulation with respect to *both* types of situation presented in the preliminary questionnaire (see tables IX and X).[7]

Subject DQ

Based on his prior experience, subject DQ had found conducting laboratory experiments enjoyable and felt that "touching" apparatus, in contrast to just reading or listening to a teacher, could help him better understand physical phenomena. He considered precision in one's work an important skill to acquire in an experimental physics course. He believed it important to try to closely follow experimental protocol and to strive for the best possible results. He felt it was discouraging to work with some of his university's lab equipment because it was old and lacked precision, and thus degraded experimental outcomes.

This subject had prior experience with an air-table in an experimental context and also with a tracing system that worked by shooting electrical discharges on carbon paper.

---

[7] Here's a sample of what CP had to say, in this respect, during the debriefing interview:

> ***CP:*** *[...] everything can be manipulated... Well, notice that today, if I show you a video clip, it can be created from A to Z on a computer and it is fictive. [...]*
>
> ***Interviewer:*** *For you, the difference between the two [simulation and video], is it still...*
>
> ***CP:*** *No, as far as I'm concerned, there is no difference [between] a video and a computer because both can be manipulated. If you've seen the movie Star Wars [Episode One], there is [only] one scene that was truly filmed; but for the rest of the movie, you say: "My God, is it real? It seems real!" And it was all done with computers but you'll watch it on your TV screen.* [citation 28]

In regards to self-assessed attitudes toward computers, it is noteworthy that DQ's self-rating for *perceived ease of use* was lower than his self-ratings for perceived *pleasantness of use* and *perceived usefulness.* This might mean that he possesses less confidence in his own abilities to operate successfully with computers.

DQ had little prior experience with simulation, except for playing SimCity.[8] He is also one of four subjects who reported the *least* frequent overall use of four multi-media applications bearing similarities to the VPLab (see table VIII). This could predispose DQ to perceiving the VPLab as being somewhat strange or novel.

A priori Attitude toward Simulation as an Educational Medium

DQ is one of two subjects who exhibited *unfavorable* attitudes toward simulation with respect to *both* types of situations presented in the preliminary questionnaire (see tables IX and X).

Difficulty with Use of the Interface

It should be noted that, of all subjects, DQ seemed to have the most difficulty in using the VPLab's interface (with the possible exception of GT). This may have caused him to be more negative in his judgments toward the VPLab.

Differences in Mental Models of a Phenomenon (The Disc's Deceleration)

After DQ had launched the disc on the air-table while the merry-go-round was turning, I asked him to explain why the disc was slowing down. I expected him to say, like most subjects, that the deceleration was caused by the simulation of non-zero air friction working against the disc's motion. Instead, he attributed the disc's deceleration to the merry-go-round's continuous rotation. (Observe that DQ still put forward an explanation and did not just say: 'I don't understand, this can't be happening.'[9]) I take this as evidence that he had a different mental model of the simulated phenomenon. As is the case for actual experiments, a cue can be used quite diversely by different subjects, depending on their mental model of a phenomenon.

Subject ER

Concerning prior lab work, ER hadn't enjoyed the classical mechanics experiments he had performed in CEGEP (as a natural sciences student) because he hadn't possessed sufficient knowledge of the theory and of the instruments to understand the experiments. However, ER did

---

[8] SimCity, a popular video game, is basically a simulation of a city and its problems. The player acts as mayor. This game has been praised for its realism and has sometimes even been used in educational contexts.

[9] Of course, if he truly did not understand what was happening, he may have felt obliged to put forward an explanation anyway in the context of the session, i.e. because he was being asked by an interviewer in a position of authority to explain a simulated scientific phenomenon.

say that experiments were important in a physics course because they allowed students to verify the validity of a theory by observing reality and by manipulating objects.[10]

This subject had prior experience in working with an actual air-table. That table, however, was different from the table represented by the simulation: instead of pumping air through holes in the table's sides, the air cushion was created by pumping air down through a hole in a disc made of *metal* (a layer of air was thus created between it and the table). In such a case, the disc's behavior can be somewhat different. ER also had prior experience with a tracing system that worked by shooting electrical discharges on carbon paper.

ER gave relatively low *computer expertise* self-ratings in regards to most of the common applications enumerated in the preliminary questionnaire (see table V), and these ratings might be correlated with his report of less frequent use of advanced functions in window-based operating systems (see table VI).

This subject had made prior use of a small educational program containing physics simulations and he had also played SimCity. He is also one of four participants who reported the *least* frequent overall use of four multi-media applications bearing similarities to the VPLab (see table VIII); this could predispose him to perceiving the VPLab as being somewhat strange or novel.

A priori Attitude toward Simulation as an Educational Medium

ER exhibited an unfavorable attitude toward simulation when used to convince skeptical students of counterintuitive concepts[11], and a favorable attitude toward simulation when used for skill training.

Lack of Guidance

I have mentioned that ER was not keen on doing experiments without proper guidance. This is important because the very first comment he made during the debriefing interview was to express his opinion that the VPLab was difficult to use without additional instructions, and without help on its features. He also felt that he had experienced difficulties during the session because he lacked information, usually dispensed before a lab session, concerning the purpose of experimental activities and the types of measurements that should be performed. This lack of information, which

---

[10] This might play against the VPLab, should the subject feel that a simulation is not an appropriate means of verifying a theory's validity.

[11] Here is an excerpt of a discussion on this matter, which occurred during the debriefing period:

> ***ER:*** *Chances are better that things really happened if they were filmed then if they are depicted with images.*
>
> ***Interviewer:*** *Would the video clip and the computer simulation be about equal for you?*
>
> ***ER:*** *No... I would prioritize video.*
>
> ***Interviewer:*** *On a scale of 1 to 5?*
>
> ***ER:*** *Video would be higher than simulation.* [citation 29]

was inherent to the method chosen for this study, seems to have had a negative effect on ER's attitudes. For instance, he felt distracted "from the physical phenomenon by the gadgets [instruments]" and it seems that his difficulties with the virtual instruments, due to lack of experience and proper guidance, may have been partly responsible for this feeling of distraction.

G.2 SUBJECTS FS, GT, HU, IV: MECHANICAL ENGINEERING STUDENTS

Subjects FS through IV were enrolled in the same mechanical engineering bachelor's program. Hereafter, I shall refer to them as 'engineering subjects'. These participants attended a different university from the one both chemistry and physics subjects were attending. This university is special, as it requires students to have acquired a three-year collegiate *technological* degree prior to admission.[12] At the time of the sessions, all engineering subjects had taken or were attending at least one mechanical engineering course which required them to perform classical mechanics experiments (more precisely, statics experiments [13]).

Three out of four engineering subjects (with GT as the notable exception) gave the maximum rating on all three scales pertaining to positive attitudes toward computers. These same three engineering subjects also rated their own computer expertise relatively high in regards to most of the common applications enumerated in the preliminary questionnaire.

Most importantly, and contrary to other participants, all of the engineering subjects had made use of computer-assisted design (CAD) software packages (these software tools afford much precision when designing system components). Not only did they design mechanical components with this package, but they also *simulated* them, in order to inspect aspects of their behavior. Consequently, these participants had probably made more extensive prior use of simulations than most other subjects.

Subject FS

FS believed that experimental work was essential to any physics course because it allowed one to prove the validity of theoretical propositions which could otherwise always be subject to doubt. FS claimed that he enjoyed hands-on experimental work. Even before seeing the VPLab, the subject spontaneously declared: "*I have to touch things, so simulations will often work so-so [for me]*" [citation 30]. FS also stated that he enjoyed performing challenging experimental manipulations requiring dexterity. He thought that acquiring precision in one's work and applying oneself when

[12] Note that three of the four engineering subjects (the exception being subject GT) had also previously studied within the *general* CEGEP science program, for various lengths of time.

[13] Statics is the subdivision of classical mechanics that is concerned with forces that act on bodies at rest under equilibrium conditions (Encyclopedia Britannica, 2001). The VPLab experiment did not deal with statics.

performing experimental manipulations should be important objectives of an experimental physics course.

In contrast to some of the other engineering subjects (and chemistry subjects), FS seemed to have more technical knowledge, but also a better grasp of theoretical knowledge concerning the subject matter which applied to the simulated experiment chosen for this study (i.e., forces in rotating frames of reference).

In regards to positive attitudes toward computers, FS is one of five subjects who gave the maximum rating on all three scales used in the preliminary questionnaire (*perceived ease of use, perceived pleasantness of use, perceived usefulness*). He is also one of five subjects who rated their own computer expertise relatively high in regards to most of the common applications enumerated in the preliminary questionnaire.

Comparatively, FS reported frequently using three types of multimedia applications bearing similarities to the VPLab (see table VIII), including realistic video games.

A priori Attitude toward Simulation as an Educational Medium

FS exhibited an unfavorable attitude toward simulation when used to convince skeptical students of counterintuitive concepts, and a favorable attitude toward simulation when used for skill training.[14]

Type of Simulation Expected

It seems noteworthy that FS was rather expecting to try software comprised of *non-visual* simulation that would mainly display numbers. When he first saw the Manipulation workspace, FS seemed satisfied because the application actually depicted objects:

> *Often enough, you'll have homemade software and the person who uses it [first] knows what it's for. But for someone who wants to learn, it's not fun to only have a textual display and enter data. To perform experimental manipulations, you have to try to make it as visual as possible because most people are visually oriented [...] At least, you see here [with the VPLab] that this is simulating something: there's a chronometer...* [citation 32]

---

[14] Concerning simulation when used to train operators for diverse tasks, FS said the following during the debriefing period:

> *A computer simulation of something that is itself normally controlled through a computer [e.g.: a nuclear reactor] will work well. However, if you simulate something like a jib-crane, the [operator] gets on the crane – and if manual operations are required – then he will have difficulties because [...] this requires "manual feel" and he'll never know that. And you have a phenomenon [associated with] the power [of the machinery] – it's not the same.* [citation 31]

Subject GT

GT had previously worked in the field of aeronautics as a parts inspector. He claimed that precision in one's work was crucial in this field.

He felt that learning how to handle apparatus adequately while using a rigorous method was essential to an experimental physics course. When asked what he liked about performing experiments, GT answered that he enjoyed obtaining conclusive results, given that an experiment's main goal is precisely to prove something (and illustrate the laws of physics).[15] GT liked to work with a well-defined experimental protocol which allowed him to obtain results with a small error margin. In his opinion, when students obtain large margins of error, blame should be cast either on the experimenters themselves or on the experimental protocol. Of all participants, GT had the weakest physics profile (fewest physics courses taken).

In regards to positive attitudes toward computers, GT is the subject whose ratings vary the most from one scale to the other (see table IV): his rating for *pleasantness of use* was lower than the one for *ease of use*, which was in turn lower than his rating for *usefulness*.

From a comparative standpoint, GT reported frequently using three types of multimedia applications bearing similarities to the VPLab, including video games[16] (see table VIII). Like all engineering subjects, he had conceived simulations of mechanical components (with a CAD package) which, he thought, were "very realistic".

A priori Attitude toward Simulation as an Educational Medium

GT exhibited an unfavorable attitude toward simulation when used to convince skeptical students of counterintuitive concepts, and a neutral attitude toward simulation when used for skill training.

Subject HU

HU felt that performing experiments was important to him because he considered himself a rather practical person and because experiments allowed him to better assimilate subject matter. In his opinion, practical skills, greater understanding of theory, and rationality were among the abilities or qualities that an experimental physics course could help promote.

In regards to positive attitudes toward computers, HU is one of five participants who gave the maximum rating on all three scales used in the preliminary questionnaire (*perceived ease of use*,

---

[15] This subject also mentioned that getting mathematical proof of theoretical propositions was necessary for engineers.
[16] During the debriefing interview, GT claimed that video games "still had a long ways to go" in terms of realism.

perceived pleasantness of use, perceived usefulness). He is also one of five subjects who rated their own computer expertise relatively high in regards to most of the common applications enumerated in the preliminary questionnaire.

HU had prior experience in working with an actual air-table and also with a tracing system that worked by shooting electrical discharges on carbon paper.

Of prime importance is the fact that HU had seen a documentary in which the motion of an object had been analyzed "using a camera" (and, in all probability, also by means of video processing tools).

A priori Attitude toward Simulation as an Educational Medium

HU is one of two subjects who exhibited *favorable* attitudes toward simulation with respect to *both* types of situation presented in the preliminary questionnaire (see tables IX and X).

Subject IV

Subject IV felt that he had had more success in physics courses which required him to perform experiments and handle apparatus, than in other physics courses. He said that hands-on activities allowed him to better assimilate subject matter. For this participant, an important part of an experimental physics course was coming into contact with instruments and learning how to handle them.

In regards to positive attitudes toward computers, IV is one of five subjects who gave the maximum rating on all three scales used in the preliminary questionnaire (*perceived ease of use, perceived pleasantness of use, perceived usefulness*). He is also one of five subjects who rated their own computer expertise relatively high in regards to most of the common applications enumerated in the preliminary questionnaire.

IV's past experience with simulation is of foremost importance: he had had the opportunity of trying out two different industrial flight simulators (made by a firm which had employed him).

A priori Attitude toward Simulation as an Educational Medium

IV exhibited an unfavorable attitude toward simulation when used to convince skeptical students of counterintuitive concepts, and a favorable attitude toward simulation when used for skill training. The latter could be linked to his prior contacts with industrial flight simulators and to contact with users (pilots) who praised their fidelity.[17]

---

[17] Here are some of IV's debriefing comments about simulation when used from training:

IV: I tried the RJ and the CF18 [simulators]. It was fun.

***Interviewer**: Did you have the impression that it really represented…*

G.3 SUBJECTS JW, KX, LY, MZ: PHYSICS STUDENTS

Subjects *JW* through *MZ* were all enrolled in a physics program, although the curriculum of their respective programs varied somewhat. Hereafter, I shall refer to them as 'physics subjects'. They should be considered as having the strongest backgrounds in physics and the most knowledge of subject matter pertaining to the VPLab's simulated air-table experiment.

Three of these participants (KX, LY, MZ) were attending the same university. At the time of the sessions, all physics subjects had taken or were attending at least one experimental physics course which featured some classical mechanics experiments among experiments in various fields of physics. It should also be noted that at the time of the session, at least three of these participants (KX, LY, MZ) had conducted an experiment at their university, using software to acquire data, in real-time, from lab apparatus (and to draw graphs displaying this data).

Subject JW

Subject JW was from Puerto Rico and was much less fluent in French than other participants (only French was used in the VPLab and the session was mostly conducted in French [18]). At the time of the session, this participant was attending a different university than the three other physics subjects. The total number of university-level physics courses he had previously attended was 13, which is more than any other subject.

JW claimed that he often did not sufficiently understand what he was doing when he performed lab experiments, and he thought that this might explain why he did not generally enjoy doing so. Although he did not enjoy lab work, JW acknowledged that hands-on work (manipulating objects with one's hands) was necessary because it allowed him to better grasp abstract concepts like conservation of momentum.

This participant reported having little prior experience with use of simulation. JW is also one of four subjects who reported the *least* frequent overall use of four multi-media applications bearing similarities to the VPLab (see table VIII). This could predispose him to perceiving the VPLab as being fairly strange or novel.

IV: Yes, that's why, when I got to that question, earlier in the questionnaire, of someone who tested a jib-crane on a simulation – " is he ready to operate the [real] jib-crane?"– I answered "yes", because I know that a pilot with the slightest prior experience, if you [first] stick him in a simulator, he can then go on to pilot the plane with no problems whatsoever. He won't even realize that he's not in his simulator anymore, and that he's in the plane instead: there's no difference. If the simulation is well designed, then we're happy. It's like the nuclear power-plant [question]: no matter that it's a nuclear power-plant which can cause a lot of damage, as long as the interface [of the simulation] is the same, there is no difference. So that's why I trust simulation.
[citation 33]

[18] The multimedia explanations of the simulation were in French as well: to make up for JW's linguistic disadvantage, I thought it appropriate to explain the Manipulation workspace simulation after the subject had explored it.

A priori Attitude toward Simulation as an Educational Medium

JW exhibited neutral attitudes with respect to both of the situations presented in the preliminary questionnaire.

Subject KX

Subject KX was enrolled in a mixed *physics/computer science* bachelor's program and had completed 7 university-level physics courses as well as courses in computer science. This participant stated that he did not generally enjoy performing lab experiments and was rather theoretically oriented. The reason he did not enjoy lab work was that he was being asked, in an experimental physics class at his university, to perform experiments without having a sufficient grasp of the corresponding theory: he thus had the impression of not fully understanding what he was doing. When he did have a good grasp of specific theoretical knowledge, one of the things he enjoyed about lab experiments was the opportunity to "validate" this knowledge.

In his opinion, statistical analysis of results was an essential skill to acquire in the course of an experimental physics class; ironically, KX also claimed that he did not enjoy performing statistical analysis and writing reports. Dealing with uncertainty was also seen by KX as an essential process.

Despite his background in computer science, this subject reported having no prior contact with computer simulation, other than playing realistic video games.[19]

A priori Attitude toward Simulation as an Educational Medium

KX exhibited an unfavorable attitude toward simulation when used to convince skeptical students of counterintuitive concepts[20], and a favorable attitude toward simulation when used for skill training.

---

[19] Moreover, KX's computer science background does not necessarily entail that he should be considered an 'expert user' in regards to the VPLab – programming expertise does not necessarily intersect with expertise needed to use the VPLab's 'direct manipulation' interface.

[20] Here is an excerpt of KX's debriefing comments on this matter:

> ***A simulation does not help to convince you, in the end. It shows you– "Look, I've programmed this thing and I can obtain the right result". However, with [the video clip], you can't help but believe it [...] it hasn't been rigged. It's easier to believe that the simulation has been rigged than [to believe that the video clip has been rigged or has been tampered with]. In addition, a simulation is based on equations, such that if your equations are flawed, your simulation will give you the outcome that you expect– as opposed to[a video clip], which is not based on equations but rather on reality, as such...*** [citation 34]

Subject LY

Before enrolling in a physics program, LY had studied software engineering for two years.

Distinctively, this subject believed that honesty and ethically correct behavior were qualities that students should acquire while completing an experimental physics course: learning to not falsify data and to explain why an experiment had been inconclusive were important to LY. Another important element that students should acquire, in his opinion, was "research acumen" [*l'esprit de recherche*], which he defined as being alert and proactive (during an experiment) by trying to anticipate the behavior of phenomena, as opposed to having a passive attitude and just waiting around for results.

In his view, the main goals of experimentation in a physics course were verifying theory and learning how to use measuring instruments. Interestingly, LY also felt that experimental error "was part of the game," and that "students didn't learn anything from perfect labs." The purpose of a lab experiment, he said, is also to learn about errors caused by instruments: "You learn about theory and at the same time, you learn that instruments are not perfect" [citation 35].

LY considered that experiments had to have visual components; in his opinion, a learning activity which made use of a model implemented through MathLab software or MAPLE software could be "like an experiment" if students could view graphs (or other visual representations).

In regards to positive attitudes toward computers, LY is one of five subjects who gave the maximum rating on all three scales used in the preliminary questionnaire (*perceived ease of use, perceived pleasantness of use, perceived usefulness*). He is also one of five participants who rated their own computer expertise relatively high in regards to most of the common applications enumerated in the preliminary questionnaire.

In CEGEP, this subject had conducted an experiment with an actual air-table which could be rotated about its center (in the VPLab's simulation, the merry-go-round is used to rotate the table and people can view motion on the table from inside the rotating frame of reference). Instead of a disc, he had used marbles as projectiles in this experiment. He had also used a carbon paper tracing system.

It must be underscored that LY had much prior experience with simulations and MAPLE software in an experimental context (as well as with SimCity and other "very realistic" video games). In particular, LY had taken a CEGEP-level physics course designed to fully integrate MAPLE software in all classroom activities, both theoretical and experimental.

A priori Attitude toward Simulation as an Educational Medium

LY is one of two participants who exhibited *favorable* attitudes toward simulation with respect to *both* types of situation presented in the preliminary questionnaire (see tables IX and X).[21] Ultimately, this subject's experience with simulation (through MAPLE software), which had apparently been very beneficial to him, probably contributed heavily to his favorable attitudes toward this medium.

Subject MZ

Subject MZ was enrolled in a physics/mathematics mixed bachelor's program and had attended 8 university-level physics courses. He seemed to have a better understanding of forces in rotational frames of reference (theory crucial to the VPLab's air-table experiment) than most other subjects.

MZ had prior experience with an air-table in an experimental context and with a tracing system that worked by shooting electrical discharges on carbon paper.

This participant felt it was necessary for students taking an experimental physics course to learn how to handle widely used instruments (e.g., oscilloscopes, multimeters) and he believed that students should also get an idea of widespread phenomena (e.g., interference, diffraction, a simple electrical circuit).

Of all participants, MZ was the most interested in aspects dealing with experimental design. Although he did not often get the chance to do so, he really enjoyed applying the experimental method (defining a problem, trying to find a solution, thinking about the experimental set-up, etc.). He also said that he enjoyed analyzing experimental data. These are distinctive traits that matter very much, with respect to this study.

MZ reported having little prior experience with use of simulation: he had made scarce use of software that simulated stellar motion.

---

[21] Here's an excerpt of what LY had to say, during the debriefing, concerning the issue of simulations vs. video clips:

> *LY: [...] the video sequence can do anything, really – it does whatever you tell it to do, whereas the simulation behaves in accordance to mathematical calculations. In the case of the video sequence, you'll say: "Maybe, it was just drawn that way," whereas with the program – if in fact you are shown with disclosure what is really happening using vectors and such – it's more credible.*
>
> ***Interviewer****: OK, so a video sequence can be...*
>
> *LY: It can be anything. Take movies: you have special effects, etc. Well, I may be pushing it a little... You do tell yourself that your school isn't working against you, but that notwithstanding... Normally, I would have more trust in simulation – it proves more. Video shows no proof. It's like television. If you watch television, you are passive – with simulation, you can interact [...] That's what we used to do in physics with MAPLE [software]: we had a model and we could change the data [...] and the model would change in accordance. Then we verified this manually by calculations on the blackboard and saw that things were accurate.* [citation 36]

A priori Attitude toward Simulation as an Educational Medium

MZ exhibited an unfavorable attitude toward simulation when used to convince skeptical students of counterintuitive concepts, and a neutral attitude toward simulation when used for skill training.[22]

---

[22] Here are excerpts of MZ's debriefing comments concerning the issue of simulation vs. video clips:

> ***MZ:*** *You can't help but be perfectly convinced when the experiment is conducted in front of your eyes. And viewing a video sequence is almost equivalent to having the experiment conducted in front of your eyes – you can't say a thing... Whereas, in the case of a computer, effects that infirm [theory] are just as programmable [as those which confirm theory].*
>
> [...]
>
> ***Interviewer:*** *More people would be convinced by the video clip [than by the simulation]?*
>
> ***MZ:*** *[...] Yes. However, that may not be a positive thing. Perhaps it's an aspect of media in our time:*
>
> *"This really happened: look we filmed it!"*
>
> *"Ah yes, now I believe it."*
>
> *But that doesn't mean that it would be more credible objectively. I think people would be more convinced but that doesn't mean that it would be more credible...*
>
> ***Interviewer:*** *From a scientific point a view?*
>
> ***MZ:*** *Yes, that's right: from a scientific point of view, [video] has no value.* [citations 37 and 38]

Appendix H: Classification of Participants According to Values for Indicators of *A priori* Attitudes toward Simulation

This appendix gives details about the processing of responses to questionnaire items that concern *a priori* attitudes toward simulation as an educational medium (see Appendix B: questions M5 to M12). Questions M5 to M8 involve computer simulation, while questions M9 to M12 are almost identical to these, but involve other media instead of simulation. These two sections were given to subjects separately. Near-identical pairs can be formed with questions M5 and M10; M6 and M9; M7 and M11; M8 and M12. Answers within these pairs were compared in order to compute the indicator values contained in tables XIV and XV, found below.

Table XIV contains indicator values for *a priori* attitudes toward simulation in comparison to video, when used to convince skeptical students of the validity of counterintuitive physics concepts during a lecture. These were obtained by comparing question M5 responses to question M10 responses, which involved a mechanics concept, as well as by comparing question M6 responses to question M9 responses, which involved a relativity concept. This process went as follows: All responses were first converted to an integer between 0 and +20 in order to accommodate both the 11-point percentage scale and the 5-point scale used for questions M5, M6, M9, and M10. The 5-point scale was thus mapped to 0 5 10 15 20, while the 11-point percentage scale was mapped to 0 2 4… 20 (as an example involving the latter scale, subject DQ's responses to questions M**5**(A) and M**10**(A) are 60% and 80%, mapping respectively to 12 and 16 [on 20]). Indicators in table XIV were then calculated by subtracting converted M10 values from M5 values, as well as M9 values from M6 values (in the above example M**5**(A) – M**10**(A)= 12 – 16 = **-4** which is the result displayed in the first cell of subject DQ's row).

Consequently, the scale of individual indicators (i.e. of the values in each cell) ranges from –20 to +20. Negative values indicate unfavorable attitudes toward simulation. Positive values indicate favorable attitudes toward simulation.

Table XIV: Indicators for *a priori* attitudes toward simulation (in comparison to video) when used to convince skeptical students of the validity of counterintuitive physics concepts

Questions / Subjects	Simulation is used to convince skeptical students of validity of counterintuitive **classical mechanics concept** (M5-M10)			Simulation is used to convince skeptical students of validity of counterintuitive **relativity concept** (M6-M9)		
	A) Convince *skeptical classmates*	*B) Convince subject*	*C) Quality of method*	A) Convince *skeptical classmates*	*B) Convince subject*	*C) Quality of method*
AN	0	- 5	0	0	0	0
BO	0	0	5	0	0	0
CP	0	5	5	0	0	0
DQ	**- 4**	- 5	- 5	- 2	- 5	- 5
ER	**- 2**	0	0	- 2	-10	0
FS	**-10**	0	- 5	- 2	0	0
GT	0	5	0	- 4	- 5	-10
HU	**- 8**	-5	-10	- 8	-10	- 5
IV	**- 2**	- 5	0	- 6	- 5	0
JW	**- 2**	0	- 5	-2	0	5
KX	**-12**	-10	- 5	-16	- 20	- 5
LY	4	0	10	0	0	10
MZ	**- 8**	- 5	-10	- 6	0	0
Negative values indicate unfavorable attitudes toward simulation. Positive values indicate favorable attitudes.						

Subjects were then classified in one of three categories (*unfavorable* attitude, *neutral* attitude, or *favorable* attitude: see table IX), by summing indicators across the entire table for each participant. For example, in subject ER's case, I summed –2, –2, –10 and obtained –14 (on a scale of –120 to +120). I considered that subjects with an indicator sum:

- inferior or equal to –10 had exhibited an unfavorable attitude toward simulation, overall
- between – 9 and + 9 had exhibited a neutral attitude
- superior or equal to +10 had exhibited a favorable attitude.

Table XV presents indicator values for *a priori* attitudes toward simulation, in comparison to use of real equipment (though simpler than the one needed for the actual task), in skill training. These indicators were obtained by comparing question M7 responses to question M11 responses, which involved training for a low risk mechanical operation, as well as by comparing question M8 responses to question M12 responses, which involved training for a high risk computer-based task. This process was essentially the same as for the previous indicators: Responses on the 5-point scales were first converted to corresponding integers between 0 and +20, that is 0 5 10 15 20; converted M11 values were then subtracted from M7 values, and M12 values from M8 values, yielding the results displayed in Table XV. As before, the scale of individual indicators (i.e. of the values in each cell) ranges from -20 to +20, with negative values indicating unfavorable attitudes toward simulation, and positive values indicating favorable ones.

Table XV: Indicators for *a priori* attitudes toward simulation (in comparison to real, albeit simple equipment) when used for skill training

Questions / Subjects	Simulation is used to train operator for **scrapyard task** (M7-M11) (low risk / mechanical operation)			Simulation is used to train operator for **nuclear reactor task** (M8-M12) (high risk / computer-based)		
	A) General level of confidence in operator	*B) Operator (not) prone to commit grave errors*	*C) Operator prepared for difficulties*	*A) General level of confidence in operator*	*B) Operator (not) prone to commit grave errors*	*C) Operator prepared for difficulties*
AN	0	0	**- 5**	0	0	5
BO	**- 5**	5	0	0	10	10
CP	10	10	15	10	10	10
DQ	**- 5**	**- 5**	**- 5**	**- 5**	**- 5**	**-10**
ER	0	0	**- 5**	5	5	5
FS	0	0	**- 5**	5	10	5
GT	5	5	**-5**	**- 5**	0	0
HU	0	**-5**	0	**-10**	**-10**	**-10**
IV	0	10	10	5	10	10
JW	0	0	0	0	0	0
KX	10	10	10	10	10	15
LY	0	0	5	0	5	5
MZ	0	0	5	0	0	0
Negative values indicate unfavorable attitudes toward simulation. Positive values indicate favorable attitudes.						

Again, I classified participants in one of three categories (*unfavorable* attitude, *neutral* attitude, or *favorable* attitude: see table X), by summing indicators for each participant. Once more, I considered that subjects with an indicator sum:

- inferior or equal to –10 had exhibited an *unfavorable* attitude toward simulation, overall
- between – 9 and + 9 had exhibited a *neutral* attitude
- superior or equal to +10 had exhibited a *favorable* attitude.

Appendix I: Observations Presented as Individual Accounts

Below, I present separate observations for each participant, in the form of individual accounts. My goal here is to show the results of the first analytical process in which I engaged and to describe more of my observations through a user-centered exposition. It would be helpful to read a subject's profile (found in Appendix G) before reading the account that concerns him.

I.1 SUBJECTS AN, BO, CP, DQ, ER: CHEMISTRY STUDENTS

Subject AN

When AN was asked what he thought of the VPLab compared to his previous lab experiences, he said that it was very realistic. The main element contributing to this favorable judgment was the disk's motion (see below).

Lack of tangibility / Evaluation of the VPLab's potential to allow performing educational experiments

During the debriefing interview, AN was required to evaluate the software's potential in allowing to perform physics experiments. I noticed that AN rated the VPLab's potential differently when he considered different pedagogical objectives:

> ***Interviewer**: To allow someone to develop abilities relating to manipulation [of apparatus], to [the application of a] method, to rigor, and accounting for things that can happen in a lab...*
>
> *AN: Well, then maybe [you could push it] further. There's one dimension that is the comprehension of concepts and another dimension that is manual experimentation. On the one hand, to help you understand [concepts], this is fine... but on the other hand, to personally perform experiments, then I think that a real lab is necessary.*
>
> ***Interviewer**: To help you understand, it's fine but to experiment, not really...*
>
> *AN: No.* [citation 39]

AN believed that the VPLab had more potential to help "understand concepts" – for which he gave a rating of 5 on a 5 point scale – and a little less potential for acquiring skills ("manual experimentation"), for which he gave a rating of "three or four" on a 5-point scale. So, it appears obvious that pedagogical objectives served here as criteria to which AN referred when performing this verisimilitude judgment.

It seems that the VPLab's most important flaw, in AN's opinion, was its lack of "palpability", i.e., that working with the VPLab was not enough of a tangible experience. The subject stated that the VPLab needed to have a more "palpable" quality to it, if it was to have a better potential for experimentation and that "maybe putting it in 3D could help" [citation 40]. I could also conclude from this that a possible cue for verisimilitude is the graphical complexity of the environment (in this case 2D vs. 3D graphics).

Verisimilitude of the disk's motion on the air-table

In AN's case, the primary cue for verisimilitude was the unpredictability of the disk's motion. This was probably related to AN's observation of the disk after he had launched it in such a way that its motion, initially back-and-forth, became irregular after a short while.

Also, the fact that the disk slowed down after having been launched gave the subject an indication that there was residual friction at work against the disk's motion. This yielded greater verisimilitude:[1]

AN: [...] air must be [acting] on it, so it [the disk] will eventually stop...

Interviewer: *You think it'll eventually stop?*

AN: Yes [..] because the pump eliminates a certain type of friction but not all of it.

Interviewer: *What do you think about the fact that we still included some friction?*

AN: Well, I would say it's truthful. Very realistic.

Interviewer: *And is that necessarily a good thing or would you say that it is not important?*

AN: Yes, it's important. You have to try to get as close to reality as possible when you experiment in physics because... If you take away many real conditions, you'll end up with a theory that is applicable only within your own conditions. [citation 41]

Another important finding in this area is that AN was able to discern visual presentation of the disk's motion from its model. When watching the disk's jerky motion,[2] as it was supposed to move extremely slowly, AN proposed that the software didn't allow for smooth presentation of the motion and that the jerky movement was really representing low velocity. He added that this was just a detail that did not bother him. This is a case where visual fidelity (and, more importantly, *perceived* visual fidelity) is poor but credibility is preserved.

Mastery over the simulation deduced from free manipulation and comparisons between the video clip (of the disk moving on the actual air-table) and the simulation

AN felt that it was stimulating to have mastery over objects in the simulation. He claimed that the simulation's graphical attributes (compared to the video image's attributes) were a sign that he "would be the protagonist [in the simulation]" exactly like the experimenters depicted in the video clip comprised in the multimedia explanations [citation 42]. I also infer from this quote that the video clip was a referent for the simulated experiment. Later, when he first interacted with the simulation, AN further deduced that he was "master" of the situation (i.e., that he had to move

---

[1] Observe that the video clip does not depict the disk's motion long enough for the subject to witness this deceleration when watching the video.

[2] This effect was not the result of the physical model of the disk's motion. Instead, the disk's jerky motion (when extremely slow) was the result of intrinsic display limitations, namely, the finite pixel dimension of the display.

objects himself) when he noticed that the disk wasn't automatically brought back to its initial position after getting stuck in a corner of the table.

Multimedia explanations of the experiment

The textual and graphical explanations of the simulation contained in the multimedia Presentation workspace helped to stabilize the meaning of the visual simulation and they provided details on the behavior of its objects as well as information on actions that are possible within the simulation.[3] AN seemed to have understood some of the simulation's features (the role of the pump in suppressing friction on the table, more specifically) by consulting the multimedia explanations; hence, the disk's behavior was more understandable and coherent. As such, the explanations in the multimedia workspaces, be they of an introductory or theoretical nature, must be considered as cues for verisimilitude.

Use of a scale factor to establish a correspondence between images displayed on the Analysis workspace monitor, and the simulation in the Manipulation workspace

In the Analysis workspace, AN used the ruler to measure the 'filmed' image of the scale marker, on which was written "20 cm". The fact that the measurement he obtained on the monitor was smaller than 20 cm established a scale correspondence to the Manipulation workspace simulation and it seemed to make the metaphor coherent; it may have also conferred a different reality status to the Manipulation workspace:

> ***Interviewer****: When you saw the 20-centimeter marker, what did that suggest?*
>
> ***AN****: 20 centimeters in reality [with emphasis on the word "reality"]. But now, you've transposed that to the monitor.* [citation 43]

Verisimilitude of the experimental method / Requiring the subject to perform uncertainty assessment

During the debriefing interview, AN was asked if the VPLab's objects could be replicated in an actual lab and he answered that they could. He also said that it was possible, in an actual lab, to accomplish the actions that he had performed in the VPLab.

On the other hand, it may be significant in itself that, when asked, AN was unable to come up with points of comparison between how work was done within the VPLab and how it is done in an actual lab. However, when required to evaluate the probability of finding a similar way of carrying out measurements in a lab, the subject said it was probable (4 on a 5-point scale).[4] Moreover, I

---

[3] It is important to note that subjects may still not be able to correctly identify objects after seeing the multimedia explanations. For example, AN continued to think that the disk was a ball after he had seen the multimedia explanations (the user has a bird's eye view of the simulated objects so that the disk may be easily mistaken for a ball, at first sight). Also interesting is the fact that this had no apparent adverse effects on the verisimilitude of this object's behavior.

[4] The condition AN set for this positive rating was that the (virtual) tape measure be replaced by a ruler. AN thought that the tape measure was less plausible – three elements seem to contribute to this: first, the tape measure had a digital

have reason to believe that asking AN to perform uncertainty assessment was itself a cue for verisimilitude:

> *[...] If you didn't ask me, I would surely say that [the data] is precise. But [uncertainty] is always there; they want to make reality more a part of it [the VPLab] [...] they want it to be closer to reality so they ask us to assess uncertainty, so that we will really be working.* [citation 20]

Of course, the very fact that uncertainty assessment *is possible* can also be taken as a cue favoring verisimilitude (it only makes sense to require subjects to assess uncertainty if the interface, and more specifically the measuring instruments, afford it). It is interesting to note that at first, AN thought that there would be some function which would allow him to automatically obtain uncertainty of measurement.

Expectations of much lower complexity compared to reality and of less variation in results when repeating experiments

As indicated in his profile (see Appendix G), AN had been aware that results may vary from trial to trial when repeating an experiment in an actual lab and that statistical methods may be used to compile results of multiple trials. It would seem that AN did not expect experimental results to vary as much with the VPLab because he believed that many elements would be missing in the simulation since a human being had programmed it.

Subject BO

Importance of verisimilitude

Subject BO spontaneously expressed how important the issue of verisimilitude is for users:[5]

> *Because the most important obstacle for software may be that people will always think that things have been pre-arranged, like special effects in a movie. They will say: "Well they've arranged it so it's just right." So, this is the advantage of having video as a complement. You can see that it hasn't been pre-arranged.* [citation 44]

From this excerpt, we also get the idea that the video clip (as part of the experiment's multimedia Presentation workspace) may have been an important cue for verisimilitude, hence playing a big role in promoting credibility. I will come back to this topic later.

---

display; second, it seemed bizarre for him to pull on what he perceived to be a string (instead of a wider tape) in order to measure; and third, the measurement was taken starting at a red circle drawn on the tape measure's plexi-glass casing (and so he could not imagine how the measurement would be processed by the tape measure if it were real).

[5] Of course, this subject could have inferred that credibility was an important issue after answering questions dealing with credibility in the preliminary questionnaire.

Evaluation of the VPLab's potential to allow performing educational experiments / The question of "tangibility"

BO assessed the VPLab's potential to allow performing educational experiments, and its likeness to experimental reality. Using a 5-point scale (with 1 signifying 'a very low potential' and 5 signifying 'a very high potential'), BO rated the VPLab between 4 and 5, saying that it was "*almost identical to the real motion* [the real phenomenon]" [citation 45]. Nonetheless, having worked on an actual air-table, he felt that the VPLab could not completely replace the actual experiment because the experience of working on the VPLab was far less tangible. He compared the VPLab to looking at a picture of someone famous and likened performing the actual experiment to shaking that person's hand in "real life." "You may appreciate the picture," he said, "but you'll appreciate his presence [even more]."

BO's attitude illustrates some of the subtle nuances that distinguish presence – the quality that seems to be lacking here – from verisimilitude. In this case at least, verisimilitude can apparently subsist despite diminished presence.[6]

Direct manipulation coupled with a high degree of control over objects and choice of methods

The high level of free interaction with the VPLab's graphical objects was something that reminded subject BO of video games he had played. One might expect that this likeness to video games would not favor verisimilitude. Just the opposite, free interaction – a high degree of control over objects and choice of methods – coupled with 'direct manipulation' conventions was precisely the most important cue for greater verisimilitude:[7]

> *[If] you do not have control over anything, then you might say: "It's programmed to do that". Whereas if you have control – to be able **to move and touch** everything that you desire, **to throw and have fun with the disk** for 15 minutes – you see that it's not really programmed... there is programming but it respects what happens in real life.* [citation 2]

---

[6] Lack of presence, for this subject, seems to be linked with lack of "tangibility" but also with the fact that a virtual lab's images are computer-generated. Surprisingly though, BO stated that he would *not* be inclined to give a higher rating to an experiment performed within a complex immersive environment (of course, knowledge of such technologies is probably obtained through media and subjects were not given the possibility to inspect one first-hand, so this kind of statement has to be taken with some caution). When asked why, BO had this to say:

> *Well, because it's still numerical – the images are drawn or made with a computer. But if you see it... You know, if you see someone in weightlessness on television, it's not the same as actually being in weightlessness yourself.* [citation 46]

I also deduce from this that watching photo-realistic images is also an experience that lacks presence, in BO's opinion.

[7] Predictably, BO was not surprised when encountering limitations to interaction if he deemed that actions which were not allowed, such as dropping the disk beside the air-table on the merry-go-round's floor, were also somewhat useless in the context of an experiment.

The video clip

For this participant, the video clip of the actual apparatus being used, coupled with references to the place where it was filmed, seems to have been a very important cue for verisimilitude:

> ***Interviewer**: So this [video clip] is important?*
>
> ***B.O:** Yes... You know, skeptical people will say: "Well this is all pre-arranged. It's software so it'll work just so– all I have to do is click and follow the path." With the video clip, they see that it's not just software– it's not just a simulation where you click and it responds like so. [The video clip] shows you the experiment done with real objects.*
> [citation 8]

Hence, the video clip functions as a referent for the simulation:

> ***BO**: That's why it's useful to see the video clip before. It provides an introduction so that someone who comes here [in the Manipulation workspace] and starts the merry-go-round will not be surprised of the disk's curved trajectory.*
>
> ***Interviewer**: Because otherwise you would be surprised?*
>
> ***BO**: Well novices would be surprised, not people who are used to it. [...]*
>
> ***Interviewer**: Does the curved trajectory seem...*
>
> ***BO**: No, it seems normal in comparison to the video clip that was shown earlier.* [citation 9]

It is noteworthy that BO tried to imitate some of the actions performed by the man who was depicted handling the disk in the video clip; I therefore conclude that the clip may also function as reference for the *experimenter's behavior*.

Graphical attributes

Since video clips are cues for verisimilitude, one may ask if a visual simulation's graphical attributes are also cues. Though the simulation's graphics, as we recall, reminded BO of video games, he did not seem to think less of the VPLab – quite the contrary, in fact.[8] In his opinion, possible lack of credibility didn't have much to do with graphical attributes and was rather linked to people's perception of the nature of software and resistance to learning through this means: he called this the "software taboo". Now, it may be that graphical quality made little difference for this particular subject, because he was not comparing the VPLab to other applications with more sophisticated graphics.

---

[8] Concerning the graphics, this is what BO had to say:

> ***BO**: The graphics aren't dull. Sometimes, because it's physics, [teachers] think that they have to make it boring. When you get textbooks and videos from the fifties in class, it's usually physics.*
>
> ***Interviewer**: So does [the VPLab] look less serious to you?*
>
> ***BO**: No. On the contrary, I think it opens some doors. It doesn't have to be ugly to be serious. It doesn't have to be boring for you to learn something.* [citation 13]

Verisimilitude of the disk's motion on the air-table

BO stated that the disk's motion on the air-table was "quite similar to the motion you would obtain on the real [apparatus]" [citation 47]. In this area, cues for verisimilitude were: "Conservation of momentum", "uniform deceleration" after collisions with the sides of the table, and angles of collision which were similar to those "on a billiards table".[9] To evaluate disk motion, BO said he relied on his prior experience using an air-table.

The VPLab's main metaphor

Even though he had never used an actual camcorder, BO did compare use of the VPLab's virtual camcorder to possible use of an actual camcorder, for the purpose of filming trajectories in the context of a lab experiment.

Referring to his prior experience with use of rapid photography to collect and analyze data, he said that certain aspects of using the Analysis Workspace monitor and camcorder [10] were very different. First of all, he claimed, with photography one cannot "play back" the recording and see what is going on at a specific instant, as is possible with the virtual camcorder. Second, with photography, the experimenter is constrained by a basic time interval between snapshots, so that in the analysis phase, he doesn't have the flexibility to modify the time interval between successive disk 'traces', as is seemingly possible with the monitor's Trace function.[11]

On the other hand, BO also stated that the VPLab's workspace was credible because, as with a real lab experiment, dots of some sort could be used as data. This was a good cue for verisimilitude. Of chief importance is the fact that differences observed by BO did not seem to have adverse effects in terms of verisimilitude. Based on comments made by BO, these differences had a negligible negative impact on verisimilitude because the basic functions of the devices (i.e., what the devices were used for) were the same.

When he zoomed in on the images displayed on the virtual monitor, BO observed that the traces were not identical. The distortion that caused differences among traces was in fact intentionally included by designers to simulate the limited resolution of existing camcorders and, at the same time, to promote uncertainty assessment– instead, BO believed that it was an unintentional

---

[9] It is of interest to note that collision behavior on a billiards table is not as described in physics textbooks and not what it is commonly held to be (see Wallace & Schroeder, 1988). Hence, in spite of what some subjects might have thought, collision behavior on a billiards table cannot be assumed, *a priori*, to be the same as the collision behavior of a disc on an air-table.

[10] Offhand, BO was able to determine the Analysis workspace's function by noticing visual similarities between the camcorder and the monitor.

[11] Interestingly enough, even though there is a lower limit to the time interval associated with both the Traces and the virtual camcorder (the frame rate, if you will), subject BO did not explicitly make this parallel with rapid photography. He may just have felt that analyzing data within the VPLab's workspace was more dynamic and flexible by nature; hence, this limitation was not identified clearly or was overlooked by BO.

computer artifact: he thought it had something to do with how pixels were being used. The subject did not seem overly bothered by the irregular traces because he felt that they would not have adverse consequences on measurements. He did mention, however, that this distortion effect following a zoom-in on the image reminded him that he was working on a computer.

Finally, it appears that BO's interpretation of the metaphor (a workbench used to perform measurements) might have at least slightly strayed from the meaning which designers had intended to convey. Although, during debriefing, BO actually made an analogy to recording an experiment with a camera and then watching the video replay, he also suggested (during the session) that writing on the Analysis workspace's display surface with a freehand-type function should be allowed.[12] Writing on a display monitor is not usually possible in reality.

Optimal conditions expected due to the VPLab's nature

BO felt that subjects should be warned about simulated factors which would cause experimental results to radically stray from theoretical predictions. If not told otherwise, BO would expect experimental conditions within the VPLab to be "optimal" because the VPLab is software.

Subject CP

Evaluation of the VPLab's potential to allow performing educational experiments / Impossibility of errors in handling apparatus

When evaluating the VPLab, CP claimed that it had very high potential (a rating of 5 on a 5-point scale) to allow performing experiments. He stated one motive for such a high rating: using the VPLab avoids encountering unplanned problems, physically caused by the apparatus or by errors in handling apparatus, that would disrupt the experiment and force the experimenter to start over (the example he gave was electrical discharges accidentally burning the carbon paper within a tracing system). Note that this may not be a good point with respect to verisimilitude. In any case, this subject showed much appreciation, overall, for the VPLab and seemed very satisfied with it.[13]

Inability to get close to measuring instruments with graduations, and lack of precision when measuring (because of visual alignment)

CP seemed to find it difficult to align graduated measuring instruments (like rulers and protractors) in order to get precise measurements. The subject also felt that he could not get as close to the measuring instrument (the ruler) as he wanted, because being too close to the screen was not optically comfortable. Strangely, had CP used the zoom functionality (which he knew about) in the Analysis workspace, getting physically closer to the screen would not have been as necessary. This

---

[12] Note however that in BO's opinion, the appearance of the display surface did not suggest that it was possible to write on it.

[13] For instance, CP commented favorably on the VPLab's graphical attributes.

not withstanding, the greater inability to get close to instruments is an important difference between the VPLab and real labs. (Participants were sometimes reticent, or forgot, to use the zoom functionality; perhaps the following section will shed some light on why.)

The VPLab's main metaphor

During the session, CP had interpreted the Analysis workspace's main display as a "screen" allowing him to see a replay "of the video sequence" he had recorded. The different color schemes used in the Manipulation and Analysis workspaces were cues for this interpretation.

Outstandingly, there was one requirement that CP found to be bothersome as he worked with the monitor in the Analysis workspace: after measuring distances between points on the virtual monitor's image, one must factor in the scale of the image (which varies with the level of zoom) to make measurements commensurate with the scale of reality (see Fig. 4.1). Judging from CP's comments, he must have felt that performing scale conversions of measurements did not correspond to anything that was part of lab work:

> *[...] but working with units and having to take into account [zoom-levels] 100%, 200%, 400% and having to translate those [units] to centimeters – I'm not used to this. When I'm in a lab, I work in centimeters and I can't get more than a 100% [real size] – I can't zoom-in on my apparatus.* [citation 48]

This frustration is understandable since this participant was not assessing the Analysis workspace by referring to a lab situation where working with different scales is necessary (as with a real lab that makes use of cameras and video analysis tools).[14]

Interestingly, CP also seemed to think that working with scaled measurements would invalidate or render impossible certain operations like interpolating between graduations when measuring with the simulated ruler (the ruler was designed to replicate a real ruler and be used much the same way).

Because CP was using carbon paper markings as a referent for the *Trace* function (of the Analysis workspace), it seemed strange and impossible that there should be traces ahead of the object in motion (the disk's image) during playback.[15] The subject said this was not possible in a lab unless you had a computer to do it– by that, he probably meant '*unless you have a computer to predict or approximate the trajectory*'. Hence, for subject CP, it seems that traces 'moving along' *ahead* of the object in motion is a cue which led to lesser verisimilitude of the metaphor.

---

[14] I believe that the majority of students in Quebec would not have prior experience with such tools in laboratory settings, and that an attitude similar to CP's might be common among them.

[15] It is essential to point out that the choice of experiment (one with an air-table) has consequences for verisimilitude judgments of the metaphor, and especially for those judgments which concern the Analysis workspace's Trace function. In educational labs, air-tables are often used in conjunction with a tracing system that works by repeatedly shooting electrical discharges on carbon paper. Students analyze object trajectories thus recorded on carbon paper as a series of dots. Had I chosen a different experiment for this study – one that was not traditionally linked with such a tracing system – verisimilitude judgments of the Trace function might have been very different (although not necessarily more negative). Note, however, that the experiment was not chosen with this in mind.

Aside from the Trace function, CP felt that it was possible, although very costly, to replicate the metaphor in an actual lab by installing "a system of cameras" and "a graphical interface on a computer" (presumably, to analyze the recordings). [citation 49]

Precision and requiring subjects to perform uncertainty assessment

In CP's case, dissonance resulted from working on "*physics* software" like the VPLab which allowed for much less precision than that which is usually allowed in most computer-assisted tasks (for example, drawing with design software allows for much more precision). However, CP did acknowledge that uncertainty assessment was a normal part of physics experimentation:

> *Then again, in physics, it's not weird to have uncertainty [of measurement]: it's experimental. So it's normal to have uncertainty: we calculate it.* [citation 50]

This suggests that requiring (and allowing) subject CP to assess uncertainty was itself a cue for verisimilitude.

Types of instruments and types of objects being measured (distances between traces)

In CP's opinion, the types of instruments used during the session, the quantities measured (distances and angles) and the quantities derived (the disk's velocity) were very likely to be the same as in an actual lab experiment. Using traces of the disk, in the form of dots, as data was a cue for verisimilitude.[16]

The video clip

The video clip was used by this subject as a basis for verisimilitude judgments even though he did not have an unfavorable *a priori* attitude toward simulation (compared to video):

> *[...] it would be possible to reproduce it [reproduce a merry-go-round in a research lab] because we see in the video clip that they did it in Paris. It is possible to do it!*
> [citation 51]

Verisimilitude of the disk's motion on the air-table

CP seemed to be impressed by the disk's motion on the air-table, as he mentioned that building the simulation must have involved a lot of work. The fact that the disk decelerated after being launched gave the subject an indication that there was residual friction at work against the disk's motion:

> ***Interviewer:*** *What was happening before you stopped the pump?*
>
> ***CP:*** *The disk was moving. It slowed down – there is a loss of speed, of course.*
>
> ***Interviewer:*** *Why?*

---

[16] This was also a cue in subject BO's case. Note, however, that BO did not have the same referent in mind as subject CP: he had measured distances between marks on carbon paper (created by electrical discharges), whereas BO had used an entirely different system which made use of rapid photography (see BO's profile in Appendix G).

CP: There is some friction; it's not totally absent.

Interviewer: What do you think about the fact that there is friction? Did you expect that?

CP: Well yes. Air creates friction. It is impossible [not to have friction] unless... We neglect it a lot [in calculations] but it's there all the same.

Interviewer: So it's normal to see this deceleration?

CP: Yes and it corroborates what would happen in a lab. But in a lab, you have steel discs so they slow down faster. I don't know if... [citation 10]

This suggests that the disk's deceleration (signaling that air friction had been included in the simulation) was a strong cue for verisimilitude.

Results deviating slightly from theoretical predictions / Conditions that are not ideal

CP believed that experimental results can and should usually deviate somewhat from theoretical predictions because experimental conditions are not perfect. He proposed that the VPLab should reflect this and not present ideal conditions. In contrast, he felt that if one performed the experiment correctly, results should come relatively close to theoretical predictions and not stray dramatically from them, which is what he had experienced in actual labs.

Impossibility of detecting degraded experimental conditions

During debriefing, CP was told that the simulation could have contained factors which would heavily degrade experimental conditions (soda dropped on the table making its surface sticky, for example). He reacted by saying that it would be impossible to detect this when using the software because users lacked the "physical feeling" of objects and the multiple points of view (seeing the table from many angles, for instance) that are helpful in detecting these types of degraded conditions in a lab. This suggests that, in the absence of specific cues allowing detection of anomalies, experimental outcomes that significantly stray from theoretical predictions would work against verisimilitude, in subject CP's case.

Subject DQ

Evaluation of the VPLab's potential to allow performing educational experiments

DQ gave the VPLab a rating of 4 on 5 for its potential to allow performing experiments. When asked why, DQ said that he saw the VPLab as an element that would bring students something distinct from lectures and regular lab work. He said that simulations were *complementary* to those means. When he was asked what the differences were between actual labs and the VPLab, DQ answered:

DQ: [...] When you're on a computer, it's not real. I think that's the biggest difference between the two. When you're in a lab, you're the one who's manipulating, you're the one who's measuring and adjusting settings, you're doing everything– when you're on a computer, you use

> *the keys but you're not the one who's in control, you're not controlling, with your own hands, the things that you do.*
>
> ***Interviewer:*** *Right now, is that also the case? It's a question of controlling things more directly with your own hands...*
>
> ***DQ:*** *For me, that's the big difference between software like this and a practical lab.*
>
> ***Interviewer:*** *What type of consequences does manipulating things with one's hands entail, compared to doing things like this [with the VPLab]? Do you see repercussions on the experiment's results? How does it change the way you do the experiment?*
>
> ***DQ:*** *I think it doesn't give the same result. Ideally, in my opinion, you should be in a lab, but software like this can be a fine complement.*
>
> ***Interviewer:*** *Does manipulating things have an impact on what you can learn and the errors that you can make?*
>
> ***DQ:*** *Sure, because [in a lab], if you make a mistake, if anything is wrong, you'll see it and you can readjust things. I think you have more control when... with equipment, when you're manipulating it. The disadvantage of a computer simulation is that you're not controlling everything. Even if you're controlling things with your keyboard and your mouse, it's not real – it's not the same.* [citation 3]

In my opinion, there are three issues to be addressed when considering the above excerpt.[17] I examine these below.

1) Difficulty in using the interface contrasted to ease of work in a lab

The first issue is a feeling of lack of control, which may be caused or exacerbated by this subject's greater difficulties in using the VPLab's interface. Supposing that this feeling of lack of control is partly due to lack of skill, it could be lessened by allowing further interaction with the interface and by offering technical support to the user.

2) Less freedom, less control over objects and less ease in detecting problems which may occur during an experiment

The second issue is a more basic sensation that working with the VPLab entails less freedom and control over objects than in a real lab, and less ease in detecting problems which may occur during an experiment. This feeling seems to be expressed in the following quote: "[in a lab], if you make a mistake, if anything is wrong, you'll see it and you can readjust things." This feeling may well be directly related to two factors: (1) the fact that users do not directly touch objects with their hands when using the VPLab (this is explicitly referred to by DQ): and (2) the subject's suspicion that the nature of a 2D simulation would not allow users to detect potential anomalies.

3) Ontological status of the VPLab and unfavorable a priori attitudes toward simulation

Both of the factors just stated should be less problematic, at least to some extent, in an immersive virtual environment. But consider the following excerpt:

[17] Notice that, contrary to DQ, other subjects like AN and BO felt rather in control of things and this feeling of mastery made things credible for them. This contrast in attitudes is very interesting but also difficult to explain.

Interviewer: Have you ever seen movies or news reports on virtual reality– of people who wear helmets and gloves?

DQ: Yes, I've seen that a few times.

Interviewer: What would you think of a [virtual reality] lab where you could manipulate things using gloves? There would be objects... and there are gloves that give you tactile sensations. I was wondering if the problem [with the VPLab] was that you were working with a mouse and a keyboard or if it would be the same [problem] for you with a helmet and gloves?

DQ: It would be the same. It remains imaginary... well, imaginary, in a way of speaking. It's not imaginary but it's not real. [citation 4]

So the third issue is the even more basic question of ontology: the VPLab's experiment is computer generated and has no material substrate. In regards to this last issue, let me recall that DQ had exhibited unfavorable *a priori* attitudes toward simulation with respect to both situations presented in the preliminary questionnaire (see tables IX and X) and that some of these unfavorable attitudes may play a role in his judgment here.

The VPLab's main metaphor

In the Analysis workspace, DQ used the ruler to measure the 'filmed' image of a marker on which "20 cm" had been written. The fact that the measurement he obtained was smaller than 20 cm established a scale correspondence with the Manipulation workspace simulation and it seemed to make the metaphor coherent; it may have conferred a different reality status to the Manipulation workspace:

Interviewer: Why was " 20 cm" written on the purple marker?

DQ: Because it's the real space. And we're in a space that's... well, not virtual, but a space with a scale. So the scale would be that 1.1 centimeters is equivalent to 20 centimeters ***in reality****. If we want to calculate, we can use this [scale] to transform...* [citation 52]

When asked to evaluate the probability of finding the Analysis workspace features in a lab, DQ rated it at 3 on a 5 point scale (1 being a very low probability and 5 a very high probability): it did not seem likely that an actual lab could include the Zoom and Trace functions. More specifically concerning the Trace function, DQ said he could not imagine how one could add and remove traces at will so easily in the context of a real experiment.

Ideal conditions (appearance of flawlessness)

When it was suggested to DQ that it would be possible to simulate factors causing experimental outcomes to stray from theoretical predictions, the subject replied that such factors would present difficulties also experienced in actual labs. He also claimed, that *due to the VPLab's appearance*, he would not have expected these factors to exist:

I would not have thought of that. [The VPLab] looks well built, very structured – it's going to work: nothing would go wrong. [citation 53]

Subject ER

Graphical attributes and a narrow field of view

During the debriefing interview, ER was asked what he thought of the VPLab in comparison to the labs he had known:

> *As for realism, it is important to also have the opportunity to see the disk moving on an actual table, in an actual lab, because I'm not so sure that it gets into your head as much when you see it on a computer– it's not as convincing as when you see it for real".* [citation 54]

When asked to explain what was contributing to this sensation, the subject spoke about three elements. He first brought up the VPLab's instruments which, he said, "were more or less real instruments." (I will be discussing this shortly.) Then he spoke of the colors (mentioning the blues, violets, and yellows[18]) of simulation objects, which emphasized the fact that the simulation's images were drawings. To this, he added that the disk did not have the appearance of a real puck. Finally, he mentioned that seeing the apparatus in a narrow space was annoying and that it would be preferable to see the whole table in large.[19]

I conclude, as far as ER is concerned, that lower *visual fidelity* (through the cues described above) can be associated with lower verisimilitude.

Evaluation of the VPLab's potential to allow performing educational experiments

When evaluating the VPLab's potential to allow performing educational experiments, ER gave it a rating of 3 on a 5-point scale. He justified this relatively low rating by the following argument:

> *I must admit that all the gadgets somewhat divert your attention from what you really should be doing– from the real phenomenon. It distances you a bit more from the physical phenomenon. You see it a bit like a game or a gizmo for drawing. It's more or less real and it... it's distracting.* [citation 55]

I shall try to expand on this comment in the sections below. For now, let me contrast this excerpt to a comment ER made as he was exploring the Analysis workspace:[20]

> *I have to admit that I like this. [...] I like this software – I enjoy performing physics experiments like this with instruments [like these].* [citation 56]

---

[18] Both the Manipulation and Analysis workspaces use color schemes comprised of vivid hues: 'warm' colors for the Manipulation workspace simulation and 'cool' colors (i.e., colors toward the blue/violet end of the spectrum) for the images displayed on the Analysis workspace monitor.

[19] When first exploring the Manipulation workspace, ER had tried to enlarge the air-table by dragging out one of its corners with the hand-shaped cursor (as is often possible with graphical objects in "direct manipulation" interfaces, but is not possible with the VPLab's objects).

[20] Importantly, this comment was made before ER realized that he had a poor grasp of the meaning of the VPLab's main metaphor, i.e., that the Analysis workspace basically simulates a monitor screen on which video recordings of the experiment ('filmed' in the Manipulation workspace) can be replayed, and that the images of these recordings are scaled down as on a real monitor.

On the one hand, ER said that he enjoyed "performing *physics experiments*" with the virtual instruments and on the other, he felt that the VPLab's features distracted him from the main goal of the experiment.

"Real" and "unreal" instruments

ER was bothered by the fact that instruments which he perceived as "real" shared the environment with others which he perceived as "unreal". On the one hand, the stopwatch, the protractor and the ruler seemed real to him, and on the other hand, the calculator did not.[21] I conclude that objects that were similar to those ER had seen, seemed more real to him than those that weren't. I also conclude that dissonance or lack of coherence occurred because both types of instruments were present in the same space.

One of the instruments, the tape measure, was most peculiar to ER. Though he had first hesitated, ER recognized that the virtual tape measure's shape was reminiscent of an actual tape measure. He thus expected its behavior, when handled, to be analogous to an actual tape measure's behavior; instead, when he used it, he felt that it behaved quite differently.[22]

Most importantly, he felt that the tape measure was "less real" because the measurement was read on its digital display and not on a tape with graduations. The digital display also seemed to create expectations for a very precise reading (more numbers after the decimal): at the same time, ER claimed that he was used to obtaining more precise values when measuring lengths. Furthermore, when assessing uncertainty of measurements made with the tape measure, ER hesitated because he felt that the tape measure combined seemingly opposite ways of producing measurements. In effect, dissonance occurred because, on the one hand, it was necessary to visually align the tape measure's components with the object that was being measured, and on the other hand, the reading of the measurement was obtained on a digital display within a computerized environment:

> *Well, it's because [the tape measure] is between... Because, given the fact that [the VPLab] is a computerized system, you tell yourself that it is going to measure precisely– direct, precise, real values. But this is rather somewhere between taking precise values and taking values that refer to something that would be collected manually. So, because it's between the two, I'm having a bit of difficulty...* [citation 19]

---

[21] The simulated calculator does not have buttons. Instead, mathematical expressions are entered into it using the keyboard. It is rectangular but, contrary to most pocket calculators, its width is twice as long as its height.

[22] First, he felt that the virtual tape measure behaved differently from a real one because, once the tape was deployed, he could make the casing rotate fluidly around the ring at the end of the tape (which was then stuck in place, to be used as the first point of reference for the measurement). Second, he did not expect to use the red slider (on the side of the casing) to immobilize the ring and move the casing around it– instead, he felt that this type of slider usually has a different function in real tape measures (that of locking the tape into place when its length is sufficient).

Performing uncertainty assessment

Performing uncertainty assessment within the VPLab was not overly strange for ER, although he felt that working with a computer usually meant that one could avoid performing certain tasks (like uncertainty assessment) by using automatic functions. Still, ER deemed it was normal to assess uncertainty when working with the VPLab, given that he considered it an important skill to acquire. Let me also note that he perceived uncertainty assessment as problematic with the tape measure but not with the ruler or the protractor.

The VPLab's main metaphor

Of chief interest is ER's poor understanding of the main metaphor and the verisimilitude judgments that concern it. After having recorded a sequence of the disk's motion in the Manipulation workspace, ER expected to view the recording in a larger format, on the spot, by obtaining a blow up of the camcorder's small screen. Consequently, it is very interesting that he did not correctly identify this as the function served by the Analysis workspace monitor when he got around to seeing it. Instead, he mistook the monitor for a "window" allowing one to launch the disk more accurately on the table or to tune parameters for launching the disk more accurately. It was only when the interviewer inadvertently gave ER a clue (by telling him to go back to the beginning of the 'filmed' sequence), that he started regarding this 'window' as a device that could offer a playback functionality. At this point, when asked to state what he thought the workspace monitor represented, ER hesitated for a long time, then said it could be a camera and finally surmised that it represented nothing that actually existed– the Zoom and Trace control panels were responsible for this conclusion.

Measuring the 'filmed' image of the scale marker was no help in stabilizing the metaphor. Though he postulated that the marker represented some kind of scale, ER could not understand why it was not possible, with the ruler, to obtain a measurement of the scale marker's image equal to the "20 cm" that was written on it.

Later, during the debriefing (after the interviewer had explained the metaphor and the use of the scale), ER stated that doing scale conversions of measurements did not correspond to reality. His past experience seems to have been crucial in forming this judgment:

> ***ER:*** *[...] I was really expecting to measure [between] dots. In fact, it's because I was relating this to when I had done this experiment in college– when I measured distances between dots [in college], I was not doing it through a window. I was measuring directly: the distance [measured] between two dots WAS the distance between two dots. I would not have expected to go to a [monitor] screen, and to have to transpose [the measurement].*
>
> ***Interviewer:*** *And now that you know, does it seem strange to work like this? Or is it normal...*
>
> ***ER:*** *Well... strange [...] It bothers me.*
>
> ***Interviewer:*** *In reference to what you've done in the past, it still bothers you?*

> ***ER**: Well, it bothers me to have to do scale conversions of measurements [...] it's like calculating something that does not correspond to anything real.* [citation 57]

Tellingly, he also likened working with the Analysis workspace to playing a video game. More to the point, he made an interesting link between the Analysis workspace and a video game which has the player act as a pilot in a cockpit:

> *When I use these instruments, it doesn't relate to anything real. It's purely like playing a video game with a plane cockpit.* [citation 58]

Although ER did not elaborate on this, one can imagine how a simulated cockpit with instruments and dials laid out below a windshield could be perceived similarly to the VPLab's virtual monitor screen, with its measuring instruments laid out around it.

Traces appearing ahead of the object in motion (in playback mode)

Measuring distances between traces was something ER had previously done in a school lab. But because ER was relating to his experience of using a carbon paper tracing system for this type of experiment, it seemed strange and impossible that there should be traces ahead of the object (the disk) which was in motion (during playback). Hence, it seems here that traces 'moving along' ahead of the object in motion (in this case, the disk) is a cue that works against verisimilitude.

Verisimilitude of the disk's motion on the air-table

Much like AN, subject ER was able to discern between the simulation's model and its presentation: he noticed that the disk's motion was jerky at very low velocities but he proposed that this was due to poor visual presentation of the motion.

This being said, the subject felt that the disk's motion was not realistic, in other regards. ER did acknowledge the presence of friction working against the disk's motion when he observed that the disk slowed down after launching it. However, he felt that it was not slowing down fast enough (note that ER had prior experience with a different type of air-table– see his profile in Appendix G). He believed that air friction had been included in the simulation, but that residual friction *due to the table's surface itself* had not. To ER, this made things out to be somewhat "less real".

Expectations of ideal conditions / Impossibility of detecting degraded experimental conditions

ER believed that the air-table's sides (on which the disk had rebounded) were perfectly uniform and that it would be impossible to replicate them in an actual lab. In a related matter, he expected that physical factors (a piece of pencil lead on the air-table, for example) which could cause experimental results to stray dramatically from theoretical predictions, would be absent [23] from the

[23] Rather than the term 'absent', ER used the word 'impossible'.

VPLab. When later told that 'physical anomalies' might in fact have been simulated, ER said he would not have expected them to exist nor would he expect to be able to detect their presence:

> *It's a computer, [so] everything goes well: there are no physiological problems with the apparatus. And also, when you experiment [in an actual lab], when you do it yourself – you see... you'll know if a piece of pencil lead [on the table] has made the [disk deviate]... but in this case [the VPLab], I don't know if one can physiologically perceive the anomalies. Anyway, it's good that these types of errors exist [in the VPLab].* [citation 6]

I.2 SUBJECTS FS, GT, HU, IV: MECHANICAL ENGINEERING STUDENTS

Subject FS

Evaluation of the VPLab's potential to allow performing educational experiments

During the debriefing interview, FS was asked to rate the VPLab's potential to allow performing educational experiments. He rated it between 4 and 5 on a 5-point scale (with 1 signifying 'a very low potential' and 5 signifying 'a very high potential'). The disk's motion (pointing to underlying constraints) and its similarity to the video clip seemed to promote such a high rating. More on these topics, below.

The video clip

The video clip (comprised in the multimedia presentation of the simulation) was an important element of reference when FS made verisimilitude judgments concerning aspects of the simulation (e.g., the disk's motion and the scale of the simulation itself). Although the subject did not mention this explicitly, the fact that the simulation was depicted using the same point of view (bird's eye view) as the video clip is a factor that probably facilitated comparison between the clip and the simulation (when assessing the simulation's scale, for example).

The disk's motion (deceleration pointing to inclusion of residual friction)

Before the subject launched the disk on the air-table for the first time, he did not expect that it would stop on its own because he believed that friction had not been included at all in the simulation (his reasons are described in the next section). When FS realized that the disk was slowing down, this became a major cue for verisimilitude because it signaled that real-world constraints had been included in the simulation:

> ***Interviewer**: Why does [the VPLab] have much potential [to allow performing physics experiments]?*
>
> ***FS**: Well, when you watch the video clip and you watch this [simulation], both do exactly the same thing– [the simulation's designers] have included friction; they have included most of the constraints that could be applied to it.* [citation 59]

Perceived lack of visual fidelity: the simulation's 'game-like' graphical attributes / Perceived target users

It is the VPLab's graphical attributes – qualified by FS as "attractive" and "game-like"– that caused the subject to expect that residual friction would not be included at all in the simulation. Since the graphics were attractive to him, he felt that the VPLab was intended for high-school (or first year college) students, because such attractive graphics would help muster beginners' interest. Furthermore, to his mind, students at this level were often told by their teachers to neglect some aspects of the phenomenon involved in the experiment (air friction, for example), in order to simplify analysis; FS probably associated the act of neglecting residual friction *at the time of analysis* with the act of neglecting residual friction *when designing the simulation itself.* In any case, FS's judgment starts with perception of graphical attributes (attractive), which probably led him to imagine appropriate target users (beginners), and then to anticipate the simulation's level of complexity (simple).

For the same reasons, FS also seemed to feel less involved in some tasks like uncertainty assessment:

> ***FS**: Well I was still thinking that I would do [uncertainty assessment] approximately.*
>
> ***Interviewer**: Is it still because [the VPLab] doesn't seem serious enough to you?*
>
> ***FS**: Well, it looks like a game... that's why. You do it quickly...* [citation 60]

Visual fidelity (or lack thereof) still seemed to matter for this subject, even though verisimilitude of the simulation had been enhanced by the realization that the simulated disk's motion was more complex than he had first thought. During the debriefing interview, the subject proposed that photo-realistic images – including elements such as "a nicer texture," as well as instruments and colors that "look more real" – may help provide "a greater impression that [the environment] is real".[24] A greater sense of presence seemed to be at stake here:

> *Of course, the nearer it gets to reality, the more you will feel part of that world. You'll forget your surroundings and you'll really concentrate on [the simulation].* [citation 61]

This may be an attitude which can be cultivated through more extensive use of 'realistic' or visually appealing video games (FS had reported playing video games often).[25]

'Direct' manipulation / Affordance of errors on measurements (uncertainty assessment)

During the session, FS seemed to believe that it was normal to launch the disk on the table by manipulating it with the mouse and cursor (rather than through other input devices and modes of

---

[24] I must note that this subject praised the VPLab for its "attractive" graphics (probably in comparison to 'home-made' software) and said that these would help foster interest in working with the environment.

[25] On the other hand, subject CP also reported playing video games "often" (see Appendix G) and he hardly mentioned the graphics except to say that they were stimulating. Moreover, subject ER reported that he "almost never played" video games but he criticized the VPLab's graphical quality, anyway.

control). He made comments which would indicate that he approved of the level of precision that was thus afforded. Later, at the beginning of the debriefing interview, FS was asked what he thought of the VPLab, in general. One of the first things he mentioned was that he appreciated 'directly' manipulating objects:

> *It's not just entering data and getting answers in return. You actually manipulate things. There is uncertainty involved and it really emphasizes that there is a stake in error [on measurements].* [citation 62]

From this excerpt, I can also infer that the affordance of error in measurements (and thus, of uncertainty assessment) is an important feature.[26] FS's initial reaction, when he first began to measure distances with the tape measure, was different however. Having made prior use of Computer Assisted Design software, he felt that the VPLab's instruments did not offer the same level of precision and convenience as the tools in such packages; for example, he would have liked to "snap" (automatically fix) the tape measure onto the extremity of the object he was measuring.

As he made further use of the tape measure, his attitude toward it seemed to change: he said he enjoyed using it because it was fun and it gave him a measurement that was "approximate, *yet still precise*" [citation 63].

It is also extremely important to note that FS was considering uncertainty assessment in reference to the context of simulating an actual lab and that it made sense to him within this context:

> ***Interviewer:*** *Is it normal or strange to ask you to assess uncertainty here?*
>
> ***FS:*** *No, no... That's always fine: no instrument can be 100% reliable. And furthermore, with this software, you realize that the purpose is to simulate something [so] you have some error [uncertainty].* [citation 64]

The VPLab's main metaphor

More than any other subject, FS seemed to interpret the VPLab's main metaphor in a very 'literal' way (Smith, 1987). For instance, he was one of very few subjects to explicitly consider whether the virtual camcorder was placed inside or outside the merry-go-round[27] (before he used it to record the disk while working in the Manipulation workspace).

Moreover, his interpretation of the Analysis worskpace's main display was extremely close to the meaning that VPLab designers had intended to convey:

> ***Interviewer:*** *What does this [work]space represent?*
>
> ***FS:*** *Well it's as if the camcorder was connected to a flat video screen placed on the ground [facing upwards]. You would have your instruments there and you could work on the screen. [...]*

---

[26] Note that requiring FS to evaluate uncertainty and discussing this topic during the session might have helped to elicit this comment.

[27] This is a crucial question in the context of an experiment concerned with rotating frames of reference because motion seen from outside the frame of reference will not be the same as motion seen from within.

It looks like a smooth screen– if this were in reality, you could put the objects [i.e., instruments] on it. [citation 65]

Three elements mainly contributed to ascribing this meaning to the display. The first cue was measuring the 'filmed' image of the scale marker with the ruler and obtaining a measurement inferior to the "20 cm" which was written on it. This established a scale correspondence [28] to the Manipulation workspace simulation and it may have also conferred a different reality status to the Analysis workspace. The second element contributing to a literal interpretation of the metaphor was the possibility of zooming in and out of the recorded image displayed in the Analysis workspace– a strong cue leading to comprehension of the metaphor thus emerged: namely, the fact that instruments and panels outside the playback area (outside the virtual monitor's frame) remained in place and kept the same scale after zooming in and out (hence only the image inside the screen's frame varied in size). The third element was the different textures used for the frame of the virtual monitor and for the screen itself. While the frame's embossed texture reminded FS of a metal floor, the center part of the display seemed flat (and transparent) as a smooth screen.

FS is one of two subjects that likened the yellow *Traces* (displayed in the Analysis workspace) to the display of special effects 'traces' that follow a hockey puck, in real-time, in hockey games broadcast on an American television network.[29] This case is very interesting for three reasons. First, it is an example of a subject using a referent radically different from that which most subjects used (and closer to the designers' own referent) – this must be somewhat related to FS's understanding of the main metaphor (see above).

Second, it is a case where various elements are combined to produce specific meaning: an actual television screen **vs.** the VPLab's virtual monitor + the hockey puck **vs.** the disk in the simulated experiment + the VPLab's yellow Traces **vs.** the traces produced by special effects on television. In effect, had the simulated experiment involved something other than a disk, say a pendulum for instance, perhaps the subject would not have made this connection with the hockey broadcast's special effects, which involved another type of disk: a hockey puck.

Third, it is a case where knowledge of other media is mobilized when considering features of a software environment. Technical knowledge of such media may be used when making verisimilitude judgments. Even though FS believed that the Traces would be very hard to reproduce in an actual lab, he did not completely exclude that possibility: he claimed that it would be necessary to use a video editing consol in order to superimpose video images of the disk corresponding to different time indexes in the recording.

---

[28] Contrary to some subjects, FS was not in the least bothered by having to do scale conversions of measurements.
[29] He referred to a television program called "NHL (National Hockey League) on FOX".

Physical feeling (presence) / Ontological status of the VPLab

I have already stated that FS gave the VPLab a very high score (4.5 on a 5-point scale) for its potential in allowing to perform physics experiments. When he was asked why he had not given it a perfect score (5 on 5), FS answered that there is a loss of physical feeling associated with working on a computer and that it was still possible to doubt simulations in cases where a simulated object's motion would seem very strange. "Everybody is a bit like Saint-Thomas," he claimed, "you'd like to get into the machine and really launch [the disk] yourself" [citation 66].

When asked if working in an immersive virtual environment would solve this problem, he answered that it would still not be the same as being in an actual lab since one would not feel things like centrifugal force acting on one's body while standing inside the merry-go-round; he added that, by working with a simulation, one loses the "sense of danger" that one experiences while doing chemistry or physics experiments in an actual lab.

Results that stray radically from theoretical predictions

During debriefing, FS stated that if a simulated experiment's results strayed radically from theoretical predictions, he would be tempted to blame the simulation for being inaccurate (after having excluded error on the part of the experimenter as a probable cause).

Subject GT

The video clip and the multimedia explanations (in the Presentation workspace)

The video clip and multimedia explanations in the Presentation workspace were used by this subject as a basis for verisimilitude judgments concerning the disk's movement and the scale of objects represented by the simulation:

> ***Interviewer:** What's going on?*
>
> ***GT:** Well, when [the disk] hits one side of the table, it keeps going so I imagine – like I saw in the film [i.e., the video clip] – that [the side of the table] is like an elastic that perpetuates the motion.*
>
> *[...]*
>
> ***Interviewer:** So why was the 20cm [marker] put there [in the simulation]?*
>
> ***GT:** In my opinion, it's to give the scale of reality.*
>
> ***Interviewer:** And where is reality?*
>
> ***GT:** Reality is what we saw in the film – the merry-go-round. [...] In comparison to the film, we see that it is realistic and that 15 people can sit on the bench [in the merry-go-round], so the size [i.e., the scale] seems realistic to me.* [citation 67]

Verisimilitude of the disk's motion on the air-table / Complexity of the simulation: ideal conditions (physical flaws not included in the simulation)

There were two dimensions to GT's judgments concerning the disk's motion. Judgments of one kind were exhibited during the session, when GT stated that the disk's motion was "quite realistic". Cues used for this judgment included angles of collisions between the disk and the sides of the table being similar to those on a billiards table (angle after collision is "opposite" to angle before collision); rotation of the disk about its own center; rapid cessation of motion when the pump is inactive; and slow deceleration of the disk after having been launched (when the pump is active). Note that GT attributed this deceleration to a "loss of energy" (for which he did not specify a cause), but he also made comments which would indicate he was not aware of the existence of residual friction working against the disk's motion.

Interestingly, during the debriefing interview, GT displayed judgments which integrated another dimension of verisimilitude: that of *constructedness* (more specifically, alteration through mediation of the phenomenon). He claimed that if he were to launch the disk on the actual air-table depicted in the video clip, the actual disk's motion would not be exactly the same as the simulated one:

> *[...] the object [the disk] may not move at the same speed or... I really have to tell you that it will never be the same; the object will never move like the real one even if it starts at the same position [and you launch it] with the same force. Given that the computer does not account for everything that happens in reality, I would not obtain the same [experimental] results at the end. It may be close, though. But you will never have the same results. So you would have three types of results: the theoretical result [i.e., prediction] shared by all, the result obtained with [the VPLab] and the result that you really would get in reality.* [citation 68]

What's even more interesting about this comment is that it was made not long after GT had been told that anomalies and 'physical' sources of error might have been included in the simulation.[30]

It is highly significant that before he was told this, GT believed even more deeply that conditions within a simulation were ideal. First evidence of this was found in his statement to the effect that it is good to include possibilities of error in measurements when "simulating a *real* experiment" – absent that, he said, "experimental results would be *practically* the same as theoretical results [i.e., predictions]" [citation 69]. Another comment made by GT demonstrates this attitude even more convincingly:

> *A computer is perfect [...] When you activate the air-cushion pump, it's precise. The pump produces constant pressure. So, this is data that will be more precise on a computer than in reality. The computer does not account for all, all, all of what is in reality so it's certain that your results will be almost perfect compared to reality.* [citation 70]

[30] In my view, this may either be a manifestation of awareness of differences between a model and reality, or else of more basic mistrust of simulation.

This part of the discussion followed a thread in which GT recalled a statics experiment that all engineering subjects had previously performed at their university. In that particular experiment, as GT recalled, outcomes had not been predicted – and, to GT's mind, could never have been predicted – by the equations which students had been using because these equations included factors presumed to be 'ideal', but which were not in reality. "So we say that experimental reality cannot get close to theoretical simulation," he concluded [citation 71]. From this, he then inferred that if the statics experiment in question were to be simulated on the VPLab, its outcome would be "perfect" (given the extreme precision of instruments which had been used in the actual lab), and its results would conform not to reality itself, but instead to equations based on presumption of an 'ideal' experimental set-up. [31]

Precision and possibilities when manipulating the disk

GT gave further justifications for his belief that actual experimental results would differ from those obtained with the VPLab's air-table simulation. He claimed that in a real lab, one could know what force had been applied when launching the disk with the elastics which lined the table's sides. This is something that he had not been able to do in the VPLab (he would not exclude that possibility, however). He also seemed to say that the initial position of the disk before its launch would not be as precise in the VPLab simulation as in an actual lab.

In another area of interest, after having tried three times to launch the disk as fast as he could during the session, GT commented that he would be able to launch the disk faster in an actual lab.

Instruments which look like they can be grabbed with one's hands (like objects depicted in video games) / Manipulation of instruments via the mouse and cursor

While exploring the Manipulation workspace, GT declared that it looked like a video game. When asked why, he answered that it had to do with the type of instruments available as well as the way they looked and the way they were controlled. For GT, "looking like a video game" had the connotation of "being very realistic":

> *In video games, we often see this – a logbook or a camera. [The VPLab's camcorder] is designed in a very real... very realistic way: you can almost manipulate it... with your fingers. You click on a button with the finger [i.e., cursor] and it closes [the camcorder's screen] automatically. So it's very realistic, it's gadgety [...] You don't enter functions with the keyboard – it's almost always done with the mouse and a hand [i.e., cursor] on the screen.* [citation 15]

---

[31] An informant (a professor who had taught the class which featured this experiment) told me that the discrepancies obtained by the students, between theory and experimental results, were due to errors in the experimental set-up. However, my informant added that these errors could themselves be simulated without too much effort. This is crucial because GT might not have been fully aware of this fact or what it entails when considering possible simulation of this statics experiment: namely, that more constraints could eventually be fed into a computer model, allowing a simulation to get very close to experimental reality.
Admittedly, extrapolating from GT's comment, one may suppose that had a simulation been used, some of the statics experiment's objectives might not have been attained by certain students– the hindrance would have been students' unfavorable attitudes toward simulation or a basic ontological limitation: students would have been comparing a more simplified model of reality (theoretical equations) to a less simplified model of reality (a sophisticated computer model with additional complexities), but not to experimental reality itself.

As shall be indicated below, this turned out to be a source of dissonance for GT.

The main metaphor / Impossibility of "snapping" instruments onto graphical objects being measured

GT's poor grasp of the main metaphor and special expectations as to how tools should behave are essential for an understanding of his judgments. I examine his reactions to the VPLab's relevant features, in two steps:

1 - Before he was given a demonstration of how to work with the VPLab
2 - After he was given a demonstration of how to work with the VPLab

Before seeing a demonstration of how to work with the VPLab

After having recorded a sequence of images in the Manipulation workspace, GT predicted that he would be able to analyze and obtain measurements from the recordings by going to the Analysis workspace. He felt that this separation of tasks, between the Manipulation and Analysis workspaces, was satisfactory given the constraint of having to work on a computer:

> *This is good. It's a lot like real results. I think it's a good way [to do things] on a computer because in reality you don't need to record since you're there, you see, you handle [apparatus], and you collect your results at the same time.* [citation 72]

While he worked in the Analysis workspace, however, GT said he "did not know how the ruler worked" [citation 73]. He kept trying to find a way of selecting an object in the virtual monitor's recorded image, as if the system could recognize and isolate objects in the image, in order to measure them with the ruler (but the ruler was designed to be used by simply taking a visual reading with the help of graduations [32]). This way of isolating and working on graphical objects is widely used within the kinds of design and CAD software packages with which GT was familiar. He thus had a very hard time understanding why it was impossible to connect the tape measure to the object being measured (i.e., to 'snap' the tape measure's ring onto a point of the recorded image).

A bit later, he figured out that the tape measure's digital display indicated '0mm' only when there was a specific alignment of the tape measure's ring with a red reference mark on the tape measure's casing. This must have cued him to the fact that he could "visually" assess lengths by using the tape measure, but tellingly he qualified this – the intended method for measuring lengths with the tape measure – "an approximation".

At that point, he might have become aware of the need for scale conversions when measuring lengths of objects in the recorded images; this, along with the impossibility of "touching objects" in the recording, probably caused him to have a better grasp of the main metaphor (i.e., that the virtual camcorder, in the Analysis Workspace, is connected to a virtual monitor which only represents a display device). He thus perceived that he could "visually compare" an image's size to the ruler's

[32] The difference in scale between the image of the 20cm scale marker and the ruler's graduations seemed to contribute to GT's confusion. At one point, he thought that the graduations had only been drawn on the tool to identify it as a ruler.

graduations. However, he immediately stipulated that this way of visually assessing lengths *lacked precision*.

Still, he looked for a more precise way of assessing lengths. He persisted in saying that he could not *measure* objects knowing only what he then knew. When pressed to measure the recorded image of the scale marker with the ruler, GT answered that it was not necessary since '20cm' was already written on the scale marker.[33]

GT's difficulties are understandable given that the act of measuring had always implied great precision for him – precision and methods available with software tools he had frequently used, and precision which had been required of him in the course of his past employment as a parts inspector in the field of aeronautics. GT was not poised to fully understand the metaphor (or to understand how measurements could be accomplished) since, to his mind, it did not seem conducive to obtaining that level of precision.[34]

After seeing a demonstration of how to work with the VPLab

At the beginning of the debriefing discussion, the interviewer felt it was appropriate to demonstrate how one could work with the VPLab.[35] Following this demonstration, GT made further comments about the Analysis workspace monitor. He explained that it was extremely unnatural for him to measure things directly on a screen, because in a professional context this was seen as lacking precision; he also explained that his point of view was now changing because he had more consideration for the intended use of the VPLab:

> *It's like when you look at a design drawing, working for a firm. They tell you not to measure on the drawing even if it is scaled – no ! – really, because this lacks precision. But here we're talking about a physical experiment.*[36] *That's why my point of view is changing a bit because I've been thinking too much in terms of components production...* [citation 74]

GT also stated that measuring distances on a video recording would be more complicated in an actual lab. He said that if he were to really film this experiment in a lab, he would fix a grid onto the table's surface in order to locate the disk precisely during playback. Although he did not say so explicitly, the virtual monitor's Trace function seemed to be the key element which for him, differentiated VPLab analysis functionalities from actual video analysis:

---

[33] GT had not yet realized that the letters "cm" were written on the ruler.

[34] This subject expected more 'magical features' (Smith, 1987) than were available in the interface. GT was thus also unable to predict how one would measure the velocity of the disk because he could not figure out how to assess time intervals between traces. He never realized that he could have used the virtual monitor's time display, and he looked instead for more 'instantaneous' ways of obtaining time intervals. He was also unable to assess uncertainty of measurement. The ensuing confusion and frustration may have caused GT to express negative judgments concerning the VPLab. The session was stopped short.

[35] The subject said that this demonstration had "opened his eyes". Discourse and assistance should eventually be seen as cues for verisimilitude when real users actually interact with the VPLab in a pedagogical context.

[36] "Physical experiment" is translated from "expérience physique" in French. There is a possibility that the subject might have actually meant "a physics experiment".

> *[...] because in reality, I would have trouble measuring distances between instant 1 and instant 2 [i.e., at different time indexes]. I would almost have to stop the camera – pause the camera – and determine a path on the television screen, and then roughly assess its length.* [citation 75]

As for the monitor's Zoom function, it was seen as allowing for precision of measurement, which in turn made the VPLab more credible. The remaining uncertainty seemed more acceptable to GT, *especially given the context of trying to simulate experimental work in physics*.

Impossibility of manipulating instruments with one's hands / Lack of precision when measuring (because of visual alignment)

Even if the Zoom function improved upon the accuracy of measurements, GT still had a more basic grievance with the interface. At the beginning of the session, he had said that the instruments were very realistic and that they looked like they could be grabbed with one's hands. During the debriefing, GT claimed that this property had, in part, caused his problems with the main metaphor. Dissonance had occurred due to tension between how GT regarded the instruments' visual presentation and the manner in which they are manipulated:

> ***GT**: We [engineers] are used to plugging numbers into formulas– numbers with lots of decimals. It's also a very serious field, very conservative [...] This is software which is attractive, it's gadgety [...] but it's not the type of software we... we use things that are only technical and that's why I was disconcerted.*
>
> ***Interviewer**: OK. You weren't in your own world.*
>
> ***GT**: That's it! Exactly. A drawing like this [protractor] interferes with my real world [...] In my real world, I could take these instruments, play around with them on a table and use the ruler, in my own way, to perform measurements. However, in this case, I can't touch [the instruments] and I have to rely on a screen with a zoom, with a [different] scale, and with pixels. It's really approximate, and I can't be sure that [the instruments] are aligned or... visually, it's hard to tell.* [citation 18]

With this excerpt, I also conclude that visual alignment of instruments on objects being measured is problematic in the VPLab (and much less so in an actual lab).

Subject HU

When asked what he thought of the VPLab compared to the lab work he had done in the past, HU answered "Everything is there," from which I infer that, in his opinion, none of the important elements of an actual lab were missing. HU's case is an example of a student which had exhibited unfavorable *a priori* attitudes toward simulation but still seemed to find the VPLab credible, on the whole.

Evaluation of the VPLab's potential to allow performing experiments / The main metaphor

During the debriefing interview, HU evaluated the VPLab's potential to allow performing physics experiments, on a 5-point scale. The rating he gave was just below 4. He put forward two arguments for not giving a higher rating. The first had to do with his impression of having a better grasp of things in an actual lab.[37] His second argument was that measuring was faster (or less fastidious) in an actual lab because you could measure distances directly– he was comparing the process of measuring in the VPLab to the process of measuring distances between marks made by electrical discharges on carbon paper (when using a tracing system in an actual lab):

> ***HU:*** *I feel more at ease when taking measurements [in an actual lab]: you can take the sheet [of carbon paper] and work directly on it without having to factor in a [scale] ratio.*
>
> ***Interviewer:*** *It's having to factor in the scale ratio that...*
>
> ***HU:*** *Well, not necessarily. It's just faster [in an actual lab]... there's no zoom [...] With [the VPLab], the concept is good except that you have to go through two or three steps in order to obtain a measurement.*
>
> ***Interviewer:*** *The measurement manipulations themselves are more fastidious?*
>
> ***HU:*** *Yes, a bit. Here, I measured three distances and it took me some time to do so, whereas, had I been in a lab, it could have taken me only one minute... On the other hand, it couldn't have been any faster [on a computer]. I don't see a way of making it faster [on a computer].* [citation 77]

There are too many steps in the process of measuring lengths and the *Zoom* function is seen as something that is unnecessary in an actual lab.[38] In my view, this is HU's chief negative judgment in regards to verisimilitude. Notice, though, that it seems acceptable enough to HU, given the constraint of having to work on a computer.

In an issue related to the virtual camcorder, HU did not consider that the available view of the air-table was very plausible. This is because he felt that the camcorder's perspective (that of rotating with the table) would be impossible to replicate in an actual student lab, if one were to rotate the table without using a merry-go-round.

Understanding the main metaphor

During the session, HU interpreted the meaning of the main metaphor on his own, while exploring the Analysis workspace. One of the cues for this was measuring the 'filmed' image of the scale marker with the ruler and obtaining a measurement inferior to the "20 cm" which was written on it. This was not sufficient, however, because he still believed it possible to obtain a measurement equal to 20 cm by zooming in on the recorded image. At this point, he thought that he was viewing the recording *through the camcorder* instead of viewing it on a monitor. It was only after he had zoomed-in on the recorded image and still obtained a measurement inferior to 20 cm that he realized it was necessary to perform scale conversions of measurements made in the Analysis workspace. Thereafter, it is very likely that HU still thought that he was viewing and replaying the scene through the camcorder (and that he was using the zoom function of a camcorder, as opposed

---

[37] This may have had something to do with feeling less *presence* in the VPLab. "Driving a real car as opposed to driving a car simulator does not provide the same feeling," said HU shortly after claiming that there was less precision when launching the disk in the VPLab than in an actual lab [citation 76].

[38] I take this to be a judgment of the main metaphor (virtual monitor).

to that of a monitor) but at least, he had realized that he could not obtain full-scale images of the objects.

Moreover, HU's understanding of the metaphor was also promoted by his recollection of a documentary in which a camera had been used to analyze the motion of an object. When asked what features of the Analysis workspace reminded him of that situation, HU named two: the time display on the virtual camcorder (it is very similar, incidentally, to the monitor's time display) and the grid-like pattern formed by the tiles on the virtual merry-go-round's floor,[39] which reminded him of grids used to locate objects more accurately in two-dimensional space. The use of this last cue is quite surprising, as the intended purpose of drawing tiles on the merry-go-round's floor was not at all to convey this impression.[40]

Zoom function and Trace function

Measuring distances between traces was something HU had previously done in a lab. However, when HU was asked, during the debriefing interview, to identify any actions he had performed within the VPLab which would be impossible to reproduce in an actual lab, he named three: zooming-in on objects, changing the interval between Traces, and changing the number of Traces. He added that this flexibility with the VPLab Trace function was a good thing (see below).

Freedom in choosing methods / Control over actions (assessment of uncertainty)

In the course of the preliminary interview, HU commented on measurement procedures:

> *I always think that it's experimental so [the procedure] can't be computer-driven; we have to do things ourselves.* [citation 78]

For this subject, the most important element which contributed to the VPLab's verisimilitude was probably freedom to choose work methods. It appears that this is linked with the degree of control that one has over actions: an example is the possibility of varying the number of *Traces* and the interval between them. Though the act itself of varying these parameters was seen as impossible (see above), the freedom to do so contributed to the overall verisimilitude of working with the VPLab since it empowered the subject to choose his own method:

> *I do everything, basically. See here: I determine the number of dots [i.e., traces] and the interval [between them] myself, as I want... For instance, I can take five different measurements, with a tolerance of 1 or 2 millimeters, and calculate their average to obtain a more precise distance: [the computer] does not do it for me. It is I who chooses the measurement methods and the calculating methods [...] I choose my own way of proceeding.* [citation 24]

Another example of this is the freedom to do (or forgo doing) uncertainty assessment:

> ***Interviewer:*** *What do you think about assessing uncertainty with software, in an environment like this one? Do you think it's normal?*

---

[39] There were no tiles on the floor of the actual merry-go-round depicted in the video clip.

[40] Instead, the designers chose to draw tiles because it was the simplest way to add texture to the merry-go-round's floor.

HU: Yes, it's normal. What I like about this is that it's the same as in a lab: it's nothing less, nothing more. In a lab, you can forgo assessing uncertainty, if you so desire – you're free – you can forget about it if you want. There is nothing to tell you: "Here, you have a column [in your notebook] to note uncertainty." [Instead:] "I give you a blank notebook and you do what you want with the columns. You write what you want at the top." [citation 79]

Though the interviewer required the subject to assess uncertainty, the absence of constraints (within the environment itself) which could force the user to comply, seems to have promoted verisimilitude.

Uncertainty of measurement / Adequate precision of instruments

It is obvious that the affordance of uncertainty of measurement was important for this subject, in regards to verisimilitude– note the strong ties with the notion of *control over actions* discussed above:

[...] it's really experimental in the sense that it is I [and not the computer] who measures the distance between dots. If ten people measured [a distance], there could be ten different results. [citation 17]

Here, I must insist that HU made this statement *before the interviewer required him to assess uncertainty* so that this requirement had nothing to do with the present judgment. After he was required to do so, HU was asked if he thought it strange, given that he was working with software. HU said it was good that students assess uncertainty themselves, rather than having the computer do it automatically for them, since this is an important skill to develop when performing experiments. This indicates that requiring HU to assess uncertainty may have been a cue favoring verisimilitude, as well.

Although the affordance of uncertainty of measurement was seen as favorable by HU, the virtual instruments' verisimilitude was diminished when the subject perceived they lacked precision compared to their real-world counterparts. The following excerpt is an excellent illustration. During the debriefing interview, subject HU rated the probability of finding the VPLab's protractor in a physics lab at 2 on a scale of 1 to 5 (with '1' meaning a very low probability and '5' meaning a very high probability). He gave the following explanation for this rating:

The protractors that I've used before had a calibration that was [detailed] to the one-degree mark. We would really see the one-degree mark... so the level of precision [of those protractors] is a bit higher [than that of the VPLab's protractor]. So this one may not be precise enough. I would say "2" - a low probability [...] because it's not precise enough for a physics lab. [citation 17]

Verisimilitude of the disk's motion on the air-table / Points of view

The fact that the disk slowed down after having been launched (while the pump was on) gave this subject an indication that there was residual friction at work against the disk's motion. This yielded greater verisimilitude– HU made the following comment spontaneously during an exploration-based task:

> *It's good because we see that the disk is somewhat slowing down. Because having absolutely no friction is impossible.* [citation 80]

Overall, while in the Manipulation workspace, HU perceived that the disk's trajectory was "normal". However, he said he had a hard time assessing the disk's motion and was basing his judgment on what he supposed its behavior should be. He claimed the difficulty stemmed from the fact that the simulation did not also offer a view of the air-table from outside the merry-go-round (as did the video clip, though very briefly). Consequently, I can extrapolate from this that the view available was not effective enough, in its own right.

Later in the Analysis workspace, HU examined the disk's motion by measuring distances between positions along its trajectory (said positions corresponding to different time indexes). During this exercise, there was one very interesting event: HU obtained a measurement which ran counter to his expectations. He then explained this seemingly anomalous result by saying it was normal to encounter it since he was involved in "practical" work.[41]

Complexity of the simulation (random fluctuations and 'anomalies')

During the debriefing interview, it was suggested to HU that 'anomalies' and random fluctuations might have been included in the simulation. Examples given were the table's surface being sticky, small random fluctuations of the merry-go-round's speed, and vibration of the merry-go-round's motor causing, in turn, the whole structure including the table, to vibrate (only the last two elements were really included in the simulation).

Concerning the sticky surface, HU claimed that it was unwarranted since the goal of the experiment was really to study and understand disk motion (read 'normal' motion), and not to be confronted to tricky situations. Furthermore, he felt that such a circumstance could exist in an actual lab but could be easily avoided if students sufficiently prepared for the experiment. Similarly, in the case of the merry-go-round's speed fluctuations, the subject said that the fluctuations should be made small enough to be neglected (which was actually the case) because dealing with them "isn't the goal of the experiment." Finally, in regards to vibrations of the merry-go-round's structure, HU proposed that it should be simulated only if the designers of the actual merry-go-round had intended these vibrations to exist. He did not believe this to be the case however:

> *If it is intentional, it must be replicated because there's a reason [for it]... but my impression is that if they were to construct another merry-go-round and wanted to do away with the vibrations, they would manage it. However, I think it's good to produce a simulation which represents, as much as possible, what it's like to really do the experiment. [...] If you look at real flight simulators, they include wind turbulence; [for] a racecar simulator, it's the condition of tires and adherence to the road... it's good to account for as many things as possible.* [citation 81]

---

[41] During the debriefing interview HU stated that it was he, and not the simulation, who would be at fault if he were to obtain results radically straying from theoretical predictions after having conducted the whole virtual experiment (he also said that he was usually at fault when this happened in an actual lab). He claimed he would not expect the computer to make mistakes.

For this subject, credibility is rather linked to the replication of as many conditions *as are 'inescapable' or 'useful'* in reality. This is an important nuance.

In a related matter, HU was asked to describe rare events witnessed in physics labs which could not take place within the VPLab. The example he gave (which pertains to another field of physics) was committing an error when connecting electrical circuits, thereby burning resistances. "In a simulator," he supposed, "the same thing could happen maybe, but well… you do a RESET and you start over" [citation 82]. Hence, this nicely addresses the topic of possible consequences when experimenters make mistakes (while handling apparatus, in HU's example) within a simulated environment– provided, of course, that it is even possible to make mistakes.

Subject IV

Measuring instruments

When asked what he thought of working with the VPLab compared to his prior experience with lab work, IV said that working with the VPLab "reflected" and "was faithful to" experimentation done in a lab. The measuring instruments were an extremely important part of IV's assessment of the VPLab: "*I can measure and do the same steps* [as I would in an experimentation]," he said [citation 83].

IV's judgments toward the virtual instruments were very complex and often seemed contradictory. A basic element of his attitude toward virtual instruments was his feeling that these tools allowed him to obtain the same data as in an actual lab:

> *[...] all the elements are present to make it as if I was in a lab. All the instruments are provided so that I can obtain the same data as I would have wanted to obtain in a lab– that's what's important, I think.* [citation 14]

On the other hand, IV claimed that he could never use a real tape measure in an actual lab with as much precision as that which he had enjoyed when using the VPLab's tape measure; thus, he said he would use a slide caliper, instead. However, he judged that the virtual tape measure was ideal in the context of the virtual lab and imagined that handling a 'virtual slide caliper' through mouse-driven actions would have been tedious and awkward.

Subject IV enjoyed using the virtual tape measure and said that its "way of functioning" was the same as for "a real tape measure". In contrast, he was dissatisfied with the way some of the virtual instruments were manipulated compared to the actual objects that they represented. This had to do with certain limitations: for instance, he complained that the virtual ruler and protractor did not allow for arbitrary rotations (but were restricted to 90-degree turns) – although he acknowledged that it was still possible to "do the same job" despite this limitation. At one point, he even went so far as to say there was an advantage to knowing that the protractor was perfectly horizontal or vertical; still, he would have deemed it more 'realistic' and satisfactory, had he been able to smoothly spin these instruments just by 'dragging' a corner in a circular motion. Consequently, verisimilitude of the ruler and protractor was probably diminished because mouse-driven actions were not well mapped onto manual operations (those possibly performed with one's hands when manipulating an actual ruler or protractor).

Coming back to the tape measure, recall that IV claimed he was allowed much more precision with the VPLab's tape measure than if he had used the object it was meant to represent in an actual lab: this is because IV felt that the position of the instrument's components could be fine-tuned with greater accuracy through mouse-driven actions in a 2D space, than with his own hands in an actual lab. Verisimilitude of the measuring process was lessened by this. (I suppose that this perception of excessive accuracy may have also been linked to the added precision provided by zoom-ins.) Still, IV stipulated that uncertainty, due to required adjustments of the cursor's position, was nonetheless present and that this made measuring more "realistic" than if users had been allowed to instantaneously "snap" instruments onto objects.[42]

Another tool – the (virtual) rod which was designed to be assembled to the virtual protractor in order to take readings – was judged unusable in an actual lab. This graphical object appeared to represent something like a string, rather than a rigid rod.

To sum up, IV's judgments toward the virtual instruments were multi-dimensional and this is well illustrated by those judgments which concern the virtual tape measure: at a basic level, the virtual tape measure provided the same type of data that IV expected to obtain in an actual lab; at another level, the virtual tape measure's basic way of functioning was seen as similar to its real-world counterpart (probably because mappings of mouse-driven actions to hand-driven actions were judged to be satisfactory: manipulating the same types of components seemed to produce the same types of effects); at yet another level, IV said he would never use the virtual tape measure's real-world counterpart in an actual lab because it could never be manipulated with as much precision as what was provided through mouse-driven actions in a 2D space; finally, some imprecision remained despite this 'excess in precision' and this preserved verisimilitude, to some extent.

The video clip / No automatic initiation of disk motion

The video clip was used by this subject as a basis for verisimilitude judgments concerning the simulated disk's movement:

> *I would expect that the faster [the merry-go-round] goes, the more [the disk] should move about, but that's not what they said in the video clip so it's normal that it doesn't do this.* [citation 84]

---

[42] Initially, he had expected to "snap" instruments onto objects because of his prior use of CAD software packages which had included this feature.

The video clip – combined with the fact that disk motion was not automatically initiated – was also useful when the subject apprehended his own role in the experiment:

> *IV:[...] when they introduced the simulation [in the video-clip], there was a man there [beside the air-table]. But now [in the simulation], nobody's there. So, I imagine that if I'm the man, I have to be there and bring the disk [...]*
>
> ***Interviewer:*** *Does it give you the impression that you are the man [in the video clip], or is it...*
>
> *IV: Well, I'm looking to do the experimentation, but as I saw in the video clip, it was the man who initiated the [disk's] motion. Because, if I start the pump and do nothing else, nothing happens. However, if I start the pump and I give [the disk] a little push, it is going to start moving.* [citation 85]

Verisimilitude of the disk's motion on the air-table / Friction on the table

On the one hand, IV said that the disk's motion, in general, "did not seem strange to him, intuitively" (adding that he was not familiar with this type of motion and could not evaluate its dynamics, per se). Additionally, IV thought that the disk reacted normally to changes in the merry-go-round's rotational speed: he observed that the motion of the disk changed when he augmented the merry-go-round's speed, and that it changed again when he stopped the merry-go-round completely– at this point, the disk took a while to come to a full stop, and this could be explained, IV believed, by "the principle of inertia". The subject thus felt confident that he could really gain knowledge about the motion of a real disk by performing the virtual experiment.

On the other hand, IV felt it was strange, when the merry-go-round's speed was high, that the disk would sometimes become stuck in one corner of the air-table after having moved around a lot. "But maybe it is normal," he added, showing that he was not totally convinced either way. In fact, this behavior *was* realistic and likely to occur because the table was slightly off-center in the merry-go-round when IV made the observation; this, however, was overlooked by IV. (I should point out that the 'strange' behavior in question was not shown in the video clip.)

While the merry-go-round was not turning, IV observed that the disk decelerated after having been launched and he seemed to be uncertain as to whether correct behavior was being represented by the simulation– note that this uncertainty may have stemmed from the rate of deceleration of the disk:

> *IV: Uh... there's no friction– of course, there is always... [The disk] should always keep moving slightly. It should not stop that much or [it should only stop] after a very, very long time.*
>
> ***Interviewer:*** *Would you say that there is uncertainty as to the presence of friction? Would you say that presently, you are not sure whether friction exists or not [on the table]?*
>
> *IV: Yes... Well no, but I know that in real life, it is impossible to have [a surface] with absolutely no friction. It is logical that this [simulation] should account for that. But the uncertainty comes from me– by which I mean: what happens if there's friction and what happens if there isn't any? It's me and not the software.* [citation 86]

Let me note that the disk's deceleration finally became a cue pointing to non-zero friction, and thus favored verisimilitude:

Interviewer: *If there weren't any friction...*

IV: *If there weren't any, [the disk] would always keep moving slightly and it would continue the motion it was given.*

Interviewer: *And, if there were friction [on the table]?*

IV: *Eventually, it would stop.*

Interviewer: *What do you observe at this moment?*

IV: *I observe that [the simulation] is representing a situation where [the disk] really tends to stop eventually, so I think that there is a tiny bit of friction somewhere. To conclude, I think that reality is well represented by this.* [citation 86]

The VPLab's main metaphor

IV did not like the fact that the virtual camcorder had an upper limit in terms of recording duration. Although he acknowledged that this was "logical if one wanted to make a true simulation that represented reality," [citation 87] he was upset that this took away a potential advantage of a virtual lab over an actual one. Moreover, he felt that the allotted recording time (a few minutes) was much too short in comparison to actual camcorders– this, in fact, might have been the element that shocked IV. [43]

While he was exploring the Analysis workspace, IV was asked to describe what he thought the workspace's main display represented. Observe that his interpretation of the metaphor was very close to what the VPLab's designers had intended to convey:

I have the impression of looking at... by analogy, it's as if I were looking at an oscilloscope and I could take measurements directly on the screen. [...] It gives me the impression that I could be in front of a screen which, I hope, would be very flat [...] [citation 88]

Oscilloscopes – the actual instruments which, in IV's view, epitomize the VPLab's metaphor – are common in labs; hence, the metaphor seemed credible to this subject. Cues contributing to this interpretation included the following elements: the grid-like pattern formed by the tiles on the virtual merry-go-round's floor (which, for IV, was indicative of a scale correspondence); the monitor's time display, which was very similar to the virtual camcorder's time display; the colors (blues, violets, and greens) used for the image displayed on the virtual monitor (instead of black and white); the blue screen which preceded the first image of each 'filmed' sequence (this made IV realize that the camcorder's small monitor and the main monitor were displaying the very same images).

Related to IV's interpretation of the metaphor, is his comparison of the yellow Traces displayed on the monitor, to the display of special effects 'traces' that follow a hockey puck during hockey game broadcasts (on an American television network). [44]

---

[43] This did not seem to be a problem for some of the other subjects (e.g., ER, FS and HU).

[44] Subject FS also made this comparison and, much like IV, his interpretation of the metaphor was extremely close to what designers had intended to convey.

Complexity and ontological status of the simulation

During the debriefing interview, IV indicated that the VPLab would be appropriate if the purpose of an experiment was simply to observe a phenomenon as described by the laws of physics but inappropriate if the goal of an experiment was to confront 'real' behavior to behavior 'predicted by theory'. "*It isn't reality which is inside [the computer]*, IV said, *because that with which you feed the computer is the stuff of theory*" [45] [citation 89].

Importantly, this attitude toward simulation subsisted even after IV was told that anomalies might have been included in the VPLab simulation: [46] although the mention of these anomalies reminded IV of trainees being confronted to problem-situations in flight simulators, it was not enough to significantly effect IV's attitude which consisted in dissociating simulation from the complexities of reality and associating it with 'pure' theory.

I.3 SUBJECTS JW, KX, LY, MZ: PHYSICS STUDENTS

Subject JW

Evaluation of the VPLab's potential to allow performing educational experiments

During the debriefing interview, subject JW rated the VPLab's potential to allow performing educational physics experiments. He rated it between 2 and 3 on a 5-point scale ('1' signifying a very low potential, and '5' a very high potential).

Impossibility of manipulating objects with one's hands (tangibility) / Ontological status of the VPLab, and visual fidelity

To explain the relatively low rating mentioned above, JW said that working with a mouse instead of manipulating apparatus and instruments with his own hands was a great disadvantage.[47] This issue seemed to be merged with the question of the VPLab's ontological status (i.e., its status as a simulated environment) – I observed this when I asked JW to compare working with the VPLab, to working in an actual lab:

> *JW: [...] I think that there are some things, even if you see them here [in the VPLab], you'll have the impression that they could be fully tampered with. For instance, when we watched the disk move in the video clip, you could see that it was real, but [...] it seems less real in the computer,*

---

[45] This was exactly the opinion expressed by subject GT. When making this argument, both GT and IV referred to the same *statics* experiment previously performed at their university.

[46] IV said that he would not have expected such anomalies to exist because a computer was supposed to be consistent and was not usually supposed to spontaneously generate errors. More importantly, in IV's opinion, the *usefulness* and *pertinence* of such anomalies were somewhat questionable in the context of the air-table experiment (when contrasted to the simulation of problem-situations in the context of skill training with a simulator).

[47] As is indicated in his profile, JW believed that manipulating apparatus with his own hands was an essential part of laboratory work.

when it's not a video clip. When you do it in a lab, you see it with your own eyes. Here [with the VPLab], you see it [...] but it's a machine that has done it all.

Interviewer: *So it's the medium itself?*

JW: *Yes, it's the fact that I don't do things with my own hands – that I don't really look upon it...*
[citation 5]

Since there was a possibility that things seeming "*less real in the computer*" might be linked to visual fidelity, JW was asked if he thought that working within an immersive virtual environment would improve credibility:

[...] if it looked real, I think that people would believe it more– I would believe it more. But it's still a computer [...] For example, if I were in a virtual reality where time dilation [a concept in the theory of relativity] would be demonstrated, maybe I would be more inclined to believe it in there [as opposed to with the VPLab], simply because it would have the sensation of being more real. At the same time, though, I could tell myself: "Yes, but this is a computer, so..."
[citation 90]

Based on this excerpt I believe that, in the case of subject JW, improving the VPLab's visual fidelity might slightly enhance verisimilitude but a basic lack of credibility would remain due to its ontological status.

The VPLab's main metaphor

JW felt that the Analysis workspace's background represented something "like a television". Cues contributing to his interpretation of the metaphor included: the impossibility of manipulating the graphical objects which had previously been movable in the Manipulation workspace's simulation; the conventional representation of the virtual camcorder and the great similarities between the virtual camcorder's screen and the virtual monitor; the virtual monitor's frame; and last but certainly not least, the invariance of the ruler's dimensions and scale, before and after having zoomed-in on the displayed image.

During the debriefing interview, JW stated that replicating a device similar to the virtual monitor in an actual lab would be possible, but only if some sort of computer was involved. However, he felt that replicating the virtual monitor's Zoom and Trace functions would be a difficult endeavor.

Verisimilitude of the disk's motion on the air-table (deceleration as a sign of residual friction)

The fact that the disk slowed down after having been launched gave this subject an indication that there was a loss of energy when the disk collided with the table's sides and that residual friction was working against the disk's motion. This yielded greater verisimilitude:

[...] it truly is like reality, for if the air-cushion was perfect – really ideal – then [the disk] would keep on going forever. This, however, gives you a taste of how things really happen.
[citation 91]

Optimal experimental conditions are expected because of the VPLab's nature

During the debriefing interview, JW said he'd expect that outcomes of an experiment with the VPLab would conform to theory, that behavior of simulated phenomena would be consistent from trial to trial and that experimental conditions would be optimal. This is because JW associated computers, in general, with 'perfection' and 'consistent' behavior. When told about the possible inclusion of anomalies and random fluctuations in simulated phenomena, JW said this would be good as it would show students that "sometimes things are not so pretty [in reality]" [citation 92].

Subject KX

Evaluation of the VPLab's potential to allow performing educational experiments

During the debriefing interview, KX evaluated the VPLab's potential for experimentation in a slightly different way, when considering different target users. He felt that the VPLab would be a very good substitute for students who did not have access to an actual lab, and hence gave it a rating of 5 (very high potential) on a 5-point scale. On the other hand, he had a feeling that students would understand and learn more if they could do the experiment "concretely" in an actual lab. He thought that students with access to an actual lab should use it rather than the VPLab, especially since *it seemed possible to replicate most of its experiments in an actual lab*. In this context, KX's rating was just slightly lower then before (4 on the 5-point scale).

Less complexity compared to reality (impossibility of making errors, no randomness, and 'anomalies') / Experimental conditions that tend toward perfection

In order to justify this slightly lower rating (see just above), KX claimed that students would learn more in an actual lab because committing errors was less possible in the VPLab and nothing was left to chance:

> ***KX**: You can have errors in a lab, but here [in the VPLab] you have nothing– it's simulated: there is no source of randomness which comes into play. In a lab, you learn to be precise, but here all you have to do is... that is, unless errors of randomness appear [in the simulation].*
>
> ***Interviewer**: Is it possible, or is it plausible that these errors exist [in the VPLab]?*
>
> ***KX**: Well, I don't know if they've been programmed.*
>
> ***Interviewer**: Is that something you would normally expect, or on contrary not at all?*
>
> ***KX**: No, because later you have to find out why the randomness [i.e., the error] has occurred and that would be a bit complicated, as opposed to a lab where you can always say: "Yeah, I know, I launched [the disk] incorrectly... etc."* [...]
>
> *It's more complex [in an actual lab]. Here [in the VPLab], you have a limited number of variables which can come into play [...] you can't simulate reality perfectly. So, I think that it would be much better in a lab.* [citation 93]

This subject is evidently judging the VPLab in terms of complexity compared to reality. I first conclude from this excerpt that KX would not normally expect the simulation's outcome to be probabilistic or to be affected by simulated 'anomalies'. Furthermore, if KX were to then realize that this was actually the case, it would become a major cue for verisimilitude. There are strong reasons to believe this because of what KX had to say when the interviewer did announce that 'anomalies' and random fluctuations could have been included in the simulation:

> *[...] if it is previously indicated that this is truly a model of a real situation, including those types of errors, then [such a simulation] would be very good in fact.* [citation 94]

So, we see that KX would want to be warned of the inclusion of random fluctuations and anomalies. Perhaps due to some of his preconceived ideas toward simulation, he rather expected the VPLab to be an environment where "*conditions are perfectly controlled*" [citation 95].

Verisimilitude of the disk's motion on the air-table (deceleration as a sign of residual friction)

KX expected the disk to slowly decelerate after having been launched because of residual friction on the table (note that this somewhat stands in contrast to the above comments, regarding expectations of ideal conditions). Consequently, the fact that the disk actually did slow down after having been launched yielded greater verisimilitude.

Types of quantities measured and types of instruments available

The types of entities that the subject was asked to measure or describe (time, distances, trajectories) promoted verisimilitude. From a general perspective, the types of instruments provided in the VPLab promoted verisimilitude for KZ, as he felt that they allowed him to measure in ways similar to how measurements were performed an actual lab.

When I examined judgments toward specific instruments, however, it became apparent that some tools like the ruler promoted verisimilitude, whereas others – for instance, the tape measure – did not. Although he later admitted to having previously used a tape measure in a lab, KX initially said that one would use a "laser", rather than a tape measure, to assess long distances.

Manipulation of the instruments (tape measure)

During the session, KX stated that it felt bizarre to handle the tape measure using a mouse, in a way that was *analogous to how he would control an actual tape measure with his hands* (the fact that he would need both hands to control a real tape measure seemed to contribute to this feeling of strangeness). He added that it did not feel strange to control the simulated ruler with the mouse.[48] He also felt that the tape measure behaved differently from a real one, as it was possible to make its ring (at the end of the tape) rotate fluidly around the casing.

---

[48] For subject KX, the fact that that the virtual ruler and protractor did not allow for arbitrary rotations (but were restricted to 90-degree turns) had a relatively small negative impact on verisimilitude, but worth mentioning nonetheless.

Lack of precision when launching the disk on the air-table

Precision seemed to be an important criterion in KX's judgments. During the session, he was dissatisfied when he tried to launch the disk as fast he could. Then, very early in the debriefing interview, KX spontaneously complained about lack of precision when launching the disk– he would have wanted to determine the disk's velocity and direction with more accuracy. For this lack of precision, he blamed use of the mouse.

He said his request for greater precision was *not* based on the premise that there would in fact be more precision when launching a real disk on an actual air-table (though he did claim this). Instead, he justified his request by saying that the computer's potential was not being exploited enough:

> *That's just it: with a computer, theoretically you can enjoy much more precision than in a real experiment so it seems to me that [the VPLab] should take advantage of this a little.*
> [citation 96]

Precision of measurements / Uncertainty assessment

Precision was also a factor in regards to instruments used to perform measurements. In one case, KX felt that the virtual protractor lacked precision and he wished that more graduations had been drawn on it, or that some other way had been found to make it as precise as an actual protractor.

In another case, KX was the only participant who thought of evaluating uncertainty on length measurements without the interviewer having to suggest that he should do so.[49] Later, he stated that assessing uncertainty was normal insofar as uncertainty was a consequence of the width of the tape measure's ring (which was used as the reference point for the beginning of the measurement):

> ***Interviewer:*** *Does it seem either normal or strange that we should ask you to evaluate uncertainty in this case? More or less normal?*
>
> ***KX:*** *Uh... It's quite normal since the [tape measure's] ring makes it imprecise enough. Absent that, I would find it a bit strange given that with a computer you can [usually] obtain as much precision as you desire... unless the context is such that one of the objectives of the lab report is to perform statistical analysis.*
> [citation 97]

I should point out that KX's verisimilitude judgment here also refers to a pedagogical objective (performing statistical analysis of errors) which he had identified as important even before interacting with the VPLab.

---

[49] In fact, his plan to assess uncertainty was prompted by the interviewer's request to measure distances as if he needed to produce a graph further on.

The VPLab's main metaphor

For KX, at first, the displayed image in the Analysis workspace did not seem to be like a recorded video sequence, as such. Then, when he was asked to interpret the Analysis workspace's main display, he stated that it was a video camera, and he later concluded that it was simply a "*board that presents results in an animated way*" [citation 98]. Both interpretations were different from what the designers had intended to convey and less 'literal' than interpretations made by some of the other subjects.

In the Analysis workspace, KX used the ruler and tape to measure the 'filmed' image of a marker on which was written "20 cm". The fact that the measurement he obtained on the monitor was smaller than 20 cm established a scale correspondence to the Manipulation workspace simulation; as can be inferred from the following citation, the necessity of having to do scale conversions of measurements may have conferred a reality status to the Manipulation workspace different from that of the Analysis workspace:

> *I converted it using the scale – I converted it to real life centimeters.* [citation 99]

On another topic, KX deemed that it would be almost impossible to find an equivalent of the Trace function in an actual lab because he perceived it as being too versatile. This may have had a small negative effect on verisimilitude.[50]

Subject LY

Students communicating to compare results / Replicable experimental manipulations

During the debriefing interview, subject LY was asked what he thought of working with the VPLab compared to prior lab work. To his mind, the two were about equivalent, except that when working with the VPLab, he could not enjoy the experience of performing the same lab experiment with other students and communicating with them. LY felt that having the opportunity of comparing with other students' experimental set-ups and results was important. He wished that a repository of other students' results could be made available to VPLab users. In order for such a feature to be useful, he thought, students would need to follow protocols detailing replicable experimental manipulations; he felt that the main manipulation he had performed during the session – launching the disk on the air cushion table by dragging it with the hand-shaped cursor and releasing it – had been rather arbitrary (as opposed to replicable).

---

[50] The width of traces, however, was perceived by KX as a source of uncertainty of measurement; this could have ultimately favored verisimilitude.

Evaluation of the VPLab's potential to allow performing educational experiments / Intuitiveness in handling of instruments

During the debriefing, LY rated the VPLab's potential to allow performing educational physics experiments:

> *I think it has good potential. Small improvements could be made – I could easily give it 3 or 4, say 3.5 [on a 5-point scale, with 1 signifying a very low potential and 5 signifying a very high potential].* [citation 100]

When asked why he hadn't given the VPLab a higher rating, LY answered that some instruments – like the virtual tape measure – should be as intuitive to use as their real counterparts:

> *Obvious things should be given. Things that you have to learn [in an actual lab] should be learned [in the virtual lab], but you shouldn't have to learn to measure with a tape measure.*[51] [citation 101]

Later however, LY stated that once he had learned how the tape measure was handled, the tool could do the job as it should be done and it could be used very much like an actual tape measure.

I must add that LY's basic faith in a simulated lab's potential to allow performing experiments was probably linked with his favorable *a priori* attitudes toward the use of simulation in educational contexts.[52] Tellingly, he claimed that training with a simulated lab was acceptable, given that the US Marines had used a special version of a desktop video game called DOOM for mission training.

Basic doubt as to deviation from a valid theoretical model / Theoretical (and mathematical) justification of the simulation's behavior

To further explain why he hadn't given the VPLab a higher rating, LY suggested that there was a basic risk to using this type of software in that a simulation might be based on an invalid theoretical model. He thus spontaneously brought up a fundamental credibility question; I should note however that he addressed it very idiosyncratically, in relation to his own tendency to scrutinize what teachers expose in class. LY asks a crucial question here: If students should always start by being skeptical of what teachers expose, then why should they blindly trust instructional simulations at face value?

> *LY: [...] you'll always have limitations: is this really representative of the theoretical model? What's behind this [simulation] to make [the disk] move like that? Did [the programmer] take a formula and simplify it to allow for nice motion? [...] That's what bothers me: you have this software but you can have it do anything you want. [...]*
>
> *Of course, you tell yourself that they are teaching a class so they won't hand you any old thing. That not withstanding though, they always tell you to act as if [what is being taught] isn't true until they prove it to you [...] they say that you should always ask yourself questions concerning what the teacher is saying: maybe he's saying nonsense. With [the VPLab], you can't really*

---

[51] LY had not been able to find the tape measure's reference points for the beginning and the end of the measurement.

[52] Let me note that LY claimed he could not give the VPLab a rating of 5 (very high potential) also because its users would not directly be in contact with the apparatus and instruments. This concerns the question of tangibility or presence.

question things because there's an [intrinsic] limit in using the program itself: if you start to question things at home like that, you lose the whole principle of using the software.

You don't know if the programmer has taken the time to include everything – to really consider all the theoretical aspects and do the correct calculations – or if he just shoved the whole thing, and said: "Here, this is what it'll do". [Maybe] a whole table has already been written up so that when such or such thing happens, [the disk] automatically goes the other way... Or does it really work with a formula, with all values truly changing according to reality? [...]

***Interviewer:** So it's really a question of trust in what the simulation can produce compared to...*

***LY:** Yes, a question of trust and [of knowing that] the principles are clear – that things aren't too hidden.*

***Interviewer:** So more disclosure is needed?*

***LY:** Yes.* [citation 1]

I believe that in LY's case, a very important cue favoring verisimilitude would be extensive mathematical and theoretical information accompanying the simulation. The interviewer tested this assumption by showing LY theoretical explanations (in the *Explanations* workspace) which contained animations of the disk's motion (including vectors). LY stated that this type of information would promote credibility of the simulation. I believe that LY's expectations in regards to mathematical and theoretical descriptions of the simulation's behavior were conditioned by his prior experience with simulations created with MAPLE software: it seems that these visual simulations had been accompanied by real-time exposition of the formulas and calculations needed to render them.

Graphical attributes / Distinction between the simulation's visual presentation and its underlying model

From what was said above, it is obvious that LY had the capacity of discerning the simulation's underlying model from its visual presentation.

During the session, the subject stated that he expected a relatively high level of complexity from the simulation's model. LY was then told that other subjects (cf. subject FS), upon seeing the graphical interface, had expected less complexity from the simulation's behavior because the graphical interface reminded them of a video game. When asked if he felt the same, LY answered that there "wasn't really a relation between content" and graphical quality [citation 11].

What's more, after having been asked if he had previously played realistic video games, the subject made the following statement:

[The VPLab] is somewhat like SimCity [the videogame] ***where everything is accounted for.*** *These are software for which the graphical interface is not realistic– [but] you look at what happens [i.e., the content] and it's very realistic.* [citation 12]

This excerpt also indicates that the simulation's complexity was sufficient in LY's opinion.[53] However, I shall see in the next section that his judgments in this area were not always so favorable.

Complexity of the simulation (disk motion, anomalies, errors in handling apparatus) / Multimedia explanations in the Presentation workspace

The fact that the disk slowed down after having been launched (while the pump was on) gave this subject an indication that there was residual friction at work against the disk's motion. This yielded greater verisimilitude.

Conversely, when LY launched the disk straight toward the table's side (at a 90-degree angle), he observed that it traveled back and forth on the table's surface without deviating from a straight path. This indicated to LY that he could launch the disk at a *perfect* 90-degree angle (to the table's side), and that the table's surface and sides "were perfect". This seemed to work against verisimilitude: the subject claimed that "the conditions were perfect" and that the disk would "totally react [according] to theory" [citation 102].

LY did not seem to be bothered by the fact that one of the elements mentioned above (presence of residual friction on the table's floor) pointed to greater complexity of the simulation, while the other (the table's 'perfect' sides) pointed to lesser complexity. This was because the explanations in the Presentation workspace made things coherent for him: LY had noticed that '*minimized friction* on the table's surface' was mentioned in the Presentation document whereas no reference had been made in regards to the table's sides (thus, he felt that designers had no obligation of making the table's sides 'imperfect'). Moreover, LY believed that the users should be informed of any physical factors which had not been included in the simulation's model:

> *I expect that [the simulation] would take into account all physical factors involved – when you do an experiment, you take all physical factors into account, except if it is specified from the start that [including a given factor] would exceed the experiment's objectives [i.e., that it would not be useful to attain its objectives]*
>
> *[...] this is just being honest with the student [...] if you tell him, he understands that something which goes on [in reality] is not represented [by the simulation] because it exceeds the course's content, or something like that...* [citation 103]

At any rate, the multimedia presentation of the experiment seemed to set the tone for LY's expectations of complexity and this was linked with his prior experiences in situations where teachers had announced, before specific experiments, that certain aspects of the physical phenomenon under study would not be taken into account. LY probably associated the act of neglecting these aspects *at the time of analysis* (in order to simplify the process), with the act of neglecting these aspects *when designing the simulation itself.*

---

[53] Note that LY made this statement after he was shown the *Explanation* workspace containing theoretical demonstrations of the disk's behavior.

When it was suggested during the debriefing interview that 'anomalies' and random fluctuations might have been included in the simulation's model, the subject reacted by saying that this would improve the simulation and raise it to another level, but he also recommended that students be warned of these factors because they would not expect them.

Later, when he was asked to name any events which could take place or actions which could be accomplished in an actual lab but not within the VPLab, LY mentioned that handling errors which would ruin the experiment (e.g., making a wrong electrical connection in another type of experiment) would be more difficult to replicate in the VPLab. LY believed that the impossibility of committing such errors within the VPLab would prevent students from being well prepared for actual lab work.

In his opinion, a very complex simulation would be needed to definitively replace actual lab work in intermediary or advanced courses– the subject believed that making the VPLab that complex (as complex as an industrial simulator, for instance) would be very costly, so that this was not very likely to happen. However, LY did feel that the software (in its actual state) would be perfect for an introductory course if its limitations were clearly exposed to students. Here again, he alluded to situations where a teacher had announced, before specific experiments, that certain aspects of the physical phenomenon under study would be neglected:

> *I think that this is perfect given that it would be used for an introductory course. I imagine that it would be clearly written, etc. In my opinion, you don't expect more than this– this is what you expect. Anyway, when you do an introductory lab experiment like this, there are some things that you neglect. The teacher says: "Neglect this type of friction or this other thing." For sure, it won't be perfect there either. You expect that too. It rounds off. It's just to show you that it tends toward what theory predicts – you don't see perfect theory.* [citation 104]

Adequate precision of instruments, and control when performing measurements / Uncertainty of measurement

During the session, LY mentioned that the virtual tape measure was precise enough when used in the VPLab. However, he added that if this tool were to be replicated exactly and used in an actual lab, it would not be precise enough to measure short distances (e.g., 2 cm). He felt that its tape – because it rather appeared to be like a string – would fold or move causing large measurement errors. Hence, in his opinion, a real tape measure designed like the VPLab's would only be precise enough to measure longer distances; for short distances, using a short ruler would be easier anyway.

Concerning the virtual protractor, LY commented favorably on the absence of a function which would have allowed the user to fix the protractor very precisely on the object being measured and automatically obtain a measurement.[54] LY said that the absence of such a function allowed an

[54] Such a function is sometimes referred to as a 'snap' feature in CAD software packages.

uncertainty factor to remain when making measurements.[55] He added that such an automatic function would be detrimental to students in a context where learning how to conduct a lab experiment is more important than getting excellent results (and this is the context he anticipated for use of the VPLab). LY's main impression was that performing measurements oneself without the help of an automatic function was favorable in that context.

When he was asked to assess the uncertainty of length measurements performed with the tape measure, LY proceeded to do so with no hesitation. Afterwards, the subject said that the method he had used to assess uncertainty was the same as the one he would have used in an actual lab. Later, when he was asked whether it was strange or normal that he should be asked to assess uncertainty in the context of working with the VPLab, the subject said:

> *It's normal: you always have to assess uncertainty on all measurements, with all instruments.*
> [citation 105]

Requiring LY to assess uncertainty may have been a cue favoring verisimilitude, but it felt quite natural for him to do so, at any rate.

Although the affordance of uncertainty of measurement was seen as favorable by LY, the virtual instruments' verisimilitude was diminished when the subject perceived that they lacked precision compared to their real-world counterparts. For instance, LY stated that the virtual protractor was not precise enough since it lacked the detail of graduation he was accustomed to finding on actual protractors (the virtual protractor had a graduation for each 5 degrees but not for each degree).

The VPLab's main metaphor

During the session, LY had interpreted the Analysis workspace's main display as a device (screen) offering a playback function. The different color schemes used in the Manipulation and Analysis workspaces, as well as the time display, had been strong cues for this interpretation. Near the end of the debriefing interview, LY was asked to estimate the probability of finding real-lab equivalents of the functions constituting the VPLab's main metaphor (recording an image sequence, viewing it, and using a trace function). LY answered that finding devices which replicated these functions in an actual lab was probable-- that is, in a new school or a school which had kept up to date with recent technologies.

During the session, LY compared the Trace function to the carbon paper tracing system which he had used for an experiment conducted in college. He appreciated the fact that the Trace function (like the carbon paper system) did not *instantaneously* provide needed information to the experimenter, but instead required him to do further work in order to obtain this information.

---

[55] Here, I must insist that LY made this statement about the inclusion of uncertainty in a simulation-based environment *before* the interviewer actually required him to assess uncertainty of measurements.

Later, when he zoomed in on the display (while assessing uncertainty on measurements of distances between traces), he observed that the traces were not identical. The distortion that caused differences among traces was in fact intentionally included by designers, in part, to promote uncertainty assessment– instead, LY believed that it was an unintentional artifact of poor visual presentation, either caused by poor resolution (he thus compared the VPLab to an 8-bit Nintendo video game) or by the process through which the Traces were calculated for display.

As a final note, I would say that the metaphor's overall credibility, in LY's case, might have been linked to his prior experience with use of other software which integrated simulations in experimental activities.

Subject MZ

Evaluation of the VPLab's potential to allow performing educational experiments

MZ's rating was 2 (on a 5-point scale) for the VPLab's potential to allow performing educational experiments at a first-year university level. The subject considered that the software would have been much more appropriate for students in high school or college. Some of his reasons will be examined in the next two sections.

The VPLab's main metaphor / Task allocation

During the session, MZ criticized the way that the metaphor structured tasks in the experiment. He felt it was strange that the experimenter had to make length measurements on "a television image" in the Analysis workspace instead of making them while handling the apparatus (in the Manipulation workspace). Also, even though he noted great similarities between the Analysis workspace's Trace function and a carbon paper tracing system he had previously used, he thought it peculiar that it was not left to the experimenter to decide if traces are to be drawn as the disk moves on the air-table. Here, considerations of verisimilitude and pedagogical value seemed to be intertwined:

> *[...] even from a pedagogical standpoint, I think it's good that one should be required, while performing the experiment, to plan ahead and say: "I'm going to have to leave traces [of the trajectory] to be able to make measurements."*
>
> *Whereas here [i.e., with the VPLab], it's like we don't really care: we move the disk around, then we go to the Analysis [workspace] where we can do anything we want. For this aspect, maybe it's not very realistic.* [citation 7]

I believe that MZ's abilities and interests in experimental design were conducive to him making these types of judgments.

During the debriefing interview, he further expressed negative judgments concerning the metaphor as a whole. He said that it felt artificial [56] and that he could not imagine, as far as this experiment was concerned, how replicating its functions in an actual lab could be advantageous:

> *I find that making measurements on a television screen, in a simple case like this one, is... well, it's artificial. I can't imagine circumstances where this could be advantageous compared to leaving a trace [on carbon paper].*
>
> *[...] I would tend to say that the approach itself does not seem realistic: to film a sequence so you can later make measurements as on a video image... it's a bit gadgety... However, I imagine it's hard to do otherwise on a computer.* [citation 106]

In this last excerpt, MZ also seemed to appreciate the difficulty of designing a realistic experiment using the computer as a medium.

Uncertainty of measurement (and lack of precision) / "Poor quality" of images following a zoom-in

MZ did consider the possibility of using a camcorder in an actual lab and he suggested ways of avoiding what he saw as the VPLab's most important flaw– lack of precision of measurements:

> *[...] if you're going to film [the experiment], you might as well arrange it so you can get good resolution; you'd get a close-up of the table in order to obtain a better image, for instance... You'd arrange to fix a grid on the table's surface so it would be easier to evaluate distances. It seems to me that these are things you think of almost naturally when you're doing it for real, whereas in [the VPLab], there are big limitations.* [citation 22]

This sensation of lack of precision occurred when the subject realized that the recorded image's quality degraded as he zoomed-in to measure distances between traces more accurately. He first judged this apparent lack of precision in terms of the accuracy that was usually available when using computers, and thus regarded the resulting uncertainty of measurement as an unnecessary consequence of poor visual rendering:

> *I'm aware that this aims to simulate the manipulation [of instruments] but... I know that the computer is powerful enough to give me dots [i.e., position of traces] which are much more precise than this. So, this is a kind of false uncertainty. It's just that the dots are too big... In reality, I'm certain that the computer knew very, very precisely where the dots were when it made them.* [57] [citation 23]

Requiring the subject to assess uncertainty may still be seen as favoring verisimilitude; in this case, however, the subject perceived uncertainty as being artificial. Here is what MZ answered when asked if it was useful or rather futile to have to deal with uncertainty:

> *I wouldn't say it is futile, because you always have to deal with uncertainty. I would say that it is artificial. Uncertainty [in the VPLab] is induced by poor resolution of the image. Well...you do have to introduce uncertainty somewhere...* [citation 107]

---

[56] As a side note, MZ felt that if one accepted the concept of working with an image displayed on a "television", it was normal to have to deal with scale conversions. He realized this after he had zoomed-in on the displayed image and noticed that the scale and size of the ruler (which was placed above the virtual monitor) had not changed.

[57] This is yet another example of the capacity of discerning between a model and its visual presentation.

The subject was then asked to temporarily set aside considerations regarding the uncertainty's source and merely judge whether there should normally be more or less uncertainty in this type of experiment (when done in an actual lab). He felt that the error percentage he had measured for distances between traces was unacceptably high (20%) compared to what he would have dealt with in an actual lab. He later explained that in an actual lab, he would have been able to focus on objects when getting extremely close to them, and thus would have measured them much more accurately than when working with the VPLab.

Measuring instruments

In general, MZ saw the measuring instruments themselves as being "realistic". A notable exception was the virtual tape measure. He felt that the tape measure was "mysterious" (though very useful) and he thought it highly improbable that this tool could be replicated, as such, in reality, since its inner workings being were difficult to explain.[58] MZ also mentioned that the tape measure's digital display was useless, given the level of precision that could actually be achieved with this instrument.

Supposing, though, that it could be replicated in reality, MZ said, it could probably be used much the same way as in the VPLab. The subject also commented, on the other hand, that in an actual lab he would rather use a ruler for all length measurements (in the VPLab, at the time of the study, the ruler could only be aligned horizontally and vertically so that it was impossible to use it to measure the length of objects oriented otherwise).

Verisimilitude of the disk's motion on the air-table (deceleration as a sign of residual friction, and spin as a sign of friction with the table's sides) / Complexity of the simulation

The fact that the disk slowed down after having been launched gave this subject an indication that residual friction was working against the disk's motion and this yielded greater verisimilitude. Another cue favoring verisimilitude in this area was the disk's rotation about its own center (spin).[59] This indicated to MZ that friction between the table's sides and the disk (at the point of impact) had been included in the collision model.[60]

During the debriefing interview, MZ was asked to imagine how he would react were he to conduct a full-fledged experiment using the VPLab's air-table simulation and then observe that results had radically strayed from theoretical predictions:

---

[58] With the virtual tape measure, the measurement starts at a red circle drawn on the tape measure's plexi-glass casing: MZ could not figure out how the measurement would be processed by the tape measure if it were to be replicated exactly in reality. Also, its tape (which was instead perceived as a string) "seemed to come out of nowhere".

[59] Some subjects (e.g., BO) also had the opportunity of witnessing the disk's spin but either they did not notice it, or else they chose not to comment on it.

[60] This type of behavior can be observed in everyday life. For instance, one may simply launch a billiard ball against one of the billiard table's sides while giving it lots of spin and watch its behavior after the collision: the billiard ball is most likely to lose most of its spin after the impact. This is due to friction with the table's sides at the point of impact.

> ***MZ****: My results would be way off, even considering experimental uncertainty?*
> ***Interviewer****: Yes. Maybe that has happened to you in the past?*
> ***MZ:*** *Yes. But in this case, I would tend to say that it would still be my fault. Even if this is software, I would not think that it is the simulation's fault– all in all, the laws of physics pertaining to this are simple enough. I would trust it.* [citation 108]

This excerpt may lead to various interpretations. First, one might say that the simulation's verisimilitude was sufficient during the session, and that credibility was thus promoted. A further interpretation might be that this subject would not expect that the simulation's behavior would be affected by anomalies causing experimental outcomes to radically stray from theoretical predications.

Handling of apparatus / Impossibility of errors in handling apparatus

When he started to handle the disk on the air-table, MZ commented that launching it with the hand-shaped cursor (through 'direct manipulation') was not very precise. He felt that more accurate knowledge of the disk's initial velocity would be necessary for an experiment.

In a similar area of interest, MZ also stated that it was impossible to simulate errors in handling of apparatus. In his opinion, the act of launching the disk too abruptly and damaging it, for instance, could not be simulated in the VPLab.

In a related issue, MZ said that he would not expect the simulation to present degraded experimental conditions (e.g., the table not being level to the ground). To his mind, users of the VPLab's air-table simulation would not be able to detect degraded experimental conditions nearly as easily as in an actual lab, and more importantly, it did not seem possible to make adjustments required to correct these defects: hence, students should not be expected to anticipate degraded conditions and should thus be warned of them.

Appendix J: Original Subject Quotes

Table XVI presents all subject quotes contained in this thesis. Whenever a participant is quoted in the text, the English translation of the citation is usually followed by a number within brackets [citation *x*]. This number refers to the number contained in the first column of the table. The third column contains the original citations in French.

Table XVI: Translated citations and original citations in French

Quote Number	English translation	Original citations in French
1	LY: […] you'll always have limitations: is this really representative of the theoretical model? What's behind this [simulation] to make [the disk] move like that? Did [the programmer] take a formula and simplify it to allow for nice motion? […] That's what bothers me: you have this software but you can have it do anything you want. […] Of course, you tell yourself that [the teachers] are teaching a class so they won't hand you any old thing. Even so, they always tell you to act as if [what is being taught] isn't true until they prove it to you […] they say that you should always ask yourself questions concerning what the teacher is saying: maybe he's saying nonsense. With [the VPLab], you can't really question things because there's an [intrinsic] limit in using the program itself: if you start to question things at home like that, you lose the whole principle of using the software. You don't know [in the case of the simulation] if the programmer has taken the time to include everything – to really consider all the theoretical aspects and do the correct calculations – or if he just shoved the whole thing, and said: "Here, this is what it'll do". [Maybe] a whole table has already been written up so that when such or such thing happens, [the disk] automatically goes the other way... Or, does it really work with a formula, with all values truly changing according to reality? […] Interviewer: So it's really a question of trust in what the simulation can produce compared to… LY: Yes, a question of trust and [of knowing that] the principles are clear – that things aren't too hidden. Interviewer: So more disclosure is needed? LY: Yes.	LY : […] tu vas avoir toujours des limitations. Ces limitations là c'est : Est-ce que c'est vraiment représentatif du modèle théorique ? Qu'est-ce qu'il y a derrière [le mécanisme sous-jacent] qui fait que ça [le disque] bouge comme ça ? Est-ce qu'il a pris une formule et qu'il l'a simplifié pour que ça fasse un beau mouvement ? […] C'est ça qui me fatigue : tu as le programme mais tu peux faire dire n'importe quoi à un programme. C'est certain que tu te dis : "Bon, ils donnent le cours, ils ne te donneront pas n'importe quoi." Sauf que, même là, ils disent toujours de prendre comme si c'était pas vrai et il fallait qu'ils te prouvent que c'est vrai. […] ils disent qu'il faut toujours te questionner sur ce que le prof. dit. Peut-être qu'il dit n'importe quoi. Avec ça [le LVP] tu ne peux pas vraiment te questionner parce que c'est limité dans le programme. Si la personne commence à faire ça chez elle, tu perds le principe du logiciel [le logiciel est rendu obsolète]. Tu ne sais pas si le programmeur a vraiment pris le temps de tout inclure les choses - vraiment tout prendre les aspects théoriques et de faire vraiment les vrais calculs - ou il a juste foutu quelque chose parce qu'il dit : "Ça va donner ça". Il y a toute une table déjà faite : quand il arrive telle chose, automatiquement, [le disque] part de l'autre côté. Donc, tu ne le sais pas si c'est vraiment... ou si c'est une formule qui agit, et que toutes les valeurs, à chaque fois, changent vraiment selon ce qui est vrai. […] Animateur : Donc c'est vraiment une question de confiance en ce que la simulation peut donner par rapport.... LY : Oui, question de confiance et c'est vraiment [de savoir si] c'est claire comme principe - que c'est pas trop caché. Animateur : Il faudrait plus de transparence ?

		LY : Oui.
2	[If] you do not have control over anything, then you might say: "It's programmed to do that." Whereas if you have control – to be able to move and touch everything that you desire, to throw and have fun with the disk for 15 minutes – you see that it's not really programmed… **there is programming but it respects what happens in real life.**	[Si] tu n'as le contrôle sur rien, là quelqu'un va être plus sceptique [et pourra] dire: "C'est programmé pour faire ça". Tandis que si quelqu'un contrôle - de bouger et de toucher à tout ce qu'il veut ; de lancer et de s'amuser avec le disque pendant 15 minutes, puis qu'il voit que c'est pas vraiment programmé... **une programmation oui sauf que ça respecte ce que ça fait dans la vraie vie.**
3	DQ: […] When you're on a computer, it's not real. I think that's the biggest difference, between the two. When you're in a lab, you're the one who's manipulating, you're the one who's measuring and adjusting settings, you're doing everything – when you're on a computer, you use the keys but you're not the one who's in control, you're not controlling, with your own hands, the things that you do. Interviewer: Right now, is that also the case? It's a question of controlling things more directly with your own hands… DQ: For me, that's the big difference between software like this and a practical lab. Interviewer: What type of consequences does manipulating things with one's hands entail, compared to doing things like this [with the VPLab]? Do you see repercussions on the experiment's results? How does it change the way you do the experiment? DQ: I think it doesn't give the same result. Ideally, in my opinion, you should be in a lab but software like this can be a fine complement. Interviewer: Does manipulating things have an impact on what you can learn and the errors that you can make? DQ: Sure, because [in a lab], if you make a mistake, if anything is wrong, you'll see it and you can readjust things. I think you have more control when… with equipment, when you're manipulating it. The disadvantage of a computer simulation is that you're not controlling everything. Even if you're controlling things with your keyboard and your mouse, it's not real – it's not the same.	DQ : […] Quand t'es sur un ordinateur, c'est pas réel. C'est la plus grosse différence, je pense entre les deux. Quand t'es en laboratoire, c'est toi qui manipule, c'est toi qui règle tes choses, qui prend les mesures, c'est toi qui fait tout – tandis que sur ordinateur, tu joues avec des touches mais c'est pas toi qui a le contrôle, c'est pas toi qui contrôle avec tes mains ce que tu fais... Animateur : Dans le cas qui nous occupe, c'est ça aussi ? C'est une question de contrôler les choses avec nos mains, plus directement.... DQ : Moi, c'est la grosse différence que je vois entre un logiciel comme ça et un laboratoire pratique. Animateur : Quel genre de conséquences ça entraîne, le fait de manipuler les choses avec ses mains, par rapport à faire ça comme ça [avec le LVP] ? Est-ce que tu vois des répercussions sur les résultats d'une expérience ou la façon de faire une expérience ? Comment ça change la façon de faire une expérience ? DQ : Je ne pense pas que ça amène le même résultat. Selon moi l'idéal c'est d'être en laboratoire mais comme complément ça peut être bon un logiciel comme ça aussi. Animateur : Le fait de manipuler des choses, est-ce que ça un impacte sur ce qu'on peut apprendre ou les erreurs que l'on peut faire ? DQ : C'est sur parce que [en laboratoire] si tu te trompes, si jamais il y a quelque chose de pas correcte, tu vas le voir, tu peux réajuster tes choses-- je pense que t'es plus en contrôle quand... avec le matériel, c'est toi qui manipule. Le désavantage d'une simulation sur ordinateur, c'est que c'est pas toi qui contrôle tout. Même si tu contrôles avec ton clavier et ta souris, c'est pas réel, c'est pas la même chose.
4	Interviewer: Have you ever seen movies or news reports on virtual reality – of people who wear helmets and gloves? DQ: Yes, I've seen that a few times. Interviewer: What would you think of a [virtual reality] lab where you could manipulate things using gloves? There would be objects… and there are gloves that give you tactile sensations. I was	Animateur : Est-ce que tu as vu certains films ou reportage sur la réalité virtuel - des gens avec des casques et des gants ? DQ : Oui, j'ai déjà vu ça un peu. Animateur : Qu'est-ce que tu penserais d'un laboratoire comme ça où tu pourrais manipuler des choses avec des gants - ça serait des objets - il y a certains gants qui donnent des sensations tactiles ?

	wondering if the problem [with the VPLab] was that you were working with a mouse and a keyboard or if it would be the same [problem] for you with a helmet and gloves? DQ: It would be the same. It remains imaginary… well, imaginary, in a way of speaking. It's not imaginary but it's not real.	Je me demandais si le problème était de travailler avec une souris et un clavier ou si c'était la même chose pour toi avec un casque et des gants ? DQ : C'est la même chose. Ça reste dans l'imaginaire - bien imaginaire entre parenthèses, c'est pas imaginaire mais c'est pas réel.
5	JW: […]I think that there are some things which, even if you see them here [in the VPLab], you'll have the impression that they could be fully tampered with. For instance, when we watched the disk move in the video clip, you could see that it was real, but […] it seems less real in the computer, when it's not a video clip. When you do it in a lab, you see it with your own eyes. Here [with the VPLab], you see it […] but it's a machine that has done it all. Interviewer: So it's the medium itself? FS: Yes, it's the fact that I don't do things with my own hands – that I don't really look upon it…	JW : […] je pense qu'il y a certaines choses que même si on le voit ici [elle pointe l'écran], on a l'impression que ça pourrait tout être manipulé. Par exemple, quand on voyait le disque qui bougeait comme ça dans le vidéo, ça se voyait que c'était vrai, mais […] ça l'air moins réel dans l'ordinateur, quand ce n'est pas un vidéo. Quand on le fait dans un labo, tu le vois avec tes yeux. Là [elle pointe l'écran], tu le vois avec tes yeux mais […] il y a machine qui a fait tout ça. Animateur : Donc, c'est le médium lui-même ? FS : Oui, le fait que je ne le fais pas avec mes mains. Que je ne le regarde pas comme ça...
6	Normally, there might be such and such physical factor that must be taken into account. I don't know... the window was open and a draft blew on my setup; but here [in the VPLab] you won't find that. […] It's a computer, [so] everything goes well […] And also, when you experiment [in an actual lab], when you do it yourself – you see… you'll know if a piece of pencil lead [on the table] has made the [disk deviate] … but in this case [the VPLab], I don't know if one can physiologically perceive the anomalies. Anyway, it's good that these types of errors exist [in the VPLab].	Normalement, il peut y avoir tel facteur physique dont il faut avoir tenu compte - je ne sais pas : la fenêtre était ouverte ça l'a fait du vent sur mon affaire sauf que là [dans le LVP], il n'y en a pas. C'est un ordinateur, ça se fait tout bien […] Puis c'est que quand tu l'expérimentes, quand tu le fais toi-même, tu vois - tu peux soit savoir [que c'est] une mine de crayon sur le truc qui a fait dévié mon affaire sauf que là, je ne sais pas si tu peux voir les anomalies physiologiquement. Mais c'est bon quand même qu'il y a des erreurs comme ça.
7	[…] even from a pedagogical standpoint, I think it's good that one should be required, while performing the experiment, to plan ahead and say: "I'm going to have to leave traces [of the trajectory] to be able to make measurements." Whereas here [i.e. with the VPLab], it's like we don't really care: we move the disk around, then we go to the Analysis [workspace] where we can do anything we want. For this aspect, maybe it's not very realistic.	[…] même d'un point de vue pédagogique, je trouve que c'est bien d'avoir à prévoir immédiatement au moment de faire l'expérience [quand on fait les manipulations] - d'avoir en tête le but - donc d'être capable de dire immédiatement : "Il va falloir que je laisse une trace pour prendre mes mesures" Alors que là, on dirait qu'on s'en fou un peu, on s'amuse à faire déplacer [il se rend à l'espace de manipulation]- on s'en va dans l'analyse puis maintenant [il retourne dans l'espace d'analyse] on peut faire ce qu'on veut. Donc pour ça, c'est peut-être pas très réaliste.
8	Interviewer: So this [video] is important? B.O: Well yes… You know, skeptical people will say: "Well this is all pre-arranged. It's software so it'll work just so. All I have to do is click and follow the path." With the video clip, they see that it's not just software – it's not just a simulation where you click and it responds like so. [The video clip] shows you the experiment done with real objects.	Animateur : Donc c'est important ça ? BO : Bien oui, ça ne fait pas juste... Tu sais.... du monde sceptique qui dit : "Oui, c'est arranger. C'est un logiciel, c'est sûr que ça va marcher comme ça. J'ai juste à cliquer puis à suivre le cheminement." Avec l'extrait vidéo, ils voient que c'est pas juste du logiciel - c'est pas juste une simulation où tu cliques là et ça va faire telle chose. En fin de compte, ça te montre l'expérience qui est fait avec

	objects.	des vrais objets.
9	BO: That's why it's useful to see the video clip beforehand. It provides an introduction so that someone who comes here [in the Manipulation workspace] and starts the merry-go-round will not be surprised of the disk's curved trajectory. Interviewer: Because otherwise you would be surprised? BO: Well novices would be surprised, not people who are used to it. […] Interviewer: Does the curved trajectory seem… BO: No, it seems normal in comparison to the video clip that was shown earlier.	BO : C'est pour ça que c'est utile de voir le vidéo avant. Ça montre que... Ça amène une introduction donc quelqu'un qui arrive ici et qui part le manège, il n'est pas surpris de la courbe prise par le disque. Animateur : Parce qu'autrement, on serait surpris ? BO : Bien les profanes seraient surpris, pas les initiés. Ceux plus qui ne réfléchiraient pas : "Ah, quand tu y penses 2 secondes, tu le sais que ça va tourner parce que c'est dans un référentiel qui tourne." Animateur : La façon dont il tourne, est-ce que ça te paraît... BO : Non, ça l'aire normal par rapport au vidéo qu'ils ont montré tantôt.
10	Interviewer: What was happening before you stopped the pump? CP: The disk was moving. It slowed down – there is a loss of speed, of course. Interviewer: Why? CP: There is some friction; it's not totally absent. Interviewer: What do you think about the fact that there is friction? Did you expect that? CP: Well yes. Air creates friction. It is impossible [not to have friction] unless… We neglect it a lot [in calculations] but it's there all the same. **Interviewer: So it's normal to see this deceleration?** **CP: Yes and it corroborates what would happen in a lab. But in a lab, you have steel disks so they slow down faster. I don't know if…**	Interviewer : Qu'est-ce qui se passait avant que t'arrêtes la pompe [avant que T9 arrête la pompe, le disque allait très lentement] CP : Mon disque bougeait. Il ralentissait là, c'est sur que tu perds de la vitesse... Interviewer : Pourquoi ? CP : Il y a quand même une friction, c'est pas SANS friction TOTALE. Interviewer : Et comment tu trouves ça qu'il y ait tout de même de la friction ? Est-ce que tu t'attendais à ça ? CP : Ben oui. Il y a l'air qui crée une friction. C'est impossible[pas de friction] à part de... On la néglige [pour les calculs] de beaucoup mais il y en a quand même. **Interviewer: Donc c'est normal que l'on voit un certain ralentissement ?** **CP : Oui. et ça corrobore beaucoup ce qui se passe en laboratoire. En laboratoire, c'est des disques d'acier par exemple, donc ils ralentissent plus rapidement. Je ne sais pas si…**
11	wasn't really a relation between content [and graphical quality]	[la qualité graphique] ça n'a pas vraiment rapport avec le contenu
12	[The VPLab] is somewhat like SimCity [the videogame] where everything is accounted for. These are software for which the graphical interface is not realistic – [but] you look at what happens [i.e. the content] and it's very realistic.	Ton logiciel est fait un peu comme Simcity où tout est tenu en ligne de compte. Ça c'est des logiciels qui sont quand même assez - l'interface graphique n'est pas réaliste - [mais] tu regardes ce qui arrive et c'est vraiment réaliste […]
13	BO: The graphics aren't dull. Sometimes, because it's physics, [teachers] think that they have to make it boring. When you get textbooks and videos from the fifties in class, it's usually physics. Interviewer: So does [the LVP] look less serious to you?	BO : […] le graphisme - le fait que ça soit pas terne. Parfois, vu que c'est en physique, ils sont obligés de mettre ça plate. Souvent les manuels et les vidéos des années 50 qui nous présentent dans les cours - c'est en physique. Animateur : Est-ce que ça fait moins sérieux comme ça [comme le LVP] ?

	BO: No. On the contrary, I think it opens some doors. It doesn't have to be ugly to be serious. It doesn't have to be boring for you to learn something. […]	comme ça [comme le LVP] ? BO : Non. Au contraire, je trouve que ça ouvre des portes. Ce n'est pas parce que c'est laid que c'est sérieux. Ce n'est pas parce que c'est plate que l'on va apprendre quelque chose. […]
14	[…] all the elements are present to make it as if I weres in a lab. All the instruments are provided so that I can obtain the same data as I would have wanted to obtain in a lab – that's what's important, I think…	tous les éléments sont là pour faire comme si j'étais en laboratoire. Tous les instruments sont fournis pour arriver à prendre les mêmes données que j'aurais voulu prendre en lab - c'est ça qui est important je pense…
15	In video games, we often see this – a logbook or a camera. [The VPLab's camcorder] is designed in a very real… very realistic way: you can almost manipulate it… with your fingers. You click on a button with the finger [i.e., pointer] and it closes [the camcorder's screen] automatically. So it's very realistic, it's gadgety […] You don't enter functions with the keyboard – it's almost always done with the mouse and a hand [i.e., pointer] on the screen.	Dans les jeux vidéo, on a souvent ça - admettons un logbook ou une caméra. C'est fait d'une façon très réelle, très réaliste : on peut presque le manipuler comme... avec nos doigts. On a le bouton ici [il pointe le bouton qui permet de replier l'écran du caméscope] avec un doigt [à ce moment, le curseur est une main avec l'index qui pointe] - on clique dessus [il replie l'écran], ça se range automatiquement. Donc c'est très réaliste, c'est gadget. […] c'est pas les fonctions qu'on tapent sur le clavier, c'est presque tout le temps avec la souris puis une main à l'ordinateur
16	tape measure's "way of functioning" was the same as "a real tape measure"	Ça marche comme un vrai ruban à mesurer de Papa.
17	The protractors that I've used before had a calibration that was [detailed] to the one-degree mark. We would really see the one-degree mark… so the level of precision [of those protractors] is a bit higher [than that of the VPLab's protractor]. So this one may not be precise enough. I would say "2" - a low probability […] because it's not precise enough for a physics lab.	Les rapporteurs d'angle que j'ai utilisé - la calibration est faite au degré. On peu vraiment voir le degré donc le niveau de précision est un peu plus élevé [que celui du LVP]. Donc celui-là est peut-être pas assez précis. Peu probable [2]. Je dis que c'est peu probable parce que c'est pas assez précis pour un laboratoire de physique.
18	GT: We [engineers] are used to plugging numbers into formulas – numbers with lots of decimals. It's also a very serious field, very conservative […] This is software which is attractive, it's gadgety […] but it's not the type of software we… we use things that are only technical and that's why I was disconcerted. Interviewer: OK. You weren't in your own world. GT: That's it! Exactly. A drawing like this [protractor] interferes with my real world […] In my real world, I could take these instruments, play around with them on a table and use the ruler, in my own way, to perform measurements. However, in this case, I can't touch [the instruments] and I **have to rely on a screen with a zoom, with a [different] scale, and with pixels. It's really approximate, and I can't be sure that [the instruments] are aligned or… visually, it's hard to tell.**	GT : Nous autres [les ingénieurs], on est habitué de 'plugger' des chiffres dans des formules - des chiffres avec plusieurs zéros après la virgule. C'est aussi très sérieux le domaine, c'est très conservateur […] Ça [le LVP] c'est un programme - c'est beau, c'est gadget […] mais ce n'est pas le genre de programme- nous autres, comme je te dis, on utilise des choses qui sont juste techniques […] c'est pour ça que j'ai été dérouté. Animateur : O.K. Tu ne te retrouves pas dans ton monde. GT : C'est ça. Exactement ! Un dessin de ça [il déplace le rapporteur], ça interfère avec mon monde vrai. Dans mon monde réel, moi je pourrais prendre ces outils là et jouer avec sur une table [il fait semblant de manipuler des objets sur le bureau] et vraiment mesurer comme je voudrais avec [?mon rapporteur?] et ma règle. Mais ici, je ne peux pas y toucher et **il faut que je me fie à un écran qui a un ZOOM, qui a des échelles et que c'est des pixels dans le fond. C'est vraiment à l'œil et je ne peux pas être sûr**

		que je suis vraiment centré ou... visuellement, c'est difficile à dire.
19	Well, it's because [the tape measure] is between… Because, given the fact that [the VPLab] is a computerized system, you tell yourself that it is going to measure precisely– direct, precise, real values. But this is rather somewhere between taking precise values and taking values that refer to something that would be collected manually. So, because it's between the two, I'm having a bit of difficulty …	Bien, c'est le fait que ça soit entre un... Parce que vu que c'est un système d'ordinateur, tu te dis que ça va mesurer précisément, directement des vraies valeurs précises. Tandis que là, c'est un peu entre quelque chose qui prend des valeurs précises et quelque chose qui prend des valeurs comme - qui réfère à quelque chose que l'on prendrait manuellement. Donc là, comme c'est entre les deux, j'ai de la misère un peu à voir.
20	[…] If you didn't ask me, I would surely say that [the data] is precise. But [uncertainty] is always there; they want to make reality more a part of it [the VPLab] […] they want it to be closer to reality so they ask us to assess uncertainty, so that we will really be working.	[…] Si on ne me le demande pas, je vais sûrement dire : "C'est précis." Mais il y en a toujours une [incertitude] ; c'est pour ça que... ils veulent plus mettre la réalité là-dedans, je veux dire.. […] ils veulent plus se rapprocher de la réalité alors ils veulent nous faire prendre des incertitudes pour qu'on soit vraiment en train de travailler.
21	[…] it's really experimental in the sense that it is I [and not the computer] who measures the distance between dots. If ten people measured [a distance], there could be ten different results.	[…] c'est vraiment expérimental dans le sens où, la distance entre les points, c'est nous qui la mesurons. Si dix personnes la mesure, il peut y avoir dix réponses différentes.
22	[…] if you're going to film [the experiment], you might as well arrange it so you can get good resolution; you'd get a close-up of the table in order to obtain a better image, for instance … You'd arrange to fix a grid on the table's surface so it would be easier to evaluate distances. It seems to me that these are things you think of almost naturally when you're doing it for real, whereas in [the VPLab], there are big limitations.	[…] tant qu'à filmer, tu t'organise pour avoir une bonne résolution, tu permets à la caméra de zoomer seulement sur la table pour avoir une meilleure image par exemple.... Tu t'organises pour avoir un quadrillé sur la table pour que ça soit plus facile d'évaluer les distances... Il me semble que c'est des choses auxquelles on pense presque naturellement au moment où on le fait pour de vrai et dans ce cas là elles sont assez limitées.
23	I'm aware that this aims to simulate the manipulation [of instruments] but… I know that the computer is powerful enough to give me dots [position of traces] which are much more precise than this. So, this is a kind of false uncertainty. It's just that the dots are too big… In reality, I'm certain that the computer knew very, very precisely where the dots were when it made them	Je sais bien que c'est une simulation de manipulation là... mais... je sais que l'ordinateur est assez puissant pour me donner des points beaucoup plus précis que ça. Donc, c'est une espèce de fausse incertitude là. Bon, c'est juste que les points sont trop gros.... alors qu'en réalité je suis certain que lui, l'ordinateur, au moment où il l'a fait [calculer la trajectoire], il savait très, très précisément où était les points.
24	I do everything, basically. See here: I determine the number of dots [i.e. traces] and the interval [between them] myself, as I want… For instance, I can take five different measurements, with a tolerance of 1 or 2 millimeters, and calculate their average to obtain a more precise distance: [the computer] does not do it for me. It is I who chooses the measurement methods and the calculating methods […] I choose my own way of proceeding.	On fait tout dans le fond. Comme ici, c'est nous qui déterminons le nombre de points [traces] que l'on veut ; quel intervalle que l'on veut... Je peux prendre, par exemple, cinq mesures et ça va être cinq mesures différentes à 1 ou 2 mm près et après faire la moyenne de ces cinq mesures pour avoir une distance plus précise. Lui [l'ordinateur] ne le fait pas à notre place. C'est nous autres qui choisissons vraiment les méthodes de mesure, nos méthodes de calcul. [...] C'est nous qui choisissons notre manière de procéder.
25	I was a bit confused. It wasn't very clear in my mind that it was a computer simulation. I thought	J'étais un peu mêlé là-dessus. J'avais pas vraiment éclairci mon idée que c'était une simulation

	mind that it was a computer simulation. I thought of it more as if it were a video. So… I could lower [my rating] a bit.	éclairci mon idée que c'était une simulation informatique. J'y réfléchissais comme si c'était de la vidéo comme modèle. Bien... je pourrais juste baisser un peu plus.
26	when you see what really happened, it's a video	quand tu vois ce qui s'est passé réellement, c'est de la vidéo.
27	BO: Well, one classmate told me that if [the VPLab] were available, he would get it. This friend who spoke to me doesn't like physics. And he told me: "It [the VPLab] helped me to understand things that I hadn't understood in class". [On the sole basis of] having done the test here, he said that [the VPLab] looked like it was really well designed and that – although he isn't a physics student – this would be the kind of software he would buy. But no, they [i.e. other subjects] did not say anything of… I was not aware of… Interviewer: I'm just curious… Did they mention any of the questions [that you would be asked here today]? BO: No.	BO : Bien il y en a un qui m'a dit que s'il était disponible, il le prendrait. Que c'était le genre de logiciel... Mon ami à qui j'ai parlé n'aime pas la physique. Et il m'a dit que "Ça m'a aidé à comprendre des choses que dans mes cours, je n'avais pas compris." Juste en venant faire le test ici, il disait que ça avait l'aire vraiment bien fait et que même si on n'était même pas en physique, ça serait le genre de logiciel qu'il achèterait. Non mais il ne m'ont pas dit rien de... Je n'étais pas au courant de... Animateur : Je suis juste curieux... Est-ce qu'ils t'ont parlé des questions ? BO : Non.
28	CP: [...] everything can be manipulated… Well, notice that today, if I show you a video clip, it can be created from A to Z on a computer and it is fictive. […] Interviewer: For you, the difference between the two [simulation and video], is it still… CP: No, as far as I'm concerned, there is no difference [between] a video and a computer because both can be manipulated. If you've seen the movie Star Wars [Episode One], there is [only] one scene that was truly filmed; but for the rest of the movie, you say: "My God, is it real? It seems real!" And it was all done with computers but you'll watch it on your TV screen.	CP : […] ça peut tout être manipulé... remarque que aujourd'hui, je te montre une séquence vidéo et elle peut être montée par ordinateur de A à Z et c'est fictif. […] Animateur : Pour toi, la différence entre les deux, est-ce qu'elle est encore... CP : Non, pour moi, un vidéo ou un ordinateur, il n'y a pas de différences parce que les deux peuvent être manipulés. T'sais, si tu as été voir le film Star Wars, il y a une scène qui a été tourner pour vrai ; le restant du film, tu dis : "Mon dieu, c'est-tu vrai, ça l'air vrai !" Ça tout été fait par ordinateur mais tu l'as dans ton écran de TV
29	ER: Chances are better that things really happened if they were filmed then if they are depicted with images. Interviewer: Would the video clip and the computer simulation be about equal for you? ER: No… I would prioritize video. Interviewer: On a scale of 1 to 5? ER: Video would be higher than simulation.	ER : Il y a plus de chance que ça se soit passé pour vrai si c'est filmé que si c'est représenté par présentation imagée. Animateur : Et pour toi, est-ce que tu penses que ça serait à peu près égal la séquence vidéo et la simulation informatique ? ER : Non... je mettrais assez en priorité le vidéo. Animateur : Sur une échelle de 1 à 5 ? ER : [Je mettrais] le vidéo plus [élevé] que la simulation.
30	I have to touch things, so simulations will often work so-so [for me].	Moi il faut que je touche. Donc souvent, les simulations ça va être so-so (comme ci, comme ça).
31	A computer simulation of something that is itself normally controlled through a computer [e.g.: a nuclear reactor] will work well. However, if you	Une simulation sur un ordinateur qui simule quelque chose qui se contrôle normalement à l'aide d'un ordinateur, ça marche bien.[Central

	simulate something like a jib-crane, the [operator] gets on the crane – and if manual operations are required – then he will have difficulties because [...] this requires "manual feel" and he'll never know that. And you have a phenomenon [associated with] the power [of the machinery] – it's not the same.	nucléaire]. Mais si tu fais une simulation d'une grue, le gars arrive dans la grue et si c'est des opérations manuelles, là il va avoir de la misère parce que […] quelque chose qui prend un feeling manuel, bien tu ne le sauras jamais. Et tu as un phénomène de puissance et tout ça -c'est pas pareil.
32	Often enough, you'll have homemade software and the person who uses it [first] knows what it's for. But for someone who wants to learn, it's not fun to only have a textual display and enter data. To perform experimental manipulations, you have to try to make it as visual as possible because most people are visually oriented […] At least you see here [with the VPLab] that this is simulating something: there's a chronometer…	Souvent, en programmation, tu vas avoir des logiciels faits maison puis le gars qui s'en sert sait à quoi ça sert mais [pour] le gars qui veut apprendre, c'est pas le fun juste d'avoir du texte puis d'entrer des données. Quand tu fais des manipulations, il faut que t'essaies que ça soit le plus visuel possible parce que la majorité du monde sont visuel. […] Au moins tu vois -ça [le logiciel] simule quelque chose : il y a un chronomètre…
33	IV: I tried the RJ and the CF18 [simulators] It was fun. Interviewer: Did you have the impression that it really represented… IV: Yes, that's why, when I got to that question, earlier in the questionnaire, of someone who tested a jib-crane on a simulation – " is he ready to operate the [real] jib-crane?" – I answered "yes", because I know that a pilot with the slightest prior experience, if you [first] stick him in a simulator, he can then go on to pilot the plane with no problems whatsoever. He won't even realize that he's not in his simulator anymore, and that he's in the plane instead: there's no difference. If the simulation is well designed, then we're happy. It's like the nuclear power-plant [question]: no matter that it's a nuclear power-plant which can cause a lot of damage, as long as the interface [of the simulation] is the same, there is no difference. So that's why I trust simulation.	IV : J'ai essayé le RJ et le CF18. C'est le fun. Animateur : Est-ce que t'avais l'impression que ça représentait vraiment... IV : Oui, c'est pour ça, dans le questionnaire tantôt quand la question arrive – quelqu'un qui a testé une grue en simulation, est-ce qu'il est prêt à conduire une grue – c'est pour ça que j'ai répondu « oui ». Parce que je sais qu'un pilote d'avion - un pilot qui a le moindrement d'expérience - si tu le mets dans un simulateur, il peut aller piloter l'avion puis il y en a même pas de problème. Il ne se rendra jamais compte qu'il n'est pas dans son simulateur puis qu'il est dans l'avion : il n'y en pas de différence. Si la simulation est bien faite, on est content. C'est comme la centrale nucléaire, ça l'a beau être une central nucléaire qui peut faire bien du dommage, mais si l'interface est pareil, il y en a pas de différence. Donc, c'est pour ça que, oui, je crois à la simulation
34	A simulation does not help to convince you, in the end. It shows you– "Look, I've programmed this thing and I can obtain the right result". However, with [the video clip], you can't help but believe it […] it hasn't been rigged. It's easier to believe that the simulation has been rigged than [to believe that the video clip has been rigged or has been tampered with]. In addition, a simulation is based on equations, such that if your equations are flawed, your simulation will give you the outcome that you expect– as opposed to [a video clip], which is not based on equations but rather on reality, as such…	C'est parce qu'une simulation, finalement, ça t'aide pas du tout à comprendre, à te convaincre. C'est comme on montre : "J'ai programmé ça et j'arrive au résultat et j'arrive au résultat." Alors que là, [pour la séquence vidéo] tu n'as pas le choix de le croire […] ça n'a pas été truqué. C'est plus facile à croire que la simulation a été truquée que ça. Parce qu'en plus, sur ta simulation, tu te bases sur tes équations donc si tes équations sont mauvaises, ta simulation va donner les résultats que [?t'attend?] alors que ça [la séquence vidéo], tu ne te bases sur aucunes équations, tu te bases sur la réalité en tant que telle donc tu as aucune possibilité de changer...
35	experimental error "was part of the game," and that "students don't learn anything from perfect labs." The purpose of a lab experiment, he said, is also to	Ça fait partie de la game. Un labo parfait, c'est un labo où t'apprends rien. Le but d'un labo c'est d'apprendre les erreurs des appareils. En même

	learn about errors caused by instruments: "You learn about theory and at the same time, you learn that instruments are not perfect."	temps que tu apprends la théorie, t'apprends que les appareils ne sont pas parfaits.
36	LY: […] the video sequence can do anything, really – it does whatever you tell it to do, whereas the simulation behaves in accordance to mathematical calculations. In the case of the video sequence, you'll say: "Maybe, it was just drawn that way," whereas with the program – if in fact you are shown with disclosure what is really happening using vectors and such – it's more credible. Interviewer: OK, so a video sequence can be… LY: It can be anything. Take movies: you have special effects, etc. Well, I may be pushing it a little… You do tell yourself that your school isn't working against you, but that notwithstanding. Normally, I would have more trust in simulation – it proves more. Video shows no proof. It's like television. If you watch television, you are passive – with simulation, you can interact […] That's what we used to do in physics with MAPLE [software]: we had a model and we could change the data […] and the model would change in accordance. Then we verified this manually by calculations on the blackboard and saw that things were accurate.	LY : […] le vidéo fait vraiment n'importe quoi – il fait ce que tu lui dis tandis que la simulation répond à des calculs mathématiques. Le vidéo, tu te dis : "Il l'a peut-être dessiné comme ça," tandis que le programme, si justement tu lui montres - la transparence - ce qui se passe vraiment avec les vecteurs et des choses comme ça, là c'est plus [davantage] crédible. Animateur : O.K., donc une séquence vidéo, ça peut être... LY : Ça peut être n'importe quoi : regardes les films : les effets spéciaux, etc. [il sourit]. C'est peut-être pousser un peu mais... Tu te dis que l'école n'est pas contre toi mais même là – […] Normalement, moi je ferais plus confiance à la simulation – elle démontre plus de preuve. Le vidéo montre aucune preuve. C'est comme la télévision. Si tu regardes la télévision, tu es passif; [avec] la simulation, tu peux peut-être plus interagir. […] C'est ça qu'on faisait en physique avec Maple - c'est qu'on avait notre modèle et on changeait les données [...] et il changeait selon les données qu'on donnait. Et après ça on vérifiait manuellement avec les calculs sur le tableau et on voyait que c'était pareil.
37	You can't help but be perfectly convinced when the experiment is conducted in front of your eyes. And viewing a video sequence is almost equivalent to having the experiment conducted in front of your eyes – you can't say a thing… Whereas, in the case of a computer, effects that infirm [theory] are just as programmable [as those which confirm theory].	On n'a pas le choix d'être parfaitement convaincu quand l'expérience est faite sous nos yeux. Et le fait que ça soit une séquence vidéo, ça équivaut presque à être fait sous nos yeux. On peut rien dire... Tandis que dans le cas de l'ordinateur, l'effet contraire pourrait être tout aussi simulable.
38	Interviewer: More people would be convinced by the video clip [than by the simulation]? MZ: […] Yes. However, that may not be a positive thing. Perhaps it's an aspect of media in our time: "This really happened: look we filmed it!" " Ah yes, now I believe it." But that doesn't mean that it would be more credible objectively. I think people would be more convinced but that doesn't mean that it would be more credible… Interviewer: From a scientific point a view? MZ: Yes, that's right: from a scientific point of view, [video] has no value.	Animateur : Il y a plus de gens qui seraient convaincu par la séquence vidéo ? MZ : […] Oui. Mais ça c'est peut-être pas positif. Ça c'est peut-être un peu l'aspect des médias... en ce moment - du genre : "C'est arrivé, regarde on l'a filmé." "Ah oui, j'y crois maintenant". Mais ça veut pas dire que objectivement, ça serait plus convaincant. Je pense que les gens seraient plus convaincus, mais ça veut pas dire que ça serait plus convaincant... Animateur : Du point de vue scientifique ? MZ : Oui, c'est ça, du point de vue scientifique, ça n'a aucune valeur.
39	Interviewer: To allow someone to develop abilities relating to manipulation [of apparatus], to [the	Animateur : Pour permettre de développer des habiletés de manipulation, de méthode, de rigueur,

	application of a] method, to rigor, and accounting for things that can happen in a lab… AN: Well, then maybe [you could push it] further. There's one dimension that is the comprehension of concepts and another dimension that is manual experimentation. On the one hand, to help you understand [concepts], this is fine… but on the other hand, to personally perform experiments, then I think that a real lab is necessary. Interviewer: To help you understand, it's fine but to experiment, not really… AN: No.	de prise en compte des différents trucs qui peuvent se passer dans un... A.N. : Là, admettons [qu'on pourrait] aller plus loin. Tu as le volet 'compréhension d'un principe' et t'as le volet 'expérimentation manuelle'. D'un côté, pour comprendre, ça va bien mais [pour] expérimenter toi-même, ça, je pense -- c'est un laboratoire réel [qui est nécessaire.] Animateur : Pour comprendre, c'est assez mais pour expérimenter vraiment... AN : Non
40	Paraphrase: Maybe putting it in 3D could help…	Que ça soit vraiment palpable ? Je ne sais pas... le mettre en 3D, je ne sais pas. Peut-être.
41	AN: […] air must be [acting] on it, so it [the disk] will eventually stop… Interviewer: You think it'll eventually stop? AN: Yes [..] because the pump eliminates a certain type of friction but not all of it. Interviewer: What do you think about the fact that we still included some friction? AN: Well, I would say it's truthful. Very realistic. Interviewer: And is that necessarily a good thing or would you say that it is not important? AN: Yes, it's important. You have to try to get as close to reality as possible when you experiment in physics because… If you take away many real conditions, you'll end up with a theory that is applicable only within your own conditions.	AN : […] il doit y avoir de l'air là-dessus, ça fait que ça va finir par arrêter... Animateur : Tu penses que ça va finir par arrêter ? AN : Oui […]Parce que la pompe élimine une certaine forme de force de frottement, mais pas tout. Animateur : Comment trouves-tu ça qu'on ait tenu compte encore d'un certain frottement ? AN : Bien c'est très véridique, je dirais. Très réaliste. Animateur : Et ça, est-ce nécessairement une bonne chose ou tu dirais que ce n'est pas important ? AN : Si, c'est important. Il faut le plus possible se rapprocher de la réalité quand tu fais une expérience de physique puisque tu vas faire quelque chose... Si tu enlèves beaucoup de conditions de réalité, tu finis par faire une théorie qui est applicable juste dans tes conditions à toi.
42	would be the protagonist [in the simulation] exactly as they did before [in the video clip]	C'est moi qui va être l'acteur [dans la simulation], finalement, exactement comme eux l'ont fait avant [dans le clip]
43	Interviewer: When you saw the 20-centimeter marker, what did that suggest? AN: 20 centimeters in reality [with emphasis on the word "reality"]. But now, you've transposed that to your monitor.	Animateur : Quand tu as vu le 20 centimètres, ça t'a suggéré ça ? AN : 20 centimètre EN RÉALITÉ [il met de l'emphase sur ces mots.] Sauf que là, tu l'as ramené sur ton écran.
44	Because the most important obstacle for software may be that people will always think that things have been pre-arranged, like special effects in a movie. They will say: "Well they've arranged it so it's just right." So, this is the advantage of having video as a complement. You can see that it hasn't been pre-arranged.	Parce que c'est peut-être la barrière la plus difficile pour un logiciel, c'est que les gens vont toujours pensé que c'est arrangé avec le gars des vues. Ils vont dire : "Ils se sont arrangé pour que ça tombe pile." Tandis que c'est l'avantage d'avoir un vidéo en complément. Tu le vois que ce n'est pas arrangé.
45	Paraphrase: saying that it was "almost identical to the real motion [the real phenomenon]." But he also said that, having worked on an air-cushion	Tu vas apprécié la photo, mais tu vas apprécié sa présence. C'est un peu la même chose : tu vas apprécié travailler là-dessus [le LVP] parce que ça

	actual table, it [the VPLab] could not completely replace the actual experiment because the experience with the VPLab was far less tangible. He compared the VPLab to having a picture of someone famous and likened performing the actual experiment to shaking that person's hand in "real life". "You may appreciate the picture," he said, "but you'll appreciate his presence [even more]".	reproduit, c'est presque identique au vrai mouvement. Mais ayant travaillé sur une vraie table, ça ne se remplace pas. [« tangible » est la traduction de « palpable », adjectif présent dans une autre citation]
46	Well, because it's still numerical – the images are drawn or made with a computer. But if you see it… You know, if you see someone in weightlessness on television, it's not the same as actually being in weightlessness yourself.	Bien vu que c'est numérique - c'est des images déssinées ou des images faites à l'ordinateur... Tandis que si on le voit là... Tu sais, si on voit quelqu'un en apesanteur à la télévision, ce n'est pas pareil comme si on est nous-mêmes en apesanteur.
47	quite similar to the motion you would obtain on the real [apparatus]	Ça ressemble pas mal au mouvement qu'on obtiendrait sur le vrai…
48	[…] but working with units and having to take into account [zoom-levels] 100%, 200%, 400% and having to translate those [units] to centimeters – I'm not used to this. When I'm in a lab, I work in centimeters and I can't get more than a 100% [zoom-level] – I can't zoom-in on my apparatus.	Mais déjà que de travailler en unités et ramener ça à 100% , 200%, 400% ramener ça en unités, ramener ça en cm - moi je ne suis pas habituer de faire ça. Quand je suis en lab, je travaille en cm tu peux pas faire plus que du 100% ; je ne peux pas zoomer ma table de travail.
49	by installing "a system of cameras" and by disposing of "a graphical interface on a computer"	installer des systèmes de caméra en laboratoire qui filment, ensuite avoir une interface graphique sur un ordinateur
50	Then again, in physics, it's not weird to have uncertainty [in measurements]: it's experimental. So it's normal to have uncertainty: we calculate it.	Remarque que, en physique, c'est pas bizarre les incertitudes : c'est expérimental. Donc c'est normal qu'il y ait des incertitudes ; on calcul des incertitudes.
51	[…] it would be possible to reproduce it [reproduce a smerry-go-round in a research lab] because we see in the video clip that they did it in Paris. It is possible to do it!	Tu sais, ça serait possible de le faire, de reproduire ça parce que tu vois dans le vidéo [la séquence vidéo dans l'esp. de présentation du LVP] qu'ils l'ont fait à Paris.
52	Interviewer: Why was " 20 cm " written on the purple marker? DQ: Because it's the real space. And we're in a space that's… well, not virtual, but a space with a scale. So the scale would be that 1.1 centimeters is equivalent to 20 centimeters in reality. If we want to calculate, we can use this [scale] to transform…	Animateur : Pourquoi on a écrit ' 20cm ' sur le ruban mauve ? DQ : Parce que c'est l'espace réel. Puis nous, on est dans un espace... bien, pas virtuel mais c'est l'espace avec une échelle. Donc l'échelle ça serait que pour 1.1 centimètres, c'est 20 centimètres dans la réalité. Si on veut faire nos calculs, à partir de ça on peut transformer....
53	I would not have thought of that. [The VPLab] looks well built, very structured – it's going to work: nothing would go wrong.	Moi je n'y aurait pas penser. Ça l'air tout bien fait, tout structuré... d'après moi, ça va marcher, il n'y aura rien qui ne marchera pas.
54	As for realism, it is also important to have the opportunity of seeing the disk moving on an actual table, in an actual lab, because I'm not so sure that it gets into your head as much when you see it on a computer– it's not as convincing as when you see it for real.	Pour ce qui est du réalisme, c'est quand même important aussi de voir vraiment sur la table à coussin d'air, les trucs qui se déplacent de même parce que par l'ordinateur, je ne suis pas sûr que ça rentre aussi bien dans la tête ; ce n'est pas aussi convaincant en fin de compte que de le voir pour vrai.
55	I must admit that all the gadgets somewhat divert your attention from what you really should be doing – from the real phenomenon.	Parce que j'avoue que tous les gadgets détournent un peu l'attention de ce qu'on doit faire vraiment - du vrai phénomène.

	It distances you a bit more from the physical phenomenon. You see it a bit like a game or a gizmo for drawing. It's more or less real and it… it's distracting.	Ça distance un peu encore plus du phénomène physique. Tu vois ça un peu comme un jeu ou un truc de dessin. C'est plus ou moins réel et ça te... ça détourne ton attention.
56	I have to admit that I like this. […] I like this software – I enjoy performing physics experiments like this with instruments [like these].	J'avoue que j'aime bien ça.[…] Le logiciel – faire des expériences physiques comme ça avec des instruments. Ça me plaît.
57	ER: […] I was really expecting to measure [between] dots. In fact, it's because I was relating this to when I had done this experiment in college– when I measured distances between dots [in college], I was not doing it through a window. I was measuring directly: the distance [measured] between two dots WAS the distance between two dots. I would not have expected to go to a [monitor] screen and to have to transpose [the measurement]. Interviewer: And now that you know, does it seem strange to work like this? Or is it normal… ER: Well… strange […] It bothers me. Interviewer: In reference to what you've done in the past, it still bothers you? ER: Well, it bothers me to have to do scale conversions of measurements […] it's like calculating something that does not correspond to anything real.	ER : Parce que moi je m'attendais réellement à mesurer des points. En fait, parce que je faisais pas mal référence à quand je l'avais fait au Cégep cette expérience là - je faisais la même affaire. Quand je mesurais des distances entre des points, je ne faisais pas ça par une fenêtre. Je mesurais ça directe : la distance entre deux points, c'était cette distance là entre deux points. Je me serais pas attendu à repasser par un écran puis faire une transposition. Animateur : Puis comment trouves-tu ça maintenant que tu le sais– est-ce que c'est tout de même étrange de fonctionner comme ça ? Ou c'est normal ou c'est plutôt… ER : Bien... étrange […] Bien... ça me gosse. Animateur : Par rapport à ce que tu as fait, ça te gosse encore ? ER : Bien ça me gosse d'avoir à faire un changement d'échelle. […] c'est comme calculer quelque chose qui correspond à rien de vrai.
58	When I use these instruments, it doesn't relate to anything real. It's purely like playing a video game with a plane cockpit.	Quand j'utilise des instruments, ça fait référence à rien de réel. C'est purement comme si tu joues à un jeu d'ordinateur puis tu as le cockpit de l'avion.
59	Interviewer: Why does [the VPLab] have much potential [to allow performing physics experiments]? FS: Well, when you watch the video clip and you watch this [simulation], both do exactly the same thing – [the simulation's designers] have included friction; they have included most of the constraints that could be applied to it.	Animateur : Qu'est-ce qui fait qu'il [le LVP] a un gros potentiel ? FS : Bien c'est que si tu regardais le vidéo avant et que tu regardais ça [la simulation], ça faisait exactement la même affaire – ils ont mis le frottement là-dessus, ils ont mis à peu près toutes les contraintes que tu pouvais mettre dessus.
60	FS: Well I was still thinking that I would do [uncertainty assessment] approximately. Interviewer: Is it still because [the VPLab] doesn't seem serious enough to you? FS: Well, it looks like a game… that's why. You do it quickly…	FS : Bien là je pensais encore : "je vais le faire à peu près". Animateur : Est-ce que c'est encore le fait que ça te semble pas assez sérieux ? FS : Bien, ça l'air d'un jeu, c'est pour ça [il sourit]. Tu le fais vite vite, ça l'air d'un jeu - c'est pour ça.
61	"**a nicer texture**" , as well as "**instruments**" and "**colors**" that "look more real" – may help provide "a greater impression that [the environment] was real" Of course, the nearer it gets to reality, the more you will feel part of that world. You'll forget your surroundings and you'll really concentrate on [the simulation].	admettons que tu mettais une belle texture en bois avec, quasiment des photos - ça ferait différent... peut-être que t'aurais plus l'impression que c'est vrai. Oui, c'est sur que plus ça se rapproche de la réalité, plus tu vas entrer dans le monde dans le fond. Tu vas oublier ce qui est autour et tu vas vraiment te concentrer là-dessus.

62	It's not just entering data and getting answers in return. You actually manipulate things. There is uncertainty involved. And it really emphasizes that there is a stake in error [on measurements].	Ce n'est pas juste d'entrer des données et ça te donne des réponses. Tu manipules des affaires. Tu as de l'incertitude dessus. Et ça met vraiment l'emphase sur- que t'as un jeu d'erreur.
63	approximate measure, yet still precise	mesure approximative mais quand même précise
64	Interviewer: Is it normal or strange to ask you to assess uncertainty here? FS: No, no… That's always fine: no instrument can be 100% reliable. And furthermore, with this software, you realize that the purpose is to simulate something [so] you have some error [uncertainty].	Animateur : Est-ce que tu trouves ça bizarre ou normal que l'on te demande d'évaluer l'incertitude là-dedans ? FS : Non, non.. C'est toujours correcte. Tout instrument peut pas être sûr à 100%. Puis encore là, sur ce logiciel là, tu te rends compte que c'est pour simuler quelque chose : tu as une erreur en quelque part.
65	Interviewer: What does this [work]space represent? FS: Well it's as if the camcorder was connected to a flat video screen placed on the ground [facing upwards]. You would have your instruments there and you could work on the screen. […] It looks like a smooth screen – if this were in reality, you could put the objects [i.e. instruments] on it.	Animateur : Qu'est-ce que ça représente l'ensemble de cet espace là ? FS : Bien c'est comme si ta caméra serait connectée à un écran vidéo plat à terre. Et là tu aurais les instruments et tu pourrais jouer dessus. […] Ça l'air d'un écran lisse – si c'était en réalité, tu pourrais mettre des objets dessus [il pointe les outils].
66	Everybody is a bit like Saint-Thomas," he claimed. "You'd like to get into the machine and really launch [the disk] yourself."	Tout le monde est [comme Saint] Thomas un peu. Tu aimerais ça te mettre dans la machine et vraiment le lancer [le disque] toi-même.
67	Interviewer: What's going on? GT: Well, when [the disk] hits one side of the table, it keeps going so I imagine – like I saw in the film [i.e. the video clip] – that [the side of the table] is like an elastic that perpetuates the motion. […] Interviewer: So why was the 20cm [marker] put there [in the simulation]? GT: In my opinion, it's to give the scale of reality. Interviewer: And where is reality? GT: Reality is what we saw in the film – the merry-go-round. […] In comparison to the film, we see that it is realistic and that 15 people can sit on the bench [in the merry-go-round], so the size [i.e. the scale] seems realistic to me.	Animateur : Qu'est-ce qui se passe ? GT : Bon, quand il [le disque] percute un mur, il continue donc j'imagine que - comme j'avais vu dans le film [la séquence vidéo] - c'est comme une bande élastique qui perpétue le mouvement. […] Animateur : Donc, le [marqueur de] 20 centimètres, pourquoi il a été mis là ? GT : C'est justement. D'après moi, c'est pour donner l'échelle de la réalité. Animateur : La réalité, où est-elle ? GT : La réalité, c'est ce qu'on a vu dans le film - l'espèce de manège.[…] Comparé au film, on peut voir que c'est réaliste et qu'il y a une quinzaine de personnes qui peuvent s'asseoir sur les bancs, comme ils disaient - c'est ça 15 personnes -donc, ça me semble une grandeur réaliste.
68	[…] the object [the disk] may not move at the same speed or… I really have to tell you that it will never be the same; the object will never move like the real one even if it starts at the same position, [and you launch it] with the same force. Given that the computer does not account for everything that happens in reality, I would not obtain the same [experimental] results at the end. It may be close,	[…] ton objet se déplacera peut-être pas à la même vitesse ou... C'est sûr, il faut vraiment que... je veux vraiment te dire que ça sera jamais pareille; ton objet ira jamais vraiment comme le vrai - même si tu le parts à la même place, à la même force, vu que ton ordinateur ne tient pas tout ce qui se passe en réalité en ligne de compte, j'aurais pas les même résultats à la fin. Peut-être que ça va se

	though. But you will never have the same results. So you would have three types of results: the theoretical result [i.e. prediction] shared by all, the result obtained with [the VPLab] and the result that you really would get in reality.	rapprocher par exemple. Mais tu n'auras pas les mêmes résultats. Donc tu aurais trois sortes de résultats : le résultat théorique que tout le monde va avoir, le résultat que tu as avec ça [il pointe l'écran] et le résultat que tu as vraiment en réalité.
69	Paraphrase: it was good to include possibilities for errors on measurements when "simulating a real experiment"– absent that, he said, "experimental results would be practically the same as theoretical results [i.e. predictions].."	Vu qu'il essaie de reproduire la réalité, il n'est pas comme un ordinateur qui va me donner exactement [la quantité voulue]. Parce que là, c'est sûr que les résultats théoriques vont être pratiquement la même chose que les résultats pratiques si tu étais capable de 'snapper' – d'avoir la vraie distance. Dans ce cadre là d'une expérience réelle, oui c'est bon.
70	A computer is perfect. When you activate the air-cushion pump, it's precise. The pump produces constant pressure. So, this is data that will be more precise on a computer than in reality. The computer does not account for all, all, all of what is in reality so it's certain that your results will be almost perfect compared to reality.	C'est parfait un ordinateur. Quand tu parts ta pompe, c'est précis. Ta pompe, elle, te donne une pression constante. Donc ça c'est une donnée que tu vas avoir - en plus sur un ordinateur plus précis que dans la réalité. Ton ordinateur ne tient pas compte de tout, tout, tout ce qu'il y a en réalité donc c'est sûr que ça va être presque parfait tes réponses comparées à la réalité.
71	So we say that experimental reality cannot get close to theoretical simulation.	On dit que la réalité ne peut pas approcher la simulation théorique.
72	This is good. It's a lot like real results. I think it's a good way [to do things] on a computer because in reality you don't need to record since you're there, you see, you handle [apparatus], and you collect your results at the same time.	C'est bon. Ça ressemble pas mal à un résultat réel. Je pense que c'est une bonne manière sur un ordinateur parce que réellement [dans la réalité], tu n'as pas besoin d'enregistrement parce que tu es là, tu vois, tu manipules, tu prends les résultats en même temps.
73	did not know how the ruler worked	Je ne sais toujours pas comment la règle fonctionne.
74	It's like when you look at a design drawing, working for a firm. They tell you not to measure on the drawing even if it is scaled – no! – really, because this lacks precision. But here we're talking about physical experiment. That's why my point of view is changing a bit because I've been thinking too much in terms of components production…	C'est comme quand on regarde un dessin en entreprise, ils nous disent de ne pas mesurer dessus même si tu pouvais faire l'échelle - NON ! - c'est justement à cause du manque d'un manque de précision. Mais là, on parle d'une expérience physique. C'est pour ça que mon point de vue change un peu parce que je suis trop dans le point de vue Production...
75	[…] because in reality, I would have trouble measuring distances between instant 1 and instant 2 [i.e. at different time indexes]. I would almost have to stop the camera – pause the camera – and determine a path on the television screen, and then roughly assess its length.	[…] parce que moi, en réalité j'aurais de la misère à mesurer les distances entre un tel nombre de moment [de temps] et [un autre] tel nombre de moment. Il faudrait quasiment que j'arrête la caméra - que je fasse des pauses sur la caméra - et que je détermine à l'écran de la télévision, un sillage et que je détermine à peu près c'est quoi la longueur de ça.
76	Driving a real car as opposed to driving a car simulator does not provide the same feeling.	Conduire une vraie voiture ou conduire un simulateur de voiture, c'est pas le même feeling.
77	HU: I feel more at ease when taking measurements [in an actual lab]; you can take the sheet [of carbon paper] and work directly on it without having to factor in a [scale] ratio.	HU : Je me sens plus à l'aise pour mesurer [...] [en labo] on peut prendre la feuille et travailler directement sur la feuille, on n'a pas à tenir compte d'un ratio.

	Interviewer: It's having to factor in the scale ratio that… HU: Well, not necessarily. It's just faster [in an actual lab]… there's no zoom […] With [the VPLab], the concept is good except that you have to go through two or three steps in order to obtain a measurement. Interviewer: The measurement manipulations themselves are morse fastidious? HU: Yes, a bit. Here, I measured three distances and it took me some time to do so, whereas, had I been in a lab, it could have taken me only one minute… On the other hand, it couldn't have been any faster [on a computer]. I don't see a way of making it faster [on a computer].	Animateur : C'est le fait de tenir compte d'un ratio qui ? HU : Bien pas nécessairement, c'est juste le fait que ça mesure plus vite... il n'y a pas de zoom. […] Ça ici [avec le LVP] le concept est bon, sauf qu'il faut que tu fasses deux ou trois étapes pour pouvoir mesurer. Animateur : La manipulation comme telle, pour mesurer est plus fastidieuse ? HU : Oui un petit peu. Comme là, j'ai mesurer trois distances et ça m'a pris un bout de temps tandis que - avoir été dans un labo, ça peut prendre 1 min... Quoique le concept [du LVP]... ça ne peut pas être bien bien plus rapide que ça. Je ne vois pas aucune manière que ça pourrait être plus vite que ça [sur un ordinateur].
78	I always think that it's experimental so [the procedure] can't be computer-driven; we have to do things ourselves.	Je pense toujours que c'est expérimental donc il ne faut pas que ça soit informatique, il faut que ça soit nous autres vraiment qui fassent les choses.
79	Interviewer: What do you think about assessing uncertainty with software, in an environment like this one? Do you think it's normal? HU: Yes, it's normal. What I like about this is that it's the same as in a lab: it's nothing less, nothing more. In a lab, you can forgo assessing uncertainty, if you so desire – you're free – you can forget about it if you want. There is nothing to tell you: "Here, you have a column [in your notebook] to note uncertainty." [Instead:] "I give you a blank notebook and you do what you want with the columns. You write what you want at the top."	Animateur : Qu'est-ce que tu penses de calculer les incertitudes dans un environnement comme ça, dans un logiciel comme ça ? Est-ce que tu trouves ça normal ? HU : Oui, c'est normal. Moi ce que j'aime de ça, c'est que c'est pareil comme ça se passe en laboratoire, c'est rien de plus, c'est rien de moins. En laboratoire, tu peux ne pas prendre les incertitudes si tu veux - t'es libre - tu peux les oublier si tu veux. Il n'y a rien qui te dis : t'as une colonne [dans le cahier] ici là pour l'incertitude. "Moi je te donne un cahier de note qui est blanc et tu fais ce que tu veux avec les colonnes, tu écris ce que tu veux en haut..."
80	It's good because we see that the disk is somewhat slowing down. Because having absolutely no friction is impossible.	C'est quand même bon parce qu'on voit que la rondelle a un certain ralentissement [le disque a ralenti un peu]. Parce que ça ne se peut pas un frottement qui est zéro, zéro, zéro [un frottement nul], ça ne se peut pas.
81	If it is intentional, it must be replicated because there's a reason [for it]… but my impression is that if they were to construct another merry-go-round and wanted to do away with the vibrations, they would manage it. However, I think it's good to produce a simulation which represents, as much as possible, what it's like to really do the experiment. […] If you look at real flight simulators, they include wind turbulence; [for] a racecar simulator, it's the condition of tires and adherence to the road… it's good to account for as many things as possible.	Si c'est voulu, il faut le reproduire parce qu'il y a une raison ... mais j'ai l'impression que s'ils ont à refaire un autre manège comme ça [au palais de la découverte] et ils ne veulent pas de vibrations, ils vont s'arranger pour qu'il n'y en ait pas. Mais je trouve ça bien de produire une simulation qui représente le plus possible ce que c'est de vraiment faire l'expérience. Moi c'est sur qu'une simulation c'est de reproduire le plus possible la réalité. Je regarde les vrais simulateurs de vol, ils vont tenir compte du vent des turbulences, ou un simulateur de course, c'est la condition des pneus et l'adhérence... c'est bon de tenir compte d'autant de choses que possible.
82	In a simulator," he said "the same thing could happen maybe but, well… you do a RESET and	Dans un simulateur, ça pourrait peut-être faire la même chose mais, bon tu fais un RESET puis tu

	you start over	recommences.
83	"reflected" "was faithful to an experimentation" "I can measure and do the same steps"	Ça reflète Fidèle à une expérimentation Je peux mesurer puis retrouver les mêmes étapes
84	I would expect that the faster [the merry-go-round] goes, the more [the disk] should move about but that's not what they said in the video clip, so it's normal that it doesn't do this.	Si je ralentis [le manège...] je m'attendrais à plus je vais vite, plus qu'il se déplace mais ce n'est pas ça qu'ils disaient dans la présentation donc c'est normal que ça fasse pas ça.
85	IV: […] when they introduced the simulation [in the video-clip], there was a man there [beside the air-cushion table]. But now [in the simulation], nobody's there. So, I imagine that if I'm the man, I have to be there and bring the disk […] Interviewer: Does it give you the impression that you are the man [in the video clip] or is it... IV: Well, I'm looking to do the experimentation but as I saw in the video clip, it was the man who initiated the [disk's] motion. Because, if I start the pump and do nothing else, nothing happens. However, if I start the pump and I give [the disk] a little push, it is going to start moving.	IV : quand on présente la simulation, il y a un petit bonhomme ici [elle pointe à droite de la table]. Là, il n'y a rien. Donc là j'imagine que si moi, je suis le petit bonhomme en question, il faut que je me place ici [elle pointe à droite de la table].Donc j'approcherais ça [elle approche le disque du côté droit de la table…] Animateur : Est-ce que tu ça te donne l'impression que tu es le petit bonhomme en question ou tu cherches plutôt ? IV : Bien je cherche à faire l'expérience mais comme je voyais dans la présentation, c'est le monsieur qui actionnait le mouvement. Parce que si je parts la pompe [elle part la pompe] mais que je fais aucun mouvement [elle ne fait pas de manipulation du disque], il ne se passe rien. Toutefois, si je parts la pompe et que je donne un petit élan [elle lance le disque lentement], ça va se déplacer.
86	IV: Uh… there's no friction – of course, there is always… [The disk] should always keep moving slightly. It should not stop that much or [it should only stop] after a very, very long time. Interviewer: Would you say that there is uncertainty as to the presence of friction? Would you say that presently, you are not sure whether friction exists or not [on the table]? IV: Yes… Well no, but I know that in real life, it is impossible to have [a surface] with absolutely no friction. It is logical that this [simulation] should account for that. But the uncertainty comes from me – by which I mean: what happens if there's friction and what happens if there isn't any? It's me and not the software. Interviewer: If there weren't any friction… IV: If there weren't any, [the disk] would always keep moving slightly and it would continue the motion it was given. Interviewer: And, if there were friction [on the table]? IV: Eventually, it would stop. Interviewer: What do you observe at this moment? IV: I observe that [the simulation] is representing	IV : Là... euh, il n'y a pas de frottement - c'est sur il va toujours y avoir.... [elle fait une grimace et semble incertaine]. Il devrait toujours continuer à bouger un peu. Il ne devrait pas arrêter tant que ça, ou [il devrait arrêter] après un très très très long temps. Animateur : Pour toi, est-ce qu'il y a une incertitude quant au frottement ? Est-ce que tu dirais que présentement, tu n'es pas certaine s'il y a un frottement ou... IV : Oui...Bien non mais je le sais que dans la vie, ça ne se peut pas quelque chose qui n'a absolument aucun frottement. Que ça [la simulation] le représente, c'est logique. Mais, l'incertitude du au frottement vient de moi. Dans le sens où qu'est-ce que ça fait s'il y a du frottement ou s'il n'y en a pas ? C'est plus ça l'incertitude. C'est plus moi que le logiciel en question. Animateur : S'il n'y avait pas de frottement... IV : S'il n'y en avait pas, ça continuerait toujours à bouger un petit peu puis ça continuerait toujours à faire le mouvement qu'on lui a imprégné. Animateur : S'il y en avait ? IV : Éventuellement, ça arrêterait.

	a situation where [the disk] really tends to stop eventually, so I think that there is a tiny bit of friction somewhere. To conclude, I think that reality is well represented by this.	Animateur : Et présentement ce que tu remarques... IV : Ce que je remarque, c'est que ça représente le fait que ça tend vraiment à arrêter éventuellement donc, il y a un mini frottement quelconque. Je pense que ça représente bien la réalité - si je fais une conclusion.
87	logical if one wanted to make a true simulation that represented reality	si on veut faire une vraie simulation et représenter la réalité, c'est logique que ça [le ruban] arrête à me moment donné.
88	I have the impression of looking at… by analogy, it's as if I were looking at an oscilloscope and I could take measurements directly on the screen. […] It gives me the impression that I could be in front of a screen which, I hope, would be very flat […]	J'ai l'impression d'être devant... bien comme si j'étais devant, par analogie, un oscilloscope où je pourrais aller prendre des mesures directement sur l'écran. […] Ça me donne l'impression que je pourrais aller devant un écran qui serait, j'espère, très plat [elle rapproche ses mains de l'écran et éloigne sa main droite de sa main gauche comme si elle tenait un galon ou une règle] et que je pourrais mesurer ce que j'ai à mesurer.
89	[…] it isn't reality which is inside [the computer], because that with which you feed the computer is the stuff of theory.	[…] là-dedans [l'ordinateur], le réel n'est pas là parce que ce avec quoi tu le nourris ton ordinateur pour générer ton expérience, c'est du théorique.
90	[…] if it looked real, I think that people would believe it more – I would believe it more. But it's still a computer […] For example, if I were in a virtual reality where time dilation [a concept in the theory of relativity] would be demonstrated, maybe I would be more inclined to believe it in there [as opposed to with the VPLab], simply because it would have the sensation of being more real. At the same time, though, I could tell myself: "Yes, but this is a computer, so…"	[…] si ça avait l'air vrai, je pense que les gens croiraient plus, que je croirais plus mais c'est vraiment un ordinateur aussi. […] Mais par exemple si j'étais dans une réalité virtuelle et que quelque chose montrait qu'en effet, il y a une dilatation du temps, peut-être que je serais plus porté à le croire comme ça [avec la RV] que comme ça [elle pointe l'écran], simplement parce que ça la sensation d'être plus vrai quand c'est comme ça [avec le casque]. Mais en même temps, je pourrais me dire : "Oui mais c'est l'ordinateur donc..."
91	[…] it truly is like reality, for if the air-cushion was perfect – really ideal – then [the disk] would keep on going forever. This, however, gives you a taste of how things really happen.	[…] c'est vraiment comme la réalité. Parce que si le coussin d'air était parfait - vraiment idéal - alors ça [le mouvement du disque] continuerait toujours. Mais là, ça donne un goût de comment ça se passe vraiment.
92	sometimes things are not so pretty [in reality]	Il va falloir qu'il sache qu'il y a des fois où les choses ne sont pas si jolies.
93	KX: You can have errors in a lab, but here [in the VPLab] you have nothing– it's simulated: there is no source of randomness which comes into play. In a lab, you learn to be precise, but here all you have to do is… that is, unless errors of randomness appear [in the simulation]. Interviewer: Is it possible, or is it plausible that these errors exist [in the VPLab]? KX: Well, I don't know if they've been programmed. Interviewer: Is that something you would normally expect, or on contrary not at all?	KX : Tu peux aussi avoir des erreurs dans un laboratoire alors qu'ici, tu n'as rien, c'est simulé : il n'y a aucune source de hasard qui entre en jeu. Dans un labo, tu apprends à être précis alors qu'ici tu n'as juste qu'à - tout est simulé, à moins qu'il y ait des erreurs de hasards qui apparaissent là... Animateur : Est-ce que c'est possible ou est-ce que c'est plausible qu'il y en ait ? KX : Bien, je ne sais pas si elles ont été programmées. Animateur : Est-ce que ça serait quelque chose à laquelle tu t'attendrais habituellement ou pas du

	expect, or on contrary not at all? KX: No, because later you have to find out why the randomness [i.e. the error] has occurred and that would be a bit complicated, as opposed to a a lab where you can always say: "Yeah, I know, I launched [the disk] incorrectly… etc." […] It's more complex [in an actual lab]. Here [in the VPLab], you have a limited number of variables which can come into play […] you can't simulate reality perfectly. So, I think that it would be much better in a lab.	tout ? KX : Non, parce qu'après, trouver pourquoi le hasard a eu lieu, ça serait un peu compliqué tandis que dans un labo tu peux toujours dire : "Oui, je sais, j'ai mal lancé... et tout", etc. […] Bien c'est parce que c'est plus complexe. Parce que là tu as un nombre limité de variables qui peuvent entrer en jeu tandis que dans un labo réel, tout entre en ligne de compte. C'est beaucoup plus une situation réelle que [celle qui est] simulée parce que tu ne peux pas simuler parfaitement la réalité. Alors, je crois que ça serait beaucoup mieux en lab.
94	[…] if it is previously indicated that this is truly a model of a real situation, including those types of errors, then [such a simulation] would be very good in fact.	[…] si c'est indiqué que c'est vraiment une modélisation d'une situation réelle, y compris des erreurs comme ça, là ça serait bien. Ça serait, en fait, vraiment bien.
95	an environment where conditions are perfectly controlled	ton environnement est parfaitement contrôlé
96	That's just it: with a computer, theoretically you can enjoy much more precision than in a real experiment so it seems to me that [the VPLab] should take advantage of this a little.	Parce que justement, avec un ordinateur, tu es capable d'être théoriquement beaucoup plus précis qu'avec une vraie expérience donc il me semble que ça [il pointe l'ordinateur] devrait faire ressortir ça un peu.
97	Interviewer: Does it seem either normal or strange that we should ask you to evaluate uncertainty in this case? More or less normal? KX: Uh… It's quite normal since the [tape measure's] ring makes it imprecise enough. Absent that, I would find it a bit strange given that with a computer you can [usually] obtain as much precision as you desire… unless the context is such that one of the objectives of the lab report is to perform statistical analysis.	Animateur : Est-ce que ça te paraît normal ou étrange qu'on te demande de calculer l'incertitude dans ce cas-là - ou plus ou moins normal ? KX : Euh... Non, c'est quand même assez normal comme c'est assez imprécis à cause de l'anneau. Mais s'il n'y avait pas d'anneau, je trouverais ça un peu étrange comme on peut être aussi précis qu'on veut avec un ordinateur, sauf dans le cadre où le but du rapport, c'est aussi de faire de l'analyse statistique.
98	board that presents results in an animated way	c'est juste un tableau de résultats finalement, mais c'est animé
99	I converted it using the scale – I converted it to real life centimeters.	Je l'ai convertie avec l'échelle - je l'ai convertie en centimètres, dans la vie réelle
100	I think it has good potential. Small improvements could be made – I could easily give it 3 or 4, say 3,5 [on a 5-point scale, with 4 signifying: high potential].	Je trouve qu'il a un bon potentiel. Selon - il y aurait peut-être des petites améliorations - ça pourrait être facilement 3 ou 4. Trois point cinq [3.5].
101	Obvious things should be given. Things that you have to learn [in an actual lab] should be learned [in the virtual lab], but you shouldn't have to learn to measure with a tape measure.	Les choses évidentes devraient être données. Les choses qu'il faut apprendre, on les apprend mais mesurer avec un tape tu n'apprends pas ça...
102	totally react [according] to theory	réagit totalement à la théorie
103	I expect that [the simulation] would take into account all physical factors involved – when you do an experiment, you take all physical factors into account, except if it is specified from the start that	Je m'attends à ce que ça tienne compte de tous les facteurs physiques ; quand tu fais une expérimentation, tu tiens compte de tous les facteurs physiques, sauf si c'est dit vraiment au

	[including a given factor] would exceed the experiment's objectives [i.e. that it would not be useful to attain its objectives] […] this is just being honest with the student […] if you tell him, he understands that something which goes on [in reality] is not represented [by the simulation] because it exceeds the course's content or something like that…	début, que ça dépasse les compétences de l'expériences : telle chose, telle chose, telle chose […] c'est être honnête avec la personne. […] si tu lui dis, elle comprend que c'est peut-être pas au programme sauf qu'il y a quelque chose qui se passe pareil qui n'est pas représenté parce que ça dépasse le contenu ou quelque chose comme ça...
104	I think that this is perfect given that it would be used for an introductory course. I imagine that it would be clearly written, etc. In my opinion, you don't expect more than this – this is what you expect. Anyway, when you do an introductory lab experiment like this, there are some things that you neglect. The teacher says: "Neglect this type of friction or this other thing." For sure, it won't be perfect there either. You expect that too. It rounds off. It's just to show you that it tends towards what theory predicts – you don't see perfect theory.	Moi je trouve ça parfait [il pointe l'écran] compte tenu des limitations que ça va être un cours d'introduction. J'imagine que ça va être bien écrit, etc. Tu ne t'attends pas à plus, tu t'attends à ça d'après moi. De toute façon, quand tu fais un laboratoire comme ça d'introduction, comme je disais, il y des choses que tu négliges. Le prof. dit : "Bon bien néglige tel frottement ou telle chose". C'est sûr que ça ne sera pas parfait là non plus. Tu t'attends à ça aussi. Ça arrondis en gros. C'est juste pour montrer que ça tend vers la théorie sans avoir la théorie parfaite.
105	It's normal: you always have to assess uncertainty on all measurements, with all instruments.	C'est normal : il faut tout le temps que tu évalues l'incertitude sur tous tes appareils, toutes tes mesures
106	I find that making measurements on a television screen, in a simple case like this one, is… well, it's artificial. I can't imagine circumstances where this could be advantageous compared to leaving a trace [on carbon paper]. […] I would tend to say that the approach itself does not seem realistic: to film a sequence so you can later make measurements as on a video image… it's a bit gadgety… However, I imagine it's hard to do otherwise on a computer.	Faire des mesures sur un écran de télévision dans un cas simple comme ça [l'expérience en question], je trouve ça ... bien c'est artificiel. Je ne vois pas dans quelle occasion ça serait avantageux de faire ça plutôt que de laisser tracer.... [sur un papier carbone] […] J'aurais tendance à dire que la démarche elle-même n'a pas l'air réaliste : le fait de filmer une séquence pour ensuite aller mesurer comme sur l'image vidéo .... oui... ça fait un peu gadget... je ne le sais pas... mais en même temps c'est difficile de faire autrement à l'ordinateur j'imagine.
107	I wouldn't say it is futile, because you always have to deal with uncertainty. I would say that it is artificial. Uncertainty [in the VPLab] is induced by poor resolution of the image. Well…you do have to introduce uncertainty somewhere…	Je ne dirais pas que c'est futile, parce qu'il faut toujours tenir compte de l'incertitude. Je dirais que c'est artificiel. Que l'incertitude est un peu provoquée par la mauvaise résolution de l'image. Bon [en haussant les épaules] c'est sur qu'il faut introduire une incertitude en quelque part là...
108	MZ: My results would be way off, even considering experimental uncertainty? Interviewer: Yes. Maybe that has happened to you in the past? MZ: Yes. But in this case, I would tend to say that it would still be my fault. Even if this is software, I would not think that it is the simulation's fault – all in all, the laws of physics pertaining to this are simple enough. I would trust it.	MZ : Je suis loin de la prédiction même compte tenu des incertitudes ? Animateur : Oui. Ça t'es peut-être déjà arrivé ? MZ : Oui. J'aurais tendance à dire même dans ce cas là que c'est de ma faute quand même. Même si c'est un programme, je ne croirais pas que c'est la faute de la simulation. Somme toute, les lois de la physique là dedans sont assez simples. J'aurais quand même confiance en ce qui me donne.