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Temporal patterns of memory source incorporations into dreams and their relationships to dreamed locus of control.

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Résumé

Les incorporations des mémoires épisodiques dans les rêves apparaissent en formes fragmentées et suivent un modèle temporel distinct qui suit une courbe sinusoïdale. Ce modèle est caractérisé par les incorporations immédiates, qui apparaissent 1-2 jours après l'événement (effet de résidus diurnes), et les incorporations tardives, qui apparaissent 5-7 jours après l'événement (effet de délai). Ces deux effets sont considérés comme des liens entre les processus de consolidation de la mémoire et la formation du rêve. Cette courbe temporelle a été observée pour une variété de stimuli expérimentaux. Cependant, aucune étude à date n'a démontré que le contenu des rêves réagit aux événements diurnes d'une manière plus générale et non-spécifique. Le but de notre étude était d'examiner si deux événements qualitativement distincts, un séjour nocturne au laboratoire (LAB), considéré comme un événement interpersonnel, et une tâche de réalité virtuelle (RV), considérée comme un événement non-interpersonnel, sont intégrés de façon différente dans le contenu onirique. Selon nos hypothèses, 1) les éléments spécifiques liés au LAB et à RV seraient incorporés dans les rêves avec des patrons tendances temporels différents, et 2) les incorporations spécifiques seraient associées à des changements plus généraux dans le locus de contrôle (LoC) du rêve. Vingt-six participants ont passé une nuit dans le laboratoire, ont été exposé à une tâche de RV, et ont rempli un journal de rêve pendant 10 jours. Les rapports de rêve ont été cotés pour les éléments spécifiques portant sur LAB et sur RV, et pour l'évolution générale de LoC du rêve.

Nos deux hypothèses ont été confirmées: 1) les incorporations de LAB et RV sont négativement corrélées et apparaissent dans le rêve selon des modèles temporels différents. Les incorporations du LAB ont suivi une courbe sinusoïdale en forme de U, avec un effet de résidu diurne et un effet de délai. Les incorporations de RV ont suivi un patron différent, et ont eu un maximum d'incorporations au jour 4. 2) les scores du LoC du rêve étaient plus externes pour le jour 1 (max incorporations du LAB) et plus internes pour le jour 4 (max incorporations de RV). Ces modèles d'incorporation distincts peuvent refléter des différences dans la façon dont les deux événements ont été traités par les processus de consolidation de la mémoire. Dans ce cas, une expérience interpersonnelle (LAB) était incorporée plus tôt dans le temps. Les résultats suggèrent que LoC du rêve reflète les processus de mémoire plus généraux, qui affectent le contenu du rêve entier, et qui sont partiellement indépendants des incorporations spécifiques.

Mots-clés: Rêves, mémoire, effet de résidu diurne, effet de délai, locus de contrôle

Abstract

Memories for a daytime event reappear in fragmented form in dream content following a distinct, U-shaped, temporal pattern: immediate incorporations appear on days 1-2 after the event (day-residue effect) and delayed incorporation appear on days 5-7 after the event (dream-lag effect). These two effects are thought to reflect memory consolidation processes linked with dreaming. The U-shaped pattern has been observed for a variety of experimental stimuli, however, no studies have investigated whether dream content also reacts to daytime events in a more general or non-specific way. The aim of this study was to examine whether two qualitatively distinct events, an overnight laboratory (LAB) stay, considered as an interpersonal event, and virtual reality maze task (VR), considered as a non-interpersonal event, are incorporated differently into dream content. We expected that 1) specific elements related to the LAB and VR events would be expressed with different temporal patterns, and 2) these specific incorporations would be associated with more general changes in Dream locus of control (LoC). 26 participants spent one night in the laboratory, underwent a VR maze task, and kept a dream diary for 10 days. Dream reports were scored for specific LAB and VR elements and for general changes in Dream LoC.

Two main findings confirmed our expectations: 1) LAB and VR incorporations were inversely related and exhibited distinct temporal patterns. LAB incorporations were U-shaped with both day-residue and dream-lag effects. VR incorporations followed a different pattern, with a peak on day 4. 2) Dream LoC scores were more external for day 1 (peak of LAB incorporations) and more internal for day 4 (peak of VR incorporations). These different incorporation patterns may reflect differences in how memory consolidation processes dealt with the two events, with the interpersonal experience being incorporated earlier in time. Dream LoC findings may reflect more general memory processes that are partially independent from the specific incorporations and that affect construction of the whole dream narrative.

Keywords: Dreams, Memory, Day-residue effect, Dream-lag effect, Locus of control

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List of Abbreviations

CTL	Control
LoC	Locus of control
EEG	Electroencephalogram
EKG	Electrocardiogram
EMG	Electromyogram
EOG	Electrooculogram
LAB	Laboratory
NREM	Non rapid eye movement
PSG	Polysomnography
REM	Rapid eye movement
TRN	Training
TWC	Total word count
VR	Virtual reality
WC	Word count

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1. Introduction

1.1 Overview

The present work examines temporal patterns of memory source incorporations into dream content, and relates these incorporations to the dream locus of control. Much recent research in the cognitive neurosciences has been concerned with uncovering the mechanisms of interplay between sleep, memory and dreams. It is now generally accepted that sleep plays an important role in consolidation of memory, however, the role of dreams in these processes remains unclear. While it does seem clear that dream narratives borrow their material from memories, the role of daily experiences in dream formation processes, and the mechanisms of memory source expression in dream content are not well understood. The first part of this thesis addresses the question of the relationship between daytime experiences of different types and how their expression in dream content changes over time. In the second part of the thesis, I consider dream production through the prism of intersubjectivity, and consider dreams as having two sources of agency: self, conceptualized as the protagonist in the dream, and non-self, considered to include everything else in the dream that is external to self and possesses agency in effectuating change.

The Introduction section is divided into six parts. Part 1 is a brief review of human sleep, its basic functions, and its role in memory consolidation. Part 2 summarizes current knowledge on dream recall from different stages of sleep. In Part 3, dreaming as considered in the present study is defined. Part 4 is a discussion of the relationship between daytime experiences and their incorporation into dream content, with a consideration of the possible roles for dreaming in memory consolidation. Part 5 introduces the notion of temporal patterns of memory sources incorporations into dreams, characterized by such concepts as day-residue and dream-lag effects. Part 6 presents evidence for the dual nature of human intersubjectivity, consisting of both self and non-self factors, and introduces a new measure of Dream Locus of Control used in the present study.

1.2. Human sleep plays a role in memory consolidation

1.2.1. Brief overview of human sleep

1.2.1.2. Defining sleep electrophysiologically

All animals sleep. That they would spend significant portions of their lives relatively unaware of their environments and thus vulnerable to predators suggests that sleep is indispensible to their survival. In the domain of neurophysiology, polysomnography (PSG) – a non-invasive method of measuring electric brain, eye movement, and muscle activity though surface electrodes, is currently the basis for defining sleep and its stages.

When the electroencephalogram (EEG) was first used to record brain activity during sleep (Loomis, Harvey, & Hobart, 1937), human sleep episodes were divided into 5 distinct stages, from wake to deep sleep, based upon a progression of EEG changes (A through E), starting with stage A, marked by a predominance of Alpha activity, i.e. relaxed wakefulness; and progressing through stages with slower oscillations to stage E, labeled as 'Random' and characterized by random or regular bursts of "slow large potentials". After the discovery of rapid eye movement (REM) sleep (Aserinsky & Kleitman, 1953), sleep stages were re-classified into stages 1 to 4 of NREM (non-REM) sleep and REM sleep (Dement & Kleitman, 1957a) and the criteria for defining them were consolidated and standardized (Rechtschaffen & Kales, 1968). A version of the latter manual is still used in most sleep laboratories today, although a more recent manual (AASM, 2007) has modified some of the original criteria (e.g., eliminating the distinction between Stages 3 and 4 sleep).

In brief, the standard EEG, EOG and EMG criteria for sleep staging specify that A) Stage 1 sleep starts at sleep onset and is characterized by progressive replacement of alpha activity (8-13 Hz) by predominantly theta (4-7 Hz) activity; B) Stage 2, accounting for nearly 50% of adult sleep, is marked by bursts of fast activity of short duration known as sleep spindles (11-16 Hz) as well as by slower frequency K complexes (brief, negative, high voltage peak, followed by a slower positive, then another negative, peak); C) Stages 3 and 4 are often considered together as slow wave sleep (SWS), deep sleep or delta sleep; delta activity (0.5-2 Hz) must occupy at least 20% of each 30-sec epoch for Stage 3 or 50% for Stage 4 (Aldrich, 1999); D) REM sleep is characterized by mixed fast frequency EEG activity, large amplitude synchronous eye movements, and dramatically reduced levels of chin muscle tone (atonia).

Additionally, many sleep laboratories now supplement the standard PSG criteria with measurements of other distinctive physiological systems to assess disorders of sleep. Electrocardiogram (EKG) is often added for recording of heart rhythm, thus allowing for diagnosis of some heart diseases; pulse oxymetry is used to determine blood oxygen saturation, and nasal and oral airflow are measured with pressure transducers or thermocouples to allow for diagnosis of sleep-related breathing disorders, such as sleep apneas; and limb EMG may be added for diagnosis of Periodic Limb Movement Disorder (PLMD).

1.2.1.3. Functions of sleep

The precise functions of sleep remain largely obscure and likely entail a complex interplay between numerous cognitive and physiological processes.

Contrary to the earlier understanding of sleep as a passive period of rest, a recent and growing body of empirical findings now describes multiple functions for sleep, and it seems that hardly any waking process is completely independent of its sleep-dependent counterpart. For instance, sleep (and REM sleep in particular) has been implicated in important ontogenetic processes, contributing to the formation of neuronal connections in infancy (Pringuey, Tible, & Cherikh, 2009), when the highest levels of brain plasticity are seen. Circadian restorative functions have long been thought to depend on sleep-wake interactions, and recent evidence shows that some immune system functions that fluctuate with circadian rhythms peak during the nighttime (e.g., circulating naïve T-cells, production of proinflammatory cytokines), while others peak during the day (e.g., cytotoxic effector leucocytes, production of anti-inflammatory cytokines) (Lange, Dimitrov, & Born, 2010; Marshall & Born, 2002). Sleep's role in enhancing immunological memory formation following vaccinations has also been noted (Lange, Dimitrov, Bollinger, Diekelmann, & Born, 2011).

The complexity of functional studies of sleep is exacerbated by findings demonstrating that both sleep duration and sleep architecture change rather dramatically across the lifespan (Cajochen, Munch, Knoblauch, Blatter, & Wirz-Justice, 2006; Feinberg & Campbell, 2010), suggesting that the developmental, physiological and cognitive functions of sleep and its different stages may also change with time.

In addition to neurochemical, physiological and developmental functions, sleep-dependent processes have been implicated in a number of interconnected mental and cognitive processes, including emotion regulation (Walker, 2009), creativity, and problem-solving (Chavez-Eakle & Chavez-Sanchez, 2011; Drago et al., 2011). Sleep-dependent learning and memory consolidation have received special attention in recent years, and will be discussed in more detail in the next section.

1.2.2. Sleep is implicated in memory consolidation

Converging evidence now supports the notion that sleep contributes to consolidation of both procedural and declarative types of memory, i.e., memory for how to execute certain actions and for general knowledge, respectively (Axmacher, Haupt, Fernandez, Elger, & Fell, 2008; Diekelmann, Wilhelm, & Born, 2009; Maquet, 2001; Peigneux, Laureys, Delbeuck, & Maquet, 2001; Peigneux, Schmitz, & Willems, 2007; Stickgold, 2005; Stickgold & Walker, 2007; Walker & Stickgold, 2004; Wamsley & Stickgold, 2010). Based on findings from animal models, it is now widely accepted that the hippocampus is central to both types of memory, modulating relationships among neocortical memory traces in order to transfer selected memories from short-term to long-term storage (Ferrara et al., 2008; Greene, 2007; Marshall & Born, 2007; Wilson, 2002). These offline sleep-dependent memory processes likely play an important role in the life-long processes of learning and experience-dependent synaptic plasticity (Aton et al., 2009; Benington & Frank, 2003; Sengpiel, 2001; Smith, 1996; Steriade & Timofeev, 2003; Tononi & Cirelli, 2001; Walker, 2004; Wilson, 2002).

Traditionally, the consolidation of procedural memories has been associated with REM sleep (Smith, Nixon, & Nader, 2004), while declarative memory consolidation has been associated with NREM sleep (Tucker & Fishbein, 2008; Tucker et al., 2006). However, REM sleep-dependent consolidation of declarative memories has also been reported (Rauchs et al., 2004) and there is evidence that REM sleep plays a special role in consolidation of emotional memories (Nishida, Pearsall, Buckner, & Walker, 2009; Wagner, Gais, & Born, 2001).

While there is little doubt in the scientific community that sleep plays some role in memory consolidation (although see Siegel, 2001; Vertes & Eastman, 2000), many empirical findings suggest that NREM sleep, and especially SWS, contributes to the reactivation and transference of memories from short-term to long-term storage (for review see (Born & Wilhelm, 2011). A smaller, but growing literature indicates that REM sleep is preferentially implicated in the consolidation of emotional memory (Nishida, et al., 2009). Emotional memory consolidation has been linked to amygdalar activity, which is known to be enhanced during REM sleep (Maquet et al., 1996; Nofzinger, 2005), and which likely reflects a complex pattern of communication between amygdala, hippocampus and neocortex. All of these regions are necessary for the consolidation of emotional events (Pare, Collins, & Pelletier, 2002; Pelletier & Pare, 2004). A recent study of motor learning (Peters, Smith, & Smith, 2007) showed that an individual's initial skill level for a learning task predicts changes in sleep microarchitecture, with both Stage 2 sleep spindles and REM eye movement density being markers of memory improvements . This suggests that the relationship between a type of memory and the sleep stage that is beneficial for its consolidation is not a simple, one-to-one correspondence. Rather, a more nuanced picture is emerging that reflects the complex and multifactorial nature of memory systems, sleep neurophysiology, and the role of subjective experiences in both waking and sleep. For example, the 'sequential hypothesis', based on rat learning studies (Ambrosini & Giuditta, 2001; Giuditta et al., 1995; Giuditta, Mandile, Montagnese, Piscopo, & Vescia, 2003), posits that information processing by the brain is a continuous process that requires the participation of wake, SWS and REM sleep mechanisms as indispensible ‘stages’ of selection and consolidation of relevant memories.

In sum, recent research provides support for a memory consolidation function of sleep. While REM sleep is preferentially implicated in the consolidation of procedural and emotional memories, NREM sleep is implicated in declarative memories. An emerging view is that both REM and NREM are both indispensable for integrating human memories in a sequential and coherent manner.

1.3. Dreams are recalled from all stages of sleep

1.3.1. Dreams have been sampled from both REM and NREM sleep

Since the early observations by Aserinsky and Kleitman linking the regularly recurring periods of eye movements with sleep mentation (Aserinsky & Kleitman, 1953), REM sleep and dreaming have been seen by many as nearly synonymous phenomena. Some researchers have even equated REM sleep time with dreaming time , and the eye movements of REM sleep to the saccadic eye movements of an alert participant ‘scanning’ events in the dream (Dement & Kleitman, 1957b; Herman et al., 1984; Roffwarg, Dement, Muzio, & Fisher, 1962).

And while there is ample evidence that individuals awakened from REM sleep will recall a dream at least 80% of the time (see Nielsen, 2000; Hobson et al, 2000 for reviews), it is also common to find that dreaming is recalled from NREM sleep—albeit less often (~50% of awakenings). The most dramatic examples of NREM dreaming come from observations of hypnagogic images in sleep onset Stage 1 sleep: participants who are awakened at the appropriate moment when falling asleep (for example, Stage 1 theta sleep – (Hayashi, Katoh, & Hori, 1999; Hori, 1982; Nielsen et al., 2005), almost invariably report dreamlike mentation. There is also evidence linking Stage 2 sleep to the recall of dreams that are short in duration and that resemble waking thoughts. For instance, in one study (Noreika, Valli, Lahtela, & Revonsuo, 2009), 30% of early NREM sleep awakenings (mostly sleep stages 2 and 3) led to dream reports, 39% led to reports of 'white dreaming' (impressions of having dreamt without remembering specific content); and 31% to complete failures of recall. Slow wave sleep (SWS), which consists of Stages 3 and 4 sleep has also been linked to some degree of dreaming (Cavallero, Cicogna, Natale, Occhionero, & Zito, 1992; Cicogna, Natale, Occhionero, & Bosinelli, 2000).

In general, research suggests that NREM sleep dreams are less numerous, shorter, less vivid, less emotional and described by dreamers as less 'dreamlike' than are REM dreams; REM dreams are usually more immersive, perceptually engaging and emotional in nature (McNamara, McLaren, & Durso, 2007; McNamara, McLaren, Smith, Brown, & Stickgold, 2005; Smith et al., 2004; Suzuki, et al., 2004; Wamsley, et al., 2007).

1.3.1.1. Different theories purport to explain REM and NREM dreaming

Based on such evidence, two opposing positions about dream formation emerged. Whereas some argued that REM and NREM sleep physiological differences explain differences in REM and NREM dreaming (Hobson & McCarley, 1977), others claimed that the physiological mechanisms of dreaming (both REM and NREM) are the same regardless of sleep stage (Solms, 2000). The ‘covert REM’ hypothesis (Nielsen, 2000) was proposed as a compromise between these two positions, and has since gained some empirical support (Bodizs, Sverteczki, Lazar, & Halasz, 2005; Bodizs, Sverteczki, & Meszaros, 2008; Nielsen, et al., 2005; Suzuki et al., 2004). This model reconciles the opposing views by suggesting that REM sleep processes appear in other, NREM, stages of sleep, thus triggering occurrences of mentation outside of clear-cut REM sleep periods as defined by the standard scoring manuals. Circadian and ultradian processes, with underlying changes in hormone secretion (Payne, 2010) and cortical activations that affect REM and NREM mentation equally, have also been proposed to play a role in dream production (Antrobus, Kondo, Reinsel, & Fein, 1995; Nielsen, 2004, 2010b; Wamsley, Hirota, Tucker, Smith, & Antrobus, 2007). For example, dream report length and quality (intensity, dreamlike quality, etc.) change across the night, and this whether dream reports are obtained from REM or NREM sleep. Several theories address qualitative differences in dream content and their relation to REM and NREM sleep’s distinctive physiology. For instance, in a meta-analysis of REM sleep imaging studies it was suggested (Maquet et al., 2005) that relative deactivation in inferior and middle frontal as well as inferior parietal areas during REM sleep may in part account for such characteristics of REM sleep dreaming as altered access to episodic and autobiographical information as well as to alterations in the executive function which are commonly associated with REM sleep dreaming.

1.4. Definition of dreaming and issues with dream recall

A number of definitions of dreaming have been proposed. Dreaming is accepted by many theorists to be: “a convincing simulation of waking reality experience” (see review in Nielsen, 2010a), a perspective that includes all perceptual, sensory and cognitive activity that is experienced during dreaming, and that appreciates the phenomenological richness and complexity of dream experiences. For the purposes of the current study, we define dreaming inclusively as ‘any remembered mental activity that occurs during sleep’ and we accepted as dreaming whatever such mental activity our participants described in their own reports. An important ontological distinction has been made between the dreaming process, the experience of the dream, a remembered dream and a reported dream (Domhoff, 2010). These four components, although essential for a full understanding of the dreaming mind, likely depend upon different underlying mechanisms and are subject to different biases and distortions, including participants’ own introspective abilities, sometimes seen as inherently unreliable (Nisbett & Wilson, 1977). We took steps to minimize the influence of these factors in our dream collection procedures (see later section).

Two main methodologies are typically used to obtain dream reports: 1) laboratory awakenings with subsequent interviews, and 2) home dream diaries. Both methods have their strengths and weaknesses. While one might consider laboratory awakenings to be the most empirically rigorous, since sleep stages can be targeted with great temporal resolution and dream reports collected and clarified with little distraction, it is also well known that the laboratory environment modifies sleep in a number of ways. Basic sleep architecture, especially that of REM sleep, is altered on the first night in the laboratory—what is referred to as the 'first night effect' (Curcio, Ferrara, Piergianni, Fratello, & De Gennaro, 2004; Moser, Kloesch, Fischmeister, Bauer, & Zeitlhofer, 2010; Rotenberg et al., 1997). The laboratory may also inhibit expression of the variability of dreaming; it has been observed that nightmares appear with a much lower frequency in the laboratory environment than at home. The laboratory experience also has a high chance of being incorporated into the dream narrative (for a review see (Schredl, 2008), a fact that will be addressed in more detail later in this work.

On the other hand, home sleep diaries likely restrict the sampling of dreams to those that take place during the last REM sleep period of the night. Home sampling is also vulnerable to participants failing to comply with study requirements. However, the main advantages of home dream diaries are that 1) home and laboratory dreams differ very little in content (Domhoff, 2003; Domhoff & Schneider, 1998). When method of reporting is the same (i.e., tape-recorder) both at home and in the laboratory, laboratory dreams differed from home dreams only in containing less impulse-related dream content, more specifically, less verbal and physical aggression

(Weisz & Foulkes, 1970).; 2) home dreams are elicited under typical sleeping routines, and 3) home dreams can be collected easily in long series, allowing them to be used for prospective studies of changes in dream content over time (see later section on the temporal patterns of dream content). In contemporary dream research, methods of dream sampling by home dream diaries has been validated by numerous researchers (Foulkes, 1979; Weisz & Foulkes, 1970; Zadra, Nielsen, & Donderi, 1998).

With such considerations in mind, in the present study we collected dreams both from late night REM sleep awakenings in the laboratory and from prospective dream diaries at home. Further, we implemented procedures for training participants to improve their recall of dreams and to render their dream experiences more accurately into typewritten reports. These procedures involved selecting participants who were objectively tested to be high on verbal and typing skills, training them to identify subtle features of dream content, and providing them with a specific format for typing out their dream reports (Nielsen, et al., in preparation).

1.5. Memory sources of dreams implicate dreaming in memory consolidation

1.5.1. A role for dreaming in memory consolidation is consistent with REM sleep neurophysiology

Growing evidence from studies of autobiographical memory and sleep-dependent memory consolidation is raising possibilities for how dreams may play a role in memory processing. It has been proposed that dreaming draws from all available memories and knowledge (Foulkes, 1985) and that its content both reflects and complements the functioning of memory systems during both sleep and wakefulness (Botman & Crovitz, 1989-1990; Grenier et al., 2005).

Consistent with current knowledge of the mechanisms of sleep-dependent memory consolidation, dreaming has been hypothesized to play an important role in this process. While dreams employ personal memories as building blocks, only a small percentage of dreams, 1-2%, contain complete episodic replays, i.e., depict the exact setting, characters and actions of an autobiographical event (Fosse, Fosse, Hobson, & Stickgold, 2003; Schwartz, 2003). Rather, most dreams use only fragments of episodic memories (e.g., a setting, a character, an action) as raw materials for building new contexts (Nielsen & Stenstrom, 2005).While it is known that autobiographical memory heavily depends on the recruitment of fronto-temporal regions (Cabeza & St Jacques, 2007), its relative inhibition during REM sleep (Hobson, Pace-Schott, & Stickgold, 2000) attests to the possibility that during dreaming, when one is relatively disconnected from autobiographic awareness, the processes of selecting and reactivating episodic memories may have very different functions from those of NREM sleep or when awake (Carr, Jadhav, & Frank, 2011). It has been suggested (Stenstrom, 2011) that while the role of NREM sleep may be to help consolidate memories, including to create stable connections between various memory elements, the role of REM sleep, and, particularly, dreaming, may lie in the loosening of these connections in favor of plasticity and creativity (Stickgold, Scott, Rittenhouse, & Hobson, 1999). Indeed, in one study it was found that the memory elements that appear together in a single, short, sleep onset dream often are temporally distant and semantically proximal, thus supporting the idea of dreams' role in creating novel connections between existing knowledge and memories (Nielsen, 1991-1992) Stenstrom et al, in preparation) . The isolated fragments of different memories that appear in dreams probably reflect underlying memory processes. Even though these processes are not yet well understood, the traceable elements in dream content are now widely seen as indicative of the functioning of memory processes.

In sum, evidence from both dream studies and neurophysiology suggest that REM sleep dreaming may play a special role in the consolidation of memory that is complementary to that of NREM sleep. In particular, dreaming may mobilize creativity and cognitive plasticity necessary for contextualizing new knowledge in a flexible manner.

1.5.2. Dream content is sensitive to waking experiences

There are broad differences in theories about how dreaming is related to waking events. Since Freud (Freud, 1994 (1900)) introduced the view of dreaming as a window into the workings of the waking mind, a number of theories dealing with both continuities and discontinuities between waking and dreaming experiences have been developed. Views on the relationship between dreaming and waking processes range from seeing dreaming as ‘cognitively deficient’ (Kahn & Hobson, 2005; Kahn, Stickgold, Pace-Schott, & Hobson, 2000) or akin to schizophrenic delusions (Gottesmann, 2006; Limosani, D'Agostino, Manzone, & Scarone, 2011; Llewellyn, 2009, 2011), to emphasizing general similarities in dreaming and waking cognition, e.g., the preservation of logical rigor in both (Kahan, LaBerge, Levitan, & Zimbardo, 1997; Kahan & Laberge, 2010; Wolman & Kozmova, 2007) or the continuity of emotional experience in both (Cartwright, 2010; E. Hartmann, 2010). In a similar vein, dreaming has recently been included in the continuum of ongoing mental activity referred to as the ‘default network’ (Domhoff, 2011; Ioannides, Kostopoulos, Liu, & Fenwick, 2009; Nir & Tononi, 2010).

1.5.2.1. Dreaming’s processing of memories is reflected in dream content

There are numerous methods for assessing dream content (see review in (Winget, Kramer, & Whitman, 1972), but it remains unknown which of these methods reflect the offline processing of memory. In the present study, we consider two dream content measures as candidates for reflecting memory processing: 1) dream incorporations, i.e., references in dream content, however fragmentary, to recently occurring autobiographical events; and 2) dreamed locus of control (LoC), i.e., the relative influence of self vs. non-self sources in control over the outcome of events in the dream. The first of these measures is based on the reasonable assumption that memory processing produces identifiable traces or ‘flags’ in dream content, that dreaming functions by reiterating, directly or indirectly, some features of the newly learned information. This type of measure is now under investigation in studies of dreaming’s role in offline memory processing (e.g., Wamsley & Stickgold, 2010). The second measure is more exploratory in nature and based on the assumption that offline memory processing produces general changes in dream content as well as specific changes. These general changes can be assessed in global dream narrative organization. This type of measure is consistent with the early theory (Jouvet, 1978) that a genetically based programming of the brain takes place during dreaming. These two measures are described in the following sections.

1.5.2.2. Dream incorporations reflect specific recent and remote features of new memories

In this section I first discuss what kinds of experiences are known to be incorporated into dream reports and then introduce the notions of day-residue and dream-lag effects as possible indicators of interpersonal and memory processes during sleep. Studies show that different facets of one’s current situation, including emotional events, physical and psychological health concerns, and even suppressed thoughts all make their way into dream content. Moreover, some research suggests that such incorporations conform, over time, to a U-shaped pattern, with high levels of immediate incorporations 1 or 2 days after a target experience (or day-residue effect) followed by a relative diminution of incorporations 3 to 4 days post-experience, and a re-appearance of higher levels of incorporation 5 to 7 days post-experience (dream-lag effect).

1.5.2.3. Different kinds of experiences are incorporated differently into dream content

Freud recognized the importance of examining a dreamer's current life situation for evidence of dreams' memory sources (Freud, 1994 (1900)). Daily experiences provided accessible material for dream content and the emotional load of such experiences contributed a motivation that was expressed in development of the dream's plot. As will be shown in the following section, contemporary empirical dream research largely confirms Freud's observations outside of the therapeutic context, and expands on them to provide a more nuanced picture of the workings of the dreaming mind in the context of emotional adaptation and memory consolidation. Much research provides evidence for the influence of an individual's life situation (e.g., salient personal experiences, physical and mental health state) on the formation of dream content (Domhoff, 1996). While it is clear that most dream content is combined from a number of different memory sources, some proximal and others more distal, the basis for selection of these memories still remains a contested topic.

Several types of incorporations have been examined empirically. A number of different kinds of stimuli and concerns have been shown to influence dream content, including current concerns and emotions, specific physical sensations such as pain, and even more tacit and subtle phenomena, such as suppressed thoughts.

1.5.2.4 Specific stimuli are often incorporated into dreams.

One line of research deals with the notion that the mental content of dreams is similar to that of waking concerns, thoughts, and emotions, and that the memory processes involved in dream formation are essential to the construction and maintenance of individual self-identity. First, two studies report that dreams of older adult women contain references to current personal goals and reflected processes of reminiscence related to earlier life events, specifically events occurring during adolescence and early adulthood, similar to the mental imagery and reminiscence found in waking state (Cappeliez, 2008; Grenier, et al., 2005). Similarly, Horton and colleagues (Horton, Moulin, & Conway, 2009) report that dream content reflects important periods of life transition that are consistent with the current changing situation of the dreamer; they suggest that these may play a role in the active day-to-day production of self-identity. Individual life context and preoccupations also, unsurprisingly, influence dream content, e.g., animal rights activists reported more animals present in their dreams, as well as friendlier animal interactions than did members of the general public (Lewis, 2008). Moreover, thoughts and emotions, i.e.

almost purely mental phenomena, also influence dream content. A number of studies report the presence of current concerns in dream narratives (Nikles, Brecht, Klinger, & Bursell, 1998); the emotional intensity and complexity in dream reports also seems comparable to those of waking experiences (Nielsen, Deslauriers, & Baylor, 1991).

The dreamer's physical state also plays a role in the generation of dream content. In one study (Raymond, Nielsen, Lavigne, & Choiniere, 2002), burn victims had a high incidence of pain sensations in their dreams; individuals who reported pain dreams were also likely to report more pain during therapeutic procedures.

Finally**,** Freud's proposed compensatory function of dreams, in which thoughts and feelings that are suppressed during wakefulness reappear in dreams has found some empirical support. Unwanted or suppressed thoughts intrude into waking, and increase one's preoccupation with them (Rassin, Merckelbach, & Muris, 2000; Wegner, Schneider, Carter, & White, 1987). Intentionally suppressing a thought (about a person) also increases the likelihood that the target person will appear in a dream on the following night (Wegner, Wenzlaff, & Kozak, 2004). Further, suppressed thoughts are more likely also manifest in the dream content of individuals who have a high tendency to suppress unwanted thoughts (Taylor & Bryant, 2007).

1.5.2.5. Dream incorporations are often of a general nature.

In addition to the specific, easily recognizable, events and concerns that have been shown to extend from waking mentation into dream scenarios, some studies show that the dream narrative also responds to waking stimuli and preoccupations in a more global way, i.e., reflecting themes rather than discrete elements. It is reported in some studies that during periods of stress and trauma, it is often not the traumatic event that is expressed in the dream narrative; rather, the emotional load is attributed to other elements in the dream. In one sample of Palestinian adolescents, those exposed to severe military trauma showed more intense and more emotionally negative dreams (Helminen & Punamaki, 2008). Similarly, in the dreams of children undergoing parental divorce (Proksch & Schredl, 1999), more 'primitivity' and 'unsuccessful roles' were reported, indicating a more global effect of the waking stressor on dream content

Dreams of bereavement have received some attention in that they express different facets of grief, such as an individual's coping mechanisms (Barrett, 1991-1992; Belicki et al, 2003; Garfield, 1996; Kuiken, et al, 2008). In one study (Kuiken, Rindlisbacher, & Nielsen, 1991), a group of participants asked to elaborate on their feelings about a sad film clip reported more subsequent dreams that bore an emotional tone similar to that of the film, while a control group asked to reflect on aesthetic audio-visual qualities of same film reported more dreams with similar action and aesthetic qualities. In a similar vein, presleep affective suggestions given to women with strong snake phobias, were shown to modulate the emotional tone of subsequent dreams (de Koninck & Brunette, 1991).

General effects on dreaming are also discernible as a result of significant historical events. One study of the events of 9/11 (Hartmann & Brezler, 2008) illustrates this point. Forty-four American adults who kept home dream diaries were asked to submit 10 dreams recorded before, and 10 dreams recorded after, the events of 9/11. Significant change was observed in the intensity and proportion of the central image in dreams, even though no exact replays or incorporations of the attacks were reported. Similarly, in our laboratory's study of 23 990 responses to an Internet questionnaire (Nielsen, Stenstrom, & Levin, 2006), a sustained (2-yr) increase in nightmare frequency for male participants between 10 and 29 years of age was observed, but no increase on a specific item testing prevalence of dreams about 'airplanes falling from the sky' (Nielsen, personal communication, 2011).

It is noteworthy that most attempts to influence dream content in a specific way (i.e. by inducing physical sensations, or by auditory stimuli) have not been particularly successful (Rechtschaffen, 1978). However, on a more global level, dreams do seem to respond to stressors, perhaps either in a symbolic manner, or in report length, presence of vestibular sensations, etc. Therefore, it seems that in addition to scoring of clear references to specific target experiences in dreams, it may well be fruitful to assess subtler general changes in dream content in addition to specific incorporations, to better appreciate the multifactorial nature of memory processing in dreams. In the present study, we chose dream locus of control (LoC) as one such measure of a global dream response.

1.6. Dream incorporation changes over several days.

1.6.1. The day-residue effect

The notion of day-residue incorporations into dreams, initially introduced by Freud in the *Interpretation of Dreams* (Freud, 1994 (1900)), referred to a process by which memory elements from the previous day are used as 'raw material' for dream formation. Freud insisted that day-residues appeared in every dream and were accessible to waking consciousness by having participants free-associate to elements of the dream. Contemporary psychodynamic theory has not substantially added to this notion of the day-residue phenomenon, however, the effect has been demonstrated in a number of empirical studies. These include self-observational studies of both morning REM-rich dreams (E Hartmann, 1968; Jouvet, 1979) and hypnagogic images (Nielsen, 1992), and multiple participant studies (Blagrove, Henley-Einion, Barnett, Edwards, & Heidi Seage, 2010; Harlow & Roll, 1992; Malamud & Linder, 1931; Nielsen & Powell, 1992). Harlow and Roll (Harlow & Roll, 1992) report that nearly 50% of dreams in a college student sample (N=88) contained unambiguous day-residue elements, as identified by the participants themselves, leading them to conclude that through a process of free association it would likely be possible to uncover day-residues in every dream as Freud had suggested.

Some studies demonstrating the day-residue effect use either presleep suggestions or placed participants in a particular psychological or physiological state. Among these are studies using induced thirst (Dement & Wolpert, 1958), hunger (Baldridge, Whitman, & Kramer, 1965), social isolation Wood, cited in (Tart, 1965), hypnotic state (Barber, 1962), and kinesthetic stimulation during REM sleep (Nielsen, 1993; Sauvageau, Nielsen, & Montplaisir, 1998). These studies show that dream content often reacts to experimental stimuli in a fragmented, indirect way, suggesting that, in addition to clearly traceable remnants of the waking experience, more subtle general features are also reflected in the dream content.

While most day-residue research is based on home diaries and thus likely concerns dreams occurring from or close to the morning REM period, there is growing experimental evidence that a similar process is at play during NREM sleep, more specifically, at sleep onset and during Stage 2 sleep. First, a study in our own laboratory (Stenstrom, Fox, Solomonova, & Nielsen, under review) demonstrated that a trained participant was able to report 6 (19%) instances of day-residue out of 31 dreams collected during 2 nights of multiple sleep onset awakenings. Second, NREM (Stage 2) day-residue incorporations of a maze task were not only readily identifiable, but were found to predict improved performance on a retest of that task (Wamsley, Tucker, Payne, Benavides, & Stickgold, 2010). Third, day-residue incorporations into NREM sleep mentation following a complex visuomotor task (Alpine Racer arcade game) were found in 30% of reports, with the nature of incorporations changing across the night; they shifted from relatively direct, concrete incorporations to more abstract representations of the original task (Wamsley, Perry, Djonlagic, Reaven, & Stickgold, 2010). Fourth, using the video game Tetris as a stimulus, day-residue incorporations into NREM (sleep onset) mentation were found to be so robust that both healthy controls and anterograde amnesiacs with bilateral medial temporal lesions displayed them (Stickgold, Malia, Maguire, Roddenberry, & O'Connor, 2000). Fifth, Tetris video game incorporations were again found in NREM sleep onset mentation reports (10%), often mixed in with other memory sources (Kusse, Shaffii, Schrouff, Matarazzo, & Maquet, 2011).

A strong day-residue effect has been observed in dreams obtained by experimental awakenings in sleep laboratories. For instance, analyzing REM sleep dreams collected across a number of different studies, Dement and colleagues (W. Dement, E. Kahn, & H. P. Roffwarg, 1965) reported that as many as 22% of reports collected in the laboratory contained unambiguous references to the laboratory situation. In a similar manner, in a review of such studeis, Schredl (Schredl, 2008) observed that direct references to the laboratory setting (i.e., elements that can unambiguously be traced back to the experimental procedures or settings) appear in from as few as 6.2% of laboratory dreams to as many as 32%. Indirect references (e.g., references to *any* laboratory or experiment) have a much higher incidence, ranging from 32% (Baekeland, 1969) to 68% of laboratory dream reports (Whitman, Pierce, Maas, & Baldridge, 1962).

Thus, among the many experimental stimuli that have been investigated for influencing dream content, the laboratory itself has a very high chance of being incorporated into dream content. Due to the robust nature of the laboratory day-residue effect, we chose laboratory incorporations as one of the two target waking stimuli in the present study.

1.6.2. Dream-lag effect

While the day-residue effect has been shown to be robust in numerous studies, the dream-lag effect has been given much less empirical attention and remains more elusive.

There are two basic ways in which dream elements have been traced back to specific life events in the context of empirical dream research: 1) by participants recording their dreams reflecting on their images, and attempting to relate them to an autobiographic incident such as those written in a home diary; and 2) by having participants undergo a common salient experience (e.g., watch an intense film, participate in a virtual reality experiment), and have them prospectively record their dreams for several days. The latter are then scored either by participants or blind judges for the presence of a target element.

The term dream-lag effect was coined by Nielsen and Powell to describe dream incorporations that are delayed by about 6-7 days (Nielsen & Powell, 1989). A series of experiments demonstrated this effect. In the first study (Nielsen & Powell, 1988; Nielsen & Powell, 1989), participants kept a 1-week home dream diary, and then retrospectively wrote down their most significant events from that same week. One significant event was chosen for each participant and matched by blind judges to target elements in the dream reports. Significant events had a higher chance of being incorporated into dream narratives on days 1 and 6 following the event than on days 2 through 5. The second study was designed as a replication of the first, and used 7-day home dream diaries of self-reported high dream recallers, that were completed after participants spent a night in the laboratory. In this case, and similar to the present method, judges rated incorporations of the laboratory situation into dream content. A day-residue effect was found, and a significant 6-day dream-lag effect was replicated. In a third study, a similar temporal pattern was observed for the incorporation of an emotionally arousing video of the ceremonial slaughter of a buffalo, but only for participants who showed high incorporation scores: they exhibited both a day-residue effect on days 1 and 2, and a dream-lag effect on days 5-7 (Powell, Cheung, Nielsen, & Cervenka, 1995). Fourth, a recurrence of incorporation of discrete sources on days 6 and 12 was noted in home dream using personally significant events rated by judges as targets (Nielsen & Powell, 1992). A fifth study revealed that, when asked to trace memory sources for a self-selected home diary dream, participants showed high correspondence between dream elements and memory items related to days 1 and 2, and 5-7; but not related to days 3 and 4 prior to the dream (Nielsen, Kuiken, Alain, Stenstrom, & Powell, 2004); items that were likely to show delayed incorporation were characterized by their interpersonal nature, spatial locations, resolved problems and positive emotions.

It is now known that emotional and impactful events, by virtue of amygdalar mediation, stand a higher chance of being transferred from short-term to long-term memory (Hamann, 2001; LaBar & Cabeza, 2006). This seems also to be true for the incorporation patterns of episodic elements into dream content. Nielsen et al (Nielsen, Alain, Kuiken, & Powell, 2003) showed that dreams that were rated by participants as having high personal impact displayed the day-residue effect, the dream-lag, or both in relation to the self-ascribed memory sources. This effect was evident only for participants who were highly confident in their recall, and only for females. In another study by our group (Lara-Carrasco et al., 2008), selective REM-sleep deprivation was found to disrupt the bimodal pattern of incorporation for emotionally negative visual imagery, which suggests further role for REM sleep in emotional visual stimuli consolidation and for the patterns of incorporation of these events into dream content. The level of involvement seems to play an important role in the likelihood of incorporation: a study of a virtual reality maze (VR maze) experience, participants who were allowed to actively explore the VR maze incorporated more elements from the maze than did a group that only viewed the maze passively (Saucier, 2007). Only the active group exhibited both day-residue and dream lag effects (Nielsen, Saucier, Stenstrom, Solomonova, & Lara-Carrasco, 2007).

Other observations support the notion of the dream-lag effect to varying degrees. First, a pioneer in sleep research, Michel Jouvet, noted the appearance of delayed incorporations of travel experiences in his personal dreams (Jouvet, 1979): readily traceable elements of travel to new locations tended to reappear 7-9 days after leaving on a trip. Also, an early study of Stage 1 NREM sleep mentation (Verdone, 1965) noted that many dream memory sources came from distal events, although precise temporal qualities of these sources were not specified. Second, Roffwarg and colleagues (Roffwarg, Herman, Bowe-Anders, & Tauber, 1978) had participants wear red-colored goggles for several days and showed that incorporations of red elements in early night dream reports were delayed by 5-7 days. Third, Blagrove et al (Blagrove, et al., 2010) had 8 female participants keep dream and waking event diaries at home for 14 days and then asked them to match the two sets of reports. Both day-residue dream-lag effects were reported, i.e., matches between dream content and waking diary entries were higher for days 5-7 than for days 2-4 or for a pre-dream baseline. Fourth, in a laboratory study by the same group (Blagrove et al, 2011) dream-lag was observed for dreams elicited from REM but not from NREM Stage 2 sleep, which suggests that the dream-lag effect may reflect processes of memory consolidation associated preferentially with REM sleep. Fifth, a form of dream-lag effect was shown in a single participant study (Kookoolis, Pace-Schott, & McNamara, 2010) assessing memory sources for dreams from both NREM and REM home awakenings across 25 nights. This participant's matches between dream content elements and home diary entries were found to be time- and sleep stage-dependent, with emotions, settings and characters being incorporated earlier (1-2 days) after the experience and events and objects being incorporated later (3-4 days) after the experience.

In sum, research has demonstrated that waking events are incorporated into dreams both immediately after the event (day-residue effect) and—with some exceptions--after a delay of about 5-7 days (dream-lag effect). When assessed together in the same study, these two effects form a U-shaped curve of dream incorporation that has been replicated on numerous occasions. This temporally patterned incorporation curve has been related to time-dependent processes of hippocampally-mediated memory consolidation (Nielsen & Stenstrom, 2005) in which recently encoded memories are thought to be dependent upon hippocampal processes (day-residue effect) but over the period of about a week are gradually transferred for longer term storage to neocortical regions such as the medial prefrontal cortex (dream-lag effect). It remains unknown whether the occurrence of dreams at these two points in time is an essential aspect of memory processing or whether it is merely an epiphenomenal expression of these underlying memory processes.

1.7. Dream formation can be viewed as due to self and non-self factors

The nature of dream formation and the major factors that govern the coordination of images and emotions in dreams remain largely unexplained. The present work approaches the problem of dream formation by viewing the dream narrative as due to interplay between two main driving forces. The first, referred to as the *self*, is conceptualized as cognitive processes that determine the make-up and actions of the dreamed *protagonist* and its ability to effect change in the dream narrative. The second, referred to as the *non-self*, encompasses the cognitive processes that determine everything in the dream that is external to the protagonist and that has some agency in affecting change in the dream. This includes the representation of other characters, dream settings and even seemingly impersonal events, such as dream weather or atmosphere. This notion of *non-self agency* is conceptually similar to that of the *Other* in intersubjectivity research and philosophy in that it refers to everything that is active and external to the *self* against which the *self* is situated and defined (i.e., Lacan, 1966). The following section briefly describes the latter, non-self, dream formation factor, summarizes some research on intersubjectivity that supports distinguishing self from non-self factors, and introduces a new measure of dream locus of control (LoC), that is used in the present study to assess the interplay between self and non-self sources of agency in the dream.

1.7.1. Description of the non-self factor in dream formation

The notion that dreaming requires a two-process dynamic is not new. Freud insisted that every dream was the result—a compromise-formation—of two competing influences: affect expression (wish-fulfillment) on the one hand and impulse repression (dream-work mechanisms) on the other. However, whereas Freud did not explicitly link these two general factors to only self and non-self processes, more recent theorists have done so to greater or lesser degrees of specificity.

First, a number of theories attributing an emotion regulation function to dreams are consistent with the proposed self/non-self dream formation dynamic. Threat-simulation and fear extinction theories of dream function, derived from current neurobiological and evolutionary perspectives, consider dreaming to be adaptive to an organism's survival by permitting "rehearsal" of adaptive reactions to external threatening situations and thus preparing the dreamer to respond appropriately and effectively to such situations when awake (Revonsuo & Valli, 2008; Valli & Revonsuo, 2009; Valli et al., 2005). While, this position has been challenged on the basis that there is a low percentage of dreams that contain realistic threatening situations with rehearsed responses that are appropriate to the dreamer's waking life situation (Malcolm-Smith & Solms, 2004; Zadra, Desjardins, & Marcotte, 2006; Germain, Nielsen, Zadra, & Monplaisir, 2000), most typical dreams, including those with threatening undercurrents, nonetheless usually involve other characters and emotionally charged settings or objects that are external to the dream protagonist and exert a degree of agency over the unfolding of events in the dream narrative.

Second, research supporting the theory that REM sleep dreams down-regulate the previous day's affect (Cartwright, 1986, 2005; Cartwright, Luten, Young, Mercer, & Bears, 1998; Kramer, 1993a, 1993b) also highlights a role for non-self imagery. Some of this research suggests that regulatory processes produce a condensation of waking affect into a 'central image' constructed from dream elements that are external to the protagonist. This allows regulation of the affective experience through a hierarchy of dreams ranging from 'big dreams' with very intense central images to more mundane dreams with lesser intensity and impact (Hartmann, 2010). The central image thus possesses considerable agency in formation of the dream narrative and realization of its regulatory function. According to the present conceptualization, dreams with more intense and impactful 'central images' are those with relatively higher external dreamed locus of control.

Third, evidence for centrality of the self/non-self dream formation dynamic comes from research on attachment theory examining the notion that different attachment patterns create different mental representations crucial for forming and maintaining relationships with others. Mikulincer and colleagues reported that adult attachment style (anxiety vs. avoidance) predicted the nature of relationships between the dream protagonist and other dream characters, especially in dreams following stressful days; for example, attachment avoidance predicted dreams with negative representations of other characters (Mikulincer, Shaver, & Avihou-Kanza, 2011). Similarly, in the dreams of romantic partners anxious-attached and avoidant-attached individuals were scored higher on stress and conflict dimensions (Selterman & Drigotas, 2009). Two additional studies (McNamara, McLaren, & Durso, 2007; McNamara, McLaren, Smith, Brown, & Stickgold, 2005) reported that social interactions were more common during dreams than during wakefulness and that the interactions in NREM sleep dreams were characteristically dreamer-initiated friendly behaviors, whereas those in REM sleep dreams were aggressive .

Fourth, some of the most striking and experientially intense evidence for the existence of non-self interpersonal experiences in dreaming comes from research on the REM parasomnia sleep paralysis (Cheyne, 2005; Cheyne, Newby-Clark, & Rueffer, 1999). ‘Felt presence’ is an acute sensation of experiencing ‘someone’ or ‘something’ alive as present in the room; it is one of the most frequently occurring hallucinatory experiences accompanying sleep paralysis, causing at times significant distress (Solomonova et al., 2007). Previous research in our laboratory has linked sleep paralysis-related felt presence experiences to both social anxiety traits (Simard & Nielsen, 2005) and a propensity to experience social imagery in the waking state (Solomonova, Nielsen, Stenstrom, Simard, et al., 2008). These links suggest that felt presence might represent an enhanced propensity for non-self social imagery, which can manifest in a variety of both waking and dreaming states and settings (Nielsen, 2007; Solomonova, Frantova, & Nielsen, 2011).

In sum, a variety of theories and research findings highlight a self/non-self dynamic in the formation of dreams and suggest that the non-self factor may even play an important role in dream function. Representations of threat scenarios, central images, attachment figures and the uncanny sense of felt presence all attest to the salience and centrality of the non-self factor. The current project includes an exploratory component in which we assess the relative agency of self vs. non-self imagery in formation of the dream through the use of a novel dream LoC scale.

1.7.2. Supportive intersubjectivity research findings

The idea that people internalize their relationships with others (and, by extension, with the world around them), and that these relationships influence and determine their relational experiences and strategies, as well as their sense of self and of the place in the family, society, and world, has been widely discussed in humanities and cognitive sciences.

In psychoanalytic terms, the *non-self* part of the intersubjectivity tandem is differently expressed as the ‘uncanny’ feeling by Freud (Freud, 1919), as the ‘double’ by Otto Rank (Rank, 1941), or as a Big Other by Lacan (Lacan, 1966), and generally represents a negative or differential ‘projection’ of the *self* onto other people, societal groups and even objects and places.

Some evidence for this dual nature of subjectivity, consisting of both *self* and *non-self* interrelated elements comes from contemporary cognitive sciences research. First, extensive work from attachment theory attests to the paramount importance of the relational strategies and styles for the development of an integrated personality: distortions in representations of self and others contribute to avoidant, anxious-ambivalent and/or insecure attachment styles (Mikulincer, Orbach, & Iavnieli, 1998). Second, since the discovery of ‘mirror neurons’ in the early 1990s (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996) the questions of intersubjectivity, empathy and interdependent association with others were brought into the domain of the cognitive neurosciences. Currently, the human mirror network is thought to be comprised of inferior frontal and superior parietal regions (Iacoboni et al., 1999), but its specificity and distribution remains contested (Bonini & Ferrari, 2011). The ‘mirror matching mechanisms’ are sometimes seen as the organizational feature of the brain, which developmentally is critically dependent on interactions with others (Gallese, 2003). The representational and action brain systems are often seen as inseparable, providing a basis for understanding causal links between imitation, empathy and acculturation (Iacoboni, 2009). Third, the importance of the *self* in development of the stability of body representation and cognitive functioning has also received some attention. Work on the phantom limb phenomenon, a realistic sensation that an amputated limb or an organ is still attached to the body after its excision, suggests that there exists an inborn neural network, a ‘neuromatrix’ (Melzack, 1990), that contributes to the stability of body ownership and representation. This widely distributed network is thought to include parallel somatosensory, limbic and thalamocortical areas (Melzack, 1999). It has also been reported that amputees tend to experience their bodies as whole in their dreams (Alessandria, Vetrugno, Cortelli, & Montagna, 2011), suggesting that stable body image processes may be inborn and are activated during sleep, when sensory input from the site of the missing limb is diminished.

In sum, intersubjectivity research has led to a vast array of findings highlighting a basic dichotomy between *self* and *non-self* imagery in multiple domains of human experience. This includes concepts and findings from disparate areas of both psychoanalysis and the cognitive neurosciences and includes, but is not limited to, key findings about processes of attachment, mirror neurons and the phantom limb phenomenon.

1.7.3. Dreamed Locus of Control

As central as the self-character may be to most dreams, its relational dimension, i.e., its movements in relation to the dream setting and its interactions with other characters, is also key to the narrative structure of dreaming. Not only does the dream self encounter other characters, but s/he is also in an active exchange with features of the dreamed environment. Sometimes the latter is responsive and welcoming, but sometimes also hostile and difficult to negotiate. Thus, while the dream self is often the primary instigator of events in the dream, their driving force is also often situated in *non-self* sources of different kinds. For example, among the most typical dream themes that have been documented are dreams in which the self is either ‘trying again and again to do something’ or ‘being chased or pursued’ by another character (Nielsen, et al., 2003). These typical themes clearly reflect dreams in which the dominant agency resides in either the dreamed self or a non-self source respectively.

The dynamic interplay between self and non-self sources of agency within the dream can be conceptualized and operationalized as a form of locus of control (LoC) within the dream. Just as real world events can be reliably categorized as being effected by primarily internal or primarily external events, so too dream events may be categorized for their predominant source of agency. We consider that the relative influence of internal vs. external sources of agency in dreams may change over time, both within a single dream and across multiple dreams, but we also suggest that individual dreams may be scored globally as being predominantly internal or external in nature.

The original concept of LoC was introduced by Julian Rotter as part of his social learning theory of personality (Rotter, 1954). In this and subsequent personality theories, LoC referred to a stable personality trait represented by a continuum between perceived internality and externality of agency such that individuals generally judge most of their life events to be driven either by other people, chance, or fate (external LoC), or by their own intentions and actions (internal LoC). A number of different psychometric scales have been used to assess relative LoC, including Rotter's original scales (Rotter, 1966), the Duttweiler's Internal Control Scale (Duttweiler, 1984; Meyers & Wong, 1988), the Nowicki-Strickland locus of control scale for children (Nowicki & Strickland, 1973), and several three-dimensional scales that expand the original dichotomy into a 3-way interplay between, e.g., fatalism, social systems control and self control (Reid & Ware, 1974; Schlegel & Crawford, 1976), or chance, powerful others and internality (Levenson, 1974).

In the present study we have modified the 2-dimensional LoC notion to apply specifically to dream narratives. Dream LoC refers to an objective judge's determination of the relative efficacy/control that is exhibited by the dreamed protagonist or non-protagonist sources in effectuating meaningful changes in the dream narrative. We do not consider the measure to reflect a stable personality trait, but rather to assess dynamic shifts between self and non-self sources of agency in the dream. Our adapted LoC measure quantifies the relative weight of contributions by the self and non-self agents to changes in the overall dream narrative.

The notion of dreamed LoC has not been used in dream research. However, LoC as classically defined as a personality trait has been probed (Blagrove & Hartnell, 2000) using Levenson's Locus of Control scale and, even earlier (Blagrove & Tucker, 1994), using Rotter's Locus of Control scale. The latter authors report that frequent lucid dreamers (participants who become aware of dreaming while they are dreaming) score higher on the internality dimension, which they consider to be consistent with the idea that during lucid dreaming the self is typically more able to effectuate control over self-actions and to change elements of the dream scenario. A more recent study (Partick & Durndell, 2004) confirmed this association, concluding that a personality type characterized by high internality, field independence and need for cognition is a characteristic predisposition for lucid dreaming. A number of concepts closely related to locus of control have been investigated in the context of dream-based therapeutic practices. Notions such as agency, self-efficacy, and core conflictual relationship themes (Luborsky & Crits-Christoph, 1990) have often been examined in the therapy setting. In one study, the best predictors of therapeutic process and outcome were dreams that were rated to be positive interpersonal, noninterpersonal and high agency in nature (Hill, Spangler, Sim, & Baumann, 2007). While this might suggest that taking an active role (internal LoC) during therapy leads to a similar dynamic in dreaming experiences, the fact that Hill et al., did not distinguish between internal and external LoC in their assessments of agency throws doubt on this conclusion. Apart from these few studies, then, LoC as a transient characteristic of dream content has not been applied in empirical dream research.

2. Objectives and hypotheses

The first objective of this study is to conceptually replicate previous studies of dream incorporation in such a way that we examine if dreams deal separately with two qualitatively different experimental tasks. This objective will examine how dream content reflects different presleep experiences by incorporating specific, experience-related, elements. The second objective is to determine if dream content reacts to presleep experiences with global changes, i.e., in shifts in the LoC characterizing the dream narrative, and not only in the incorporation of specific, task-related, elements. This objective, too, will involve examining differential responses to two different types of presleep experience.

In this study, the overnight laboratory stay and a VR maze task were treated as separate target experiences. We considered the laboratory experience to be an external LoC situation, i.e., to be relatively more interpersonal, more emotionally charged, and more passive in nature than the VR maze task. Participants underwent a number of experimental interventions, including electrode applications, dream report training, monitoring during sleep, and awakening for an interactive dream collection interview. In contrast, we considered the VR maze task to be an internal LoC situation, i.e., to be relatively more spatial, solitary and emotionally neutral in nature. In this case, participants explored, alone, a virtual maze consisting of several distinct scenes and interacted only with crude virtual characters.

2.1. Hypotheses

1) Incorporation temporal profiles (patterns of incorporation over 10 days) for two distinct presleep experiences (LAB, VR maze) will differ. Differences will be seen especially for the day-residue and dream-lag incorporation effects.

2) Different Dream LoC scores will be associated with the different incorporation profiles observed:

    a. LoC will be primarily external for dreams with LAB incorporations;

    b. LoC will be primarily internal for dreams with VR maze incorporations.

3. Methodology:

3.1 Participants

Twenty-six healthy volunteers (men=10; women=16; average age=26.2 yrs; SD=3.7; range=21-34), self-reported to be free of major physical and psychiatric conditions and medications known to affect sleep and dreaming, were recruited by word of mouth and by advertisements. They were made aware that they were participating in a 14-day study of the memory sources of dreaming. Since daily transmission of home dream reports was an essential requirement of the study, participants were selected who had access to a computer equipped with both text editing software and Internet access. Also, to optimize the accuracy of dream reporting and transcribing, individuals were selected according to the following inclusion criteria: 1) self-reported dream recall of at least 3 dreams per week; 2) self-reported English and French language proficiency; 3) ability to type. Levels of linguistic ability and typing were tested during the laboratory visit. Of the 26 participants, 14 were French native speakers, 6 were English, and 6 reported some other native language but were still proficient in French (N=2) or English (N=4). In total, 16 participants submitted French dream reports and 10 submitted English dream reports. Participants were asked to abstain from consumption of recreational drugs, excessive caffeine, and alcohol for the duration of the study. Participants were given a detailed consent form (Appendix I) and gave signed informed consent. All received monetary compensation (CAD $125) upon completion of the study.

3.2. Experimental setting:

3.2.1. The laboratory

Participants spent 1 night sleeping in the laboratory, where they had 16-channel surface EKG, EMG, EOG, and EEG electrodes installed according to the norms of the international 10-20 system (Niedermeyer & da Silva, 2005). There were no more than two participants present in the laboratory at a time and each slept in a separate isolated room monitored by a video camera. All communication between participants and staff during the night took place through an intercom system.

3.2.1.1 Training sessions

On arriving at the laboratory, participants were randomly assigned to one of two conditions referred to as the training (TRN) and control (CTL) groups. While seated comfortably on the bed, participants in both groups received instructions about how to report their dreams. They were told to pay close attention to their dreams and to reflect on them more than once upon awakening. They were also asked to first report the ‘last 60 seconds’ of their dream, and then the ‘rest of the dream’ before that. They were then asked to reflect on the specific memory sources of their dreams and to date them. These instructions were followed by a dream recall practice procedure that took place both in the evening and the next morning. First, in the evening, they viewed and recalled a short film clip shown on a 19-in computer monitor suspended in front of them while they were seated on the bed. Second, also in the evening, they recalled hypnagogic dreams from 4 consecutive sleep-onset awakenings. Third, in the morning, they recalled a dream from the last REM sleep period of the night. These procedures were part of a larger study of the effects of self-observational training on dream recall and will not be reported in detail here. Some preliminary findings have been presented (Nielsen, 2010; Solomonova, Nielsen, Stenstrom, Lara-Carrasco, et al., 2008), and a manuscript is in preparation (Nielsen et al, in preparation).

3.2.2. Virtual reality (VR) maze task

Once electrodes were removed after the morning awakening, participants underwent a VR maze task. The task, built using the ATARI Unreal Tournament 3 engine (Epic Games Inc.), consisted of an underground maze from which participants had to find an exit. To increase the associated sense of immersion, the maze was presented while participants stood in a darkened room wearing Cybermind 900st hi-resolution goggles with an Intersense InterTrax2 positioning tracker and a 5.1 sound surround system (Sony Home Theater System STR-DE985; 6 Acoustic Research speakers). The goggles allowed participants to navigate the VR environment in a relatively realistic way, with life-like head movements producing corresponding changes of visual angle in the maze. A hand-held mouse (L button) was used to move forward in the maze. Participants were required to navigate 3 different environments that were connected by long granite corridors; these consisted of 1) a collection of indoor industrial-style rooms, 2) an outdoor, snow-covered forest, and 3) a second set of indoor spaces. Once through all of the environments, participants were required to ‘jump’ into a river of lava, an experience that added an aspect of vestibular realism to the experience. Average time for completing the VR maze task was 23.2 min.

(SD=8.15; min=8.67, max=43.00). Images of the VR environments are shown in Appendix II.

3.2.3. Dream diary

Participants kept dream diaries for 4 days prior to the laboratory stayover and for 10 days after, for a total of 14 days. All dream reports were completed at home, except for the post-laboratory day 1, which was completed in the laboratory. Participants typed their dreams in the morning using one of 2 Microsoft Word templates provided for them (Appendix III). For the 4-day pre-laboratory dreams, the template was the same for both TRN and CTL groups and included instructions to first recall and report the 'last 60 seconds' part of the dream, and then report the 'rest of dream', as well as to note any memory sources related to either part of the dream. For the 10-day post-laboratory dreams, the same template was given to participants in the CTL group while a template that reiterated instructions given during the laboratory dream recall training session was given to participants in the TRN group. The latter reminded them to recall and report the 'last 60 seconds' of the dream in detail first, followed by recall and reporting of the 'rest of dream', and then to report memory sources.

3.3. Measures and statistical analyses

3.3.1 Incorporation and locus of control ratings

Two bilingual judges, blind to both training condition and whether each diary dream preceded or followed the laboratory visit, and familiar with the experimental procedures, the laboratory, and the VR task, scored the dreams for a) type and number of elements of the laboratory (LAB); b) type and number of elements of the VR maze task (VR maze); and c) Dream LoC. The degree of directness of LAB and VR maze incorporations was scored on 3-point scales where 0=no incorporation, 1=indirect incorporation, and 2=direct incorporation. The number of elements consisted of a simple tally of all incorporated elements of each type in each part of the dream. Items considered as belonging to the laboratory included, but were not limited to, the experimenters; the hospital environment; the laboratory environment including PCs, amplifiers, electrodes and related equipment; being a participant in an experiment including being monitored while asleep; content from the training film clip. Among the target elements for the maze incorporation were: features of the 3 maze environments including snow, lava, rusted metal, corridors, and doors; being underground; looking for an exit; jumping. Incorporation ratings were made separately for the ‘last 60 seconds’ and ‘rest of dream’ parts of the dream; because preliminary analyses indicated that these two parts of the dream did not differ from each other, the two sets of incorporation ratings and the two element frequency counts were summed to produce a total incorporation rating and a total element frequency count.

Dream locus of control (Dream LoC) was scored on a 7-point Likert-type scale in response to this question: *To what extent did the events in the dream seem to* *be determined by either the protagonist (internal), or the dream characters and/or settings (external) or both?* Scale anchors were: 1=internal; 4=both internal and external; 7=external. Participants' descriptions of memory sources of the dream content were also used by judges in scoring Dream LoC. Dream LoC was evaluated separately for the two parts of the dream 'last 60 seconds'; 'rest of dream') and also combined by averaging the two scores (full dream).

3.3.2. Word counts

Dream length was assessed as a means of controlling for differences in dream report length. Two blind judges used the Total Word Count (TWC) method of Antrobus (Antrobus, 1983) to count all words minus pauses, fillers, corrections, repetitions and commentary. Counts were made separately for 'last 60 seconds' and 'rest of dream' parts of the dream; the TWC was calculated as a sum of these two.

3.3.3. Statistical analyses

Most participants did not report dreams on all days following the laboratory visit. Thus, to increase the number of valid observations available for repeated measures analyses of variance, incorporation scores for adjacent days were averaged (1 and 2, 3 and 4, etc). Because participants underwent the VR maze task on the morning after sleeping in the laboratory; the 1st available day for maze incorporation was the 2nd day of the post-laboratory diary; this resulted in 9 rather than 10 observations for post-maze analyses. Curvilinear incorporation trends (linear, quadratic, cubic) were assessed by one way ANOVAs with combined days (days 1+2, 3+4, 5+6, 7+8 and 9+10) as repeated measures. Differences in incorporation for peak and nadir days were assessed with independent samples t-tests. Differences in Dream LoC on peak and nadir incorporation days were also assessed by independent samples t-tests. All analyses were performed using IBM SPSS Statistics 17 for Mac and PC.

4. Results

4.1. Dream recall and task incorporations

Average post-laboratory dream recall was 6.9 out of 10 days (SD=2.46, min=1, max=10). A total of 180 dreams was collected, of which 178 (98.9%) contained ‘last 60 seconds’ reports and 127 (70.6%) contained ‘rest of dream’ reports. 125 (69.4%) contained both types of report; 53 (29.4%) consisted solely of ‘last 60 seconds’ reports; and 2 (1.1%) contained only ‘rest of dream’ reports. Dreams collected prior to the laboratory visit were assessed separately to determine the effects of training on dream recall and were excluded from most analyses (see forthcoming paper (Nielsen et al, in preparation).

The average number of dreams bearing any LAB incorporations was 1.0 per participant (SD=0.9, min=0, max=3); the average percentage of dreams with LAB incorporations per participant was 16.0% (SD=21.0%, min=0%, max=100%). The average number of dreams with VR maze incorporations was 0.9 (SD=3.0, min=0, max=3) while the average percentage with VR maze incorporations was 12.0% (SD=12.0%; min=0%, max=38%). Six participants (23.1%) did not incorporate either the LAB or the VR maze; 4 participants (15.4%) incorporated the LAB but not the VR maze, while 1 participant (3.9%) incorporated the VR maze but not the LAB experience.

4.1.1. Dream recall and Word Count

Average word count for the ‘last 60 seconds’ part of the dreams was 201.6 (SD=166.7, min=3, max=890); and for the ‘rest of dream’ part was 236.1 (SD=187.6, min=4, max=827). Average full dream TWC for both parts combined was 365.9 words (SD=288.6, min=3, max=1506). Average TWC across the 10 days of the dream diary are shown in Figure 1.

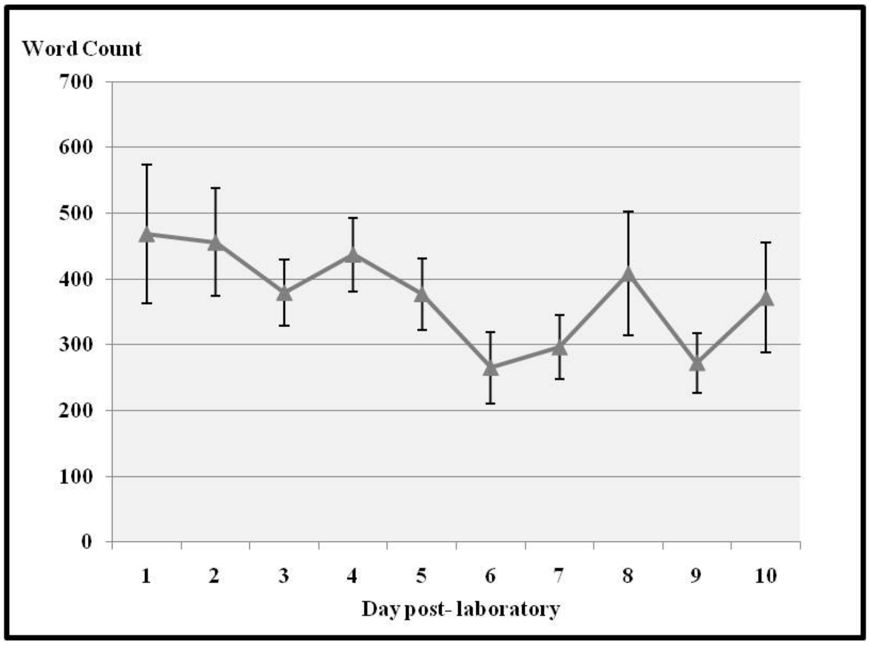

Figure 1 Distribution of mean (±SEM) word count scores for the full dream across the 10-day dream diary.

Independent samples t-tests performed on days with the most and the fewest words (days 1 and 6) revealed a marginally higher TWC score for day 1 (M=468.7, SD=406.88; N=15) than for day 6 (M=265.0, SD=225.22; N=17; t(21.24)=1.72, p=0.10).

Mean TWC did not differ for dreams bearing only LAB (Mean=376.0, SD=259, N=24) or only VR maze (Mean=417.3; SD=214.12; N=24) incorporations (t(44)=.59, p=.56). This comparison excluded the 2 dreams (1.1%) that contained both LAB and VR maze references. For the latter, in 1 case an indirect VR maze incorporation was scored ('last 60 seconds' part), with an indirect incorporation of LAB for the 'rest of dream' part, while in the other, an indirect LAB incorporation was scored ('rest of dream' part) in the same context as a direct VR element.

Some representative excerpts of dream reports scored as direct or indirect incorporations of either LAB or VR maze experiences are presented in Table 1.

Table 1 Examples of laboratory (LAB) and VR maze incorporations in diary dreams with corresponding incorporation elements and Dream LoC score (scored on a 7-point scale: 1=internal, 4=both internal and external, 7=external).

Participant information	Dream excerpt	Day and Type	Elements incorporated	LoC score
Male, 34 years old, TRN group.	"…I feel as if I am inside a *computer game*. It is a *labyrinth… I turn left, then right, then right*, and then continue forward, after more turns" - (translated from French)	Day 3 VR maze	Direct: computer game, labyrinth, navigating a sequence of environments	3
Male, 23 years old, TRN group,	"…walking through my old high school *… up and down various floors*. (…) *the hallways are all apparently empty*, which is strange …"	Day 2 VR maze	Indirect: sequence of empty hallways	4
Female, 23 years old, TRN group	"… I wake up and get out of the *laboratory bedroom*. Laboratory is exactly the same as I saw it yesterday when I went to sleep. I see *my friends L. and A*. there. (…) somebody is taking the *electrodes* off my head…"	Day 1 LAB	Direct: laboratory, electrodes, experimenters	7
Male, 34 years old, CTL group	"… I am being admitted to a *hospital* because I am unable to *remember my dreams*. A *team of doctors* stands over the gurney, telling me that I must be hospitalized for eight days…"	Day 9 LAB	Indirect: hospital, dream recall training, experimenters	7
Male, 23 years old, TRN group	"... A man and his son are discussing some action to take, perhaps how to roll over with all these wires attached. But they are not in bed; the son is on the father`s shoulders, (...). When they decide on what to do, they march toward the point of my perspective, though I feel omnipresent, like when an actor exits the scene by walking toward the camera..."	Day1 LAB	Indirect: wires, bed	7
Male, 22 years old, CTL group	"...Seascape. Night. Awareness of stars, but they were not clear. (...) Quite cartoonish. There were some ''sharks.''... something arrived... the sharks began their defensive movements. The attacking thing retreated (...)They sat there, evenly spaced in front of me, (...) talking	Day1 LAB	Indirect: elements from a film clip presented in the lab	7

4.2. No effect of training on incorporation scores

Independent samples t-tests comparing TRN and CTL groups on LAB and VR maze incorporation scores as well as Dream LoC scores for both ‘last 60 seconds’ and ‘rest of dream’ reports produced no significant differences. Therefore, for all analyses of incorporation and Dream LoC the full dream reports were used.

4.3 Immediate and delayed incorporation effects

Spearman nonparametric correlations revealed a strong relationship between incorporation scores and #elements incorporated (see Table 2). There was a strong positive relationship between incorporation scores and #elements for both LAB and VR maze target elements, and there was a strong negative relationship between LAB incorporation and #elements scores and corresponding VR maze variables. Based on the high degree of redundancy between the directness and #elements measures, we opted to use only the #elements incorporated measure for further analyses of incorporation patterns.

Table 2 Spearman correlations between incorporation directness (INC) scores and corresponding number of target elements (#elements) for laboratory (LAB) and VR maze (VR).

	LAB INC	**LAB #elements**	**VR INC**	**VR #elements**
LAB INC	1.000	.923*	-.890*	-.900*
LAB #elements	.923*	1.000	-.905*	-.915*
VR INC	-.890*	-.905*	1.000	.954*
VR #elements	.954*	-.915*	.954*	1.000

N=46; *p<.001

4.3.1 LAB Incorporations

The #LAB elements incorporated in dreams over the 10 post-laboratory days are displayed in Table 3 and plotted in Figure 2. Most elements were observed for day 1 (M=0.87, SD=1.13), day 2 (M=0.24, SD=0.44), and day 9 (M=0.53. SD=1.12). (Note: The same U-shaped pattern was seen for the directness of incorporation score for LAB elements; the highest scores were on day 1 (M=0.53, SD=0.61), day 2 (M=0.21, SD=0.40) and day 9 (M=0.18, SD=0.34)).

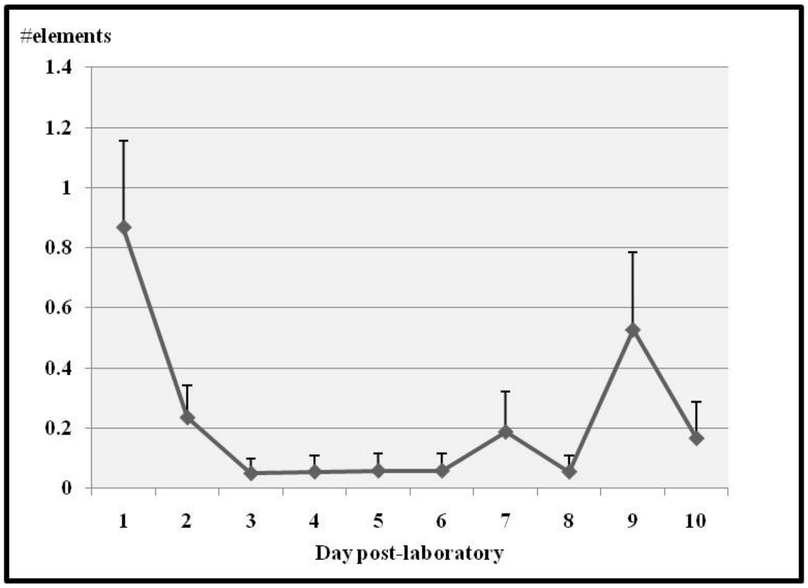

Figure 2 Distribution of scores for the Mean ((±SEM) #LAB elements incorporated over the 10-day dream diary

Table 3 Mean laboratory incorporation scores (±SD): incorporation directness, number of target elements (#elements), and number of dreams bearing any laboratory incorporation across the 10-day dream diary

Day	#elements			Incorporation directness			#dreams
	Full dream	'last 60 seconds	'rest of dream'	Full dream	'last 60 seconds'	'rest of dream'	
1	0.87(±1.13)	0.53(±0.74)	0.56(±1.33)	0.53(±0.61)	0.53(±0.74)	0.33(±0.71)	8
2	0.24(±0.44)	0.19(±0.40)	0.08(±0.28)	0.21(±0.40)	0.19(±0.40)	0.15(±0.55)	4
3	0.05(±0.22)	0.05(±0.22)	0.00(±0.00)	0.03(±0.11)	0.05(±0.22)	0.00(±0.00)	1
4	0.06(±0.24)	0.06(±0.24)	0.00(±0.00)	0.03(±0.12)	0.06(±0.24)	0.00(±0.00)	1
5	0.06(±0.24)	0.06(±0.24)	0.00(±0.00)	0.03(±0.12)	0.06(±0.24)	0.00(±0.00)	1
6	0.06(±0.24)	0.06(±0.24)	0.00(±0.00)	0.06(±0.24)	0.06(±0.24)	0.00(±0.00)	1
7	0.19(±0.54)	0.06(±0.25)	0.22(±0.44)	0.09(±0.27)	0.06(±0.25)	0.22(±0.44)	2
8	0.06(±0.24)	0.00(±0.00)	0.08(±0.28)	0.03(±.012)	0.00(±0.00)	0.08(±0.28)	1
9	0.53(±1.12)	0.17(±0.38)	0.54(±1.33)	0.18(±0.34)	0.22(±0.55)	0.15(±0.38)	5
10	0.17(±0.51)	0.00(±0.00)	0.20(±0.56)	0.08(±0.26)	0.00(±0.00)	0.20(±0.56)	2
All days	0.21(±0.62)	0.11(±0.34)	0.15(±0.62)	0.12(±0.31)	0.11(±0.37)	0.10(±0.37)	27

Trend analyses calculated with an ANOVA with #LAB elements scores for adjacent pairs of days (1+2, 3+4, 5+6, 7+8, 9+10) as repeated measures revealed a quadratic trend (F(1)=9.95, p=.007, N=15) describing a strong day-residue effect on days 1+2 (M=.80, SD=.76), followed by few elements on days 3+4 (M=.13, SD=.35), 5+6 (M=.07, SD=.26), and 7+8 (M=.13, SD=.35) and then a delayed dream-lag effect on days 9+10 (M=.60, SD=1.24). These scores are plotted in Figure 3.

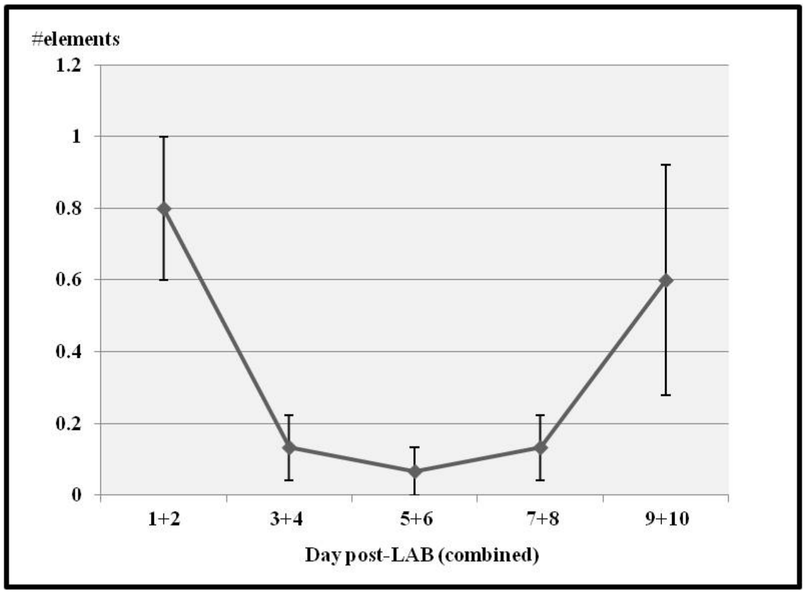

Figure 3 Mean (±SEM) #LAB elements incorporated into diary dreams by combined post-laboratory days.

4.3.2. VR maze Incorporations

The #VR maze elements incorporated over the 9 post-VR days are displayed in Table 4 and plotted in Figure 4. Most elements were observed for day 4 (M=0.35, SD=0.49), day 5 (M=0.41, SD=1.06), and day 8 (M=0.37, SD=1.12).

Table 4 Mean VR maze incorporation scores (±SD): incorporation directness, number of target elements (#elements), and number of dreams bearing any VR maze incorporation across the 10-day dream diary

Day	#elements			Incorporation directness			#dreams
	Full dream	'Last 60 seconds'	'Rest of dream'	Full dream	'Last 60 seconds'	'Rest of dream'	
1	0.12(±0.33)	0.06(±0.25)	0.08(±0.28)	0.12(±0.33)	0.06(±0.25)	0.15(±0.55)	2
2	0.10(±0.31)	0.10(±0.31)	0.00(±0.00)	0.05(±0.15)	0.10(±0.31)	0.00(±0.00)	2
3	0.11(±0.47)	0.06(±0.24)	0.07(±0.26)	0.06(±0.24)	0.06(±0.24)	0.07(±0.26)	1
4	0.35(±0.49)	0.18(±0.39)	0.25(±0.45)	0.21(±0.31)	0.18(±0.39)	0.25(±0.45)	6
5	0.41(±1.06)	0.18(±0.53)	0.44(±1.33)	0.12(±0.28)	0.18(±0.53)	0.11(±0.33)	3
6	0.13(±0.34)	0.06(±0.25)	0.11(±0.33)	0.06(±0.17)	0.06(±0.25)	0.11(±0.33)	2
7	0.22(±0.65)	0.17(±0.51)	0.08(±0.28)	0.08(±0.26)	0.11(±0.32)	0.08(±0.28)	2
8	0.37(±1.12)	0.11(±0.47)	0.38(±0.96)	0.13(±0.40)	0.06(±0.24)	0.31(±0.75)	2
9	0.17(±0.38)	0.06(±0.24)	0.13(±0.35)	0.11(±0.27)	0.06(±0.24)	0.20(±0.56)	3
All days	0.20(±0.61)	0.10(±0.35)	0.14(±0.53)	0.09(±0.26)	0.09(±0.31)	0.13(±0.42)	25

An ANOVA with #VR maze incorporations for adjacent days (days 1+2, 3+4, 5+6, 7+9) as repeated measures did not reveal any statistically significant linear, quadratic or cubic trend. Although the greatest #elements for VR were observed on day 5, the total number of dreams bearing any VR incorporation for this day is 3, whereas 6 dreams with elements were seen for day 4. This is because the #elements score on day 4 was inflated by 1 dream containing 4 discrete VR elements. Therefore, for the following analyses we considered day 4 as having most incorporations and compared it to days 2 and 6, as having comparably low incorporation scores. Independent samples t-tests revealed significantly higher #elements on post-VR maze day 4 (M=.35, SD=.49; N=17) than on day 2 (M=.1, SD=.31; N=20; t(35)=-1.84;

p=.08), as well as a trend for higher #elements on day 4 than on day 6 (M=.13, SD=.34; N=16; t(28.6)=1.55, p=.13).

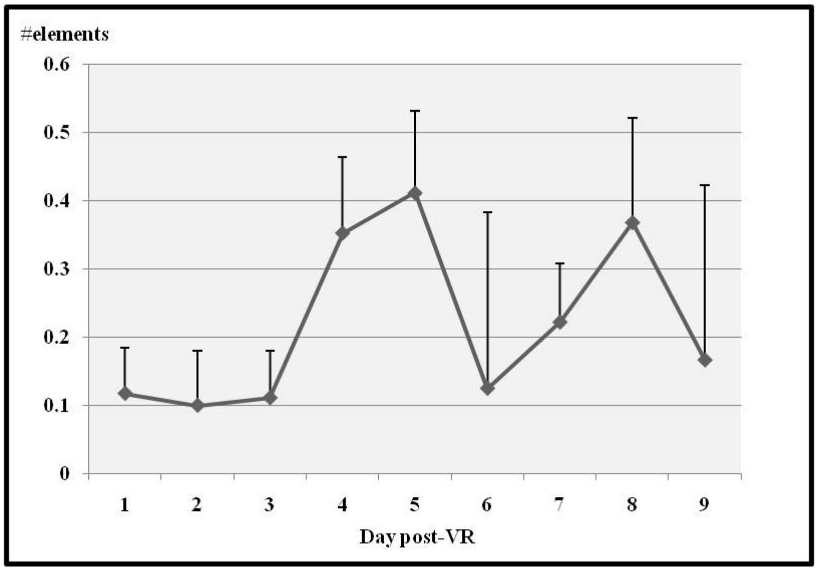

Figure 4 – Distribution of mean (±SEM) VR maze #elements over the 9 dream diary days. Note that although more elements were identified for day 5, more participants with incorporated elements were identified for day 4. Day 4 was therefore selected as the most representative 'peak incorporation' day.

4.4. Locus of control:

Participants reporting no incorporations of any kind over the course of the diary (N=6) were considered 'non-incorporators' and excluded from analyses of Dream LoC.

4.4.1 Dream LoC and incorporation pattern for #LAB elements

Independent samples t-tests performed on days 1 and 5, i.e., post-LAB days with most and least incorporated LAB elements respectively, revealed Dream LoC scores for full dream on day 1 that were significantly more external in nature (M=6.04, SD=1.28; N=13); and scores for day 5 that were more internal in nature (M=4.68, SD=1.65; N=14; t(25)=2.38, p=.025). The same pattern was observed for the 'last 60 seconds' part of the dream (day1: M=6.08, SD=1.56, N=13; day5: M=4.57, SD=1.65, N=14, t(25)=2.44, p=.022), but not for the 'rest of dream' (t(14)=.464, p=.65).

Similar t-tests performed for Dream LoC scores on days 5 and 9 did not reveal any significant differences for full dream, 'last 60 seconds' or 'rest of dream'. These results are plotted in Figure 5.

To test whether the observed Dream LoC differences were independent from the incorporation differences reported above, t-tests were repeated for the same days but with only those dreams containing no incorporations. A partial independence of the two effects was suggested by the fact that Dream LoC scores on days 1 and 5 still produced a trend for more external Dream LoC on day 1 (M=5.64, SD=1.55, N=7) than on day 5 (M=4.53, SD=1.65, N=16) for the full dream (t(21)=1.51, p=.15) as well as for the 'last 60 seconds' (day1: M=5.57, SD=1.90, N=7; day5: M=4.38, SD=1.67, N=17, t(21)=1.52, p=.14), but not for the 'rest of dream' (t(14)=1.00, p=.33).

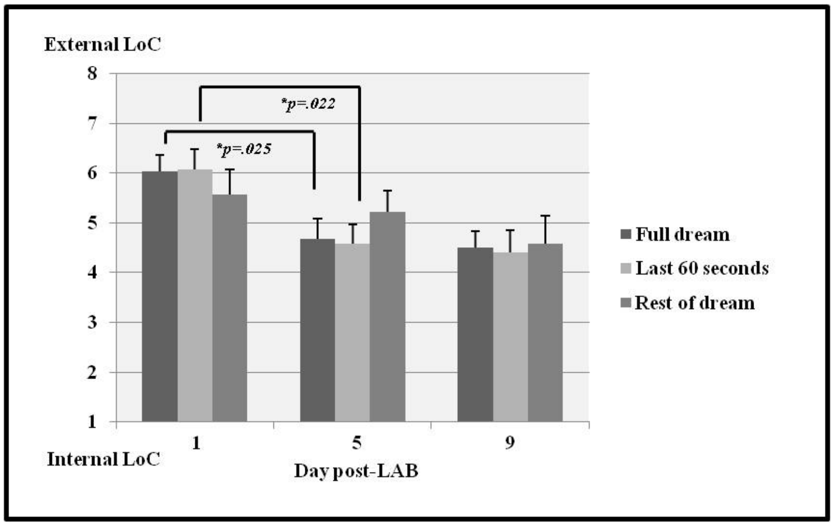

Figure 5 Mean (±SEM) Dream LoC scores for post-LAB days with most (days 1 and 9) and least (day 5) incorporated LAB elements.

4.4.2 Dream LoC and incorporation pattern for #VR maze elements

Similar independent samples t-tests performed on post-VR maze days 2 and 4, i.e., days with the most and least VR incorporations respectively, revealed a pattern opposite to that for LAB elements. For the full dream, there was no significant difference in Dream LoC for days 2 and 4 (day2: M=5.28, SD=1.67, N=16; day 4: M=4.68, SD=1.65, N=14; t(28)=.991, p=0.60). However, for the 'last 60 seconds' there was a more external Dream LoC score on day 2 (M=5.69, SD=1.4, N=16) and a more internal Dream LoC score on day 4 (M=4.57, SD=1.4, N=14; t(28)=2.00, p=.055). For the 'rest of dream', no significant differences for Dream LoC were found for day2 (M=4.64, SD=2.37, N=14) and day 4 (M=5.22, SD=1.48, N=9; t(21)=-.652, p=0.48). Similar analyses performed for days 4 and 6 did not reveal any differences for Dream LoC scores. These results are plotted in Figure 7.

When considering only those dreams without any scored VR incorporation, a repeat of the t-tests did not reveal any statistically significant difference for the Dream LoC scores on days 2 and 4 following VR. However, there was a trend indicating a more internal Dream LoC score on day 4 than on day 2 for the 'last 60 seconds' (day2: M=5.71, SD=1.40, N=17; day4: M=4.73, SD=1.79, N=11, t(26)=1.62, p=.12), but not for the full dream or for the 'rest of dream' Dream LoC scores.

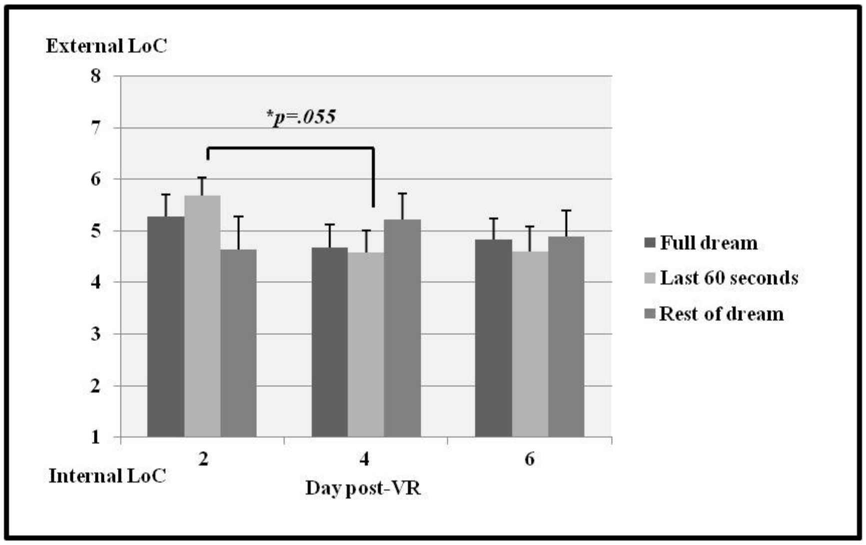

Figure 6 Mean (±SEM) Dream LoC scores for post-VR maze days with least (days 2 and 6) and most (day 4) incorporated VR maze elements

4.4.3 Dream LoC before and after laboratory visit.

To test whether there were differences between Dream LoC scores prior to and after the laboratory visit, we calculated a baseline Dream LoC scores by averaging scores on the 4 days before the LAB visit for full dream, 'last 60 seconds' and ‘rest of dream’. We then compared the baseline Dream LoC scores with those on peak and nadir days of LAB incorporation (days 1, 5 and 9 post-laboratory).

Independent samples t-tests revealed Dream LoC scores significantly higher in externality on day 1 post LAB for full dream (M=6.10, SD=1.21, N=15), than for baseline scores (M=5.13, SD=.69, N=26, t(19.3)=-2.84, p=.010). Similarly, for the ‘last 60 seconds’ Dream LoC was significantly more external on day 1 (M=6.13, SD=1.46, N=15) than for baseline (M=5.12, SD=1.03, N=26, t(39)=-2.60, p=.013). For the ‘rest of dream,’ LoC scores on day 1 were marginally more external (M=5.78, SD=1.40, N=9) than for baseline (M=5.02, SD=.96, N=24, t(31)=-1.78, p=.086).

For the baseline days and day 5 post-LAB (nadir of LAB incorporations and peak of VR incorporations), the independent samples t-tests revealed a non-significant trend for more internal Dream LoC scores on day 5 for the ‘last 60 seconds’ (M=4.47, SD=1.66, N=17) than for baseline (M=5.12, SD=1.03, N=26, t(24.12)=1.44, p=.162). No significant differences were found for full dream or ‘rest of dream’.

Similar independent t-tests for baseline days and day 9 post-LAB (day of recurrence of LAB incorporations) did not reveal any significant differences for full dream ‘last 60 seconds’ and ‘rest of dream’. These results are plotted in Figure 7.

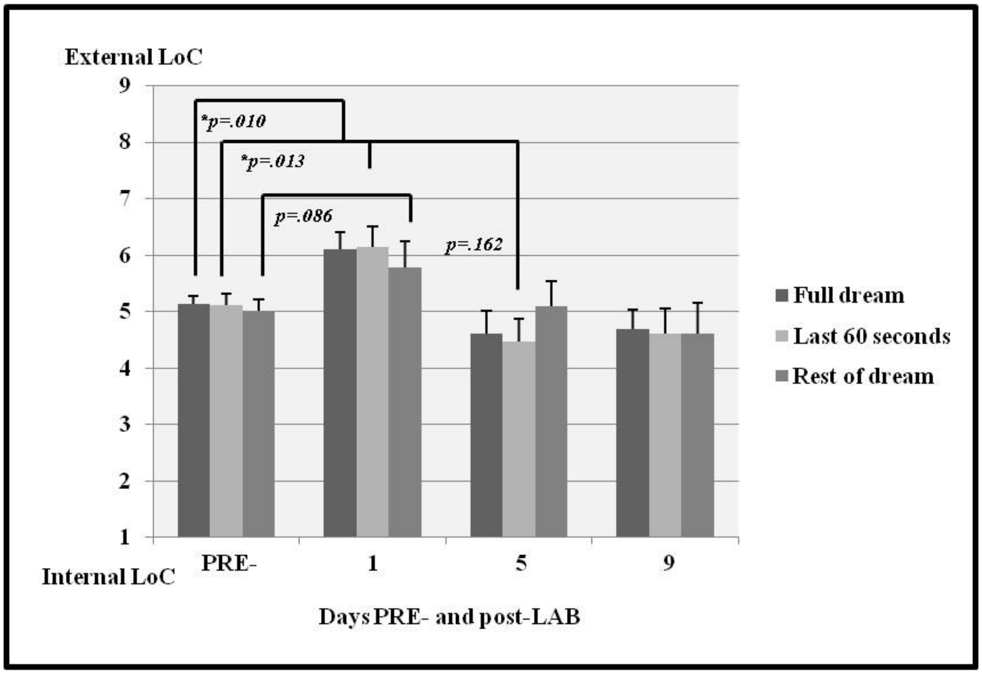

Figure 7 Mean (±SEM) Dream LoC scores for pre-laboratory baseline dreams (PRE-) and post-LAB dreams from days 1 (peak of LAB incorporations), 5 (nadir of LAB and peak of VR incorporations), and 9 (recurrence of LAB incorporations).

5. Discussion

5.1. Different target experiences lead to distinct dream formation processes.

The findings provide some support for the two hypotheses of the study. They support the first hypothesis that two distinct experiences (laboratory and VR maze) will exhibit different patterns of incorporation into dream content, and that these differences will be reflected in alterations of the day-residue and dream-lag effects. Specifically, laboratory and VR maze elements were observed to be restricted almost entirely to different dreams; they appeared in the same dream on only 2 occasions and one of these was only an indirect incorporation. Accordingly, there was a strong negative correlation between scores for incorporation of laboratory and VR maze elements. Second, incorporations of LAB elements showed a somewhat modified version of the expected U-shape curve, expressing both a day-residue effect on day 1 and a dream-lag effect on a later day (day 9 in this case), whereas incorporations of VR maze elements showed a markedly different pattern: a peak on day 4 that was preceded and followed by days with relatively few incorporations.

The results also support our second hypothesis that Dream LoC will differ for dreams with different types of target stimulus incorporation. In this case, there was evidence that dreams highest in LAB elements reflected a LoC that was more external in nature, whereas dreams highest in VR maze elements reflected a LoC that was more internal in nature. As the mean score for the latter fell around 5 on the 7-pt LoC scale, these dreams are best considered to be relatively more external and internal combined than dreams with LAB incorporations. Together, these findings support the notion that the two, distinct target experiences stimulated dream formation processes that were also temporally distinct and which were characterized by changes that were both specific (incorporated elements) and more general (changes in Dream LoC) in nature.

5.1.1. Different day-residue effects

The fact that we observed a strong day-residue effect for LAB incorporations but not for VR maze incorporations raises the possibility that experiences that are in close temporal proximity when they first occur compete for expression as day-residues in later dream content. In a previous study in our laboratory (Saucier, 2007), participants underwent the same VR maze task but without sleeping overnight in the laboratory, and showed robust day-residue incorporations of the VR maze. The lack of an overnight stay in that study may therefore have removed another significant experience that might have competed with the VR maze and thus prevented any interference with subsequent reactivation during dreaming.

Selection between the two competing experiences by dream processes may be based upon which one of the experiences is encountered first. In the present case, the laboratory sleepover was undertaken slightly before (about 12 h) the VR maze task, and it appeared before the VR maze task in dream content in the form of day-residue. Alternatively, it may be that selection between experiences is based upon which experience is most salient and self-relevant. The sleep laboratory experience may have had more of an emotional, interpersonal impact, and may therefore have been given preferential treatment by memory processes. This notion is consistent with previous findings showing that the day-residue and dream-lag effects are linked to personally relevant experiences (Nielsen, et al., 2004) and is consistent with current theories and evidence suggesting that there is a self-relevance selection bias in memory consolidation (Hamann, 2001; LaBar & Cabeza, 2006). Similarly, since our subjects underwent dream reporting training sessions during their laboratory stay, which included 4 sleep onset awakenings and a morning REM awakening for dream collection, the very act of completing the home dream diary likely reminded them of the laboratory protocol, thus rendering the LAB stimulus more salient to them.

However, neither of the previous explanations easily accounts for why the less preferred target experience (the VR maze task) first occurred in dream content 4 days, rather one day, later as is normally the case for the day-residue effect. One possibility is that the memory processes underlying treatment of the selected day-residue ‘reserve’ an invariant window of about 3 days to complete their function, such that treatment of other memories is postponed until this function is complete. In the present study, VR maze incorporations may have been inhibited until day 4—only well after processing of the LAB elements was complete. Some observations from previous studies of the day-residue effect are consistent with this possibility in that they demonstrate the occurrence of an apparent day-residue effect only 3-4 days after a target event. In one study (Nielsen & Powell, 1995) participants exposed to a stressful film before sleeping overnight in the laboratory reported dreams containing elements of the film only 4 days following the stimulus. Since participants also slept in the sleep laboratory, the results of this study are strikingly similar to those of the present study, i.e., a 4-day delay for the VR maze stimulus. In a second study (Nielsen, 2008; Lara-Carrasco, et al., unpublished), a group of healthy participants selectively deprived of REM sleep reported incorporations of a fearful pre-sleep stimulus (negative slides from the International Affective Picture System, IAPS) only 3-4 days after viewing the stimulus, whereas a control group that was not REM sleep-deprived reported dreams with normal day-residues 1-2 day post-stimulus. In the present protocol, our participants underwent repeated sleep-onset awakenings, which delayed their final sleep onset for about an hour. Combined with a morning REM sleep awakening for dream collection, this procedure might have reduced their normal REM sleep duration by the end of their laboratory stay. This may be one factor contributing to the delayed incorporations of the VR stimulus. In a third study using a VR maze, delayed incorporations were observed when the stimuli were initially presented on a large TV display (days 3-4) as opposed to with immersive VR goggles (days 1-2) (Nielsen, 2008); the TV display was more immersive, leading to more cybersickness symptoms, and may have contributed to delayed incorporation of the VR maze. Finally, in a single participant study (Kookoolis, Pace-Schott, & McNamara, 2010), it was found that personally significant events were incorporated earlier, on days 1 and 2, than were objects, which appeared on days 3 and 4.

In sum, the present findings demonstrate that distinct target events are incorporated into subsequent dream content at different times. The processes determining which stimulus is selected for incorporation into dream content remain unknown, but they may be a function an event's recency and/or its self-relevance. Further, the observation of a 4-day delay for the 'unselected' target stimulus is consistent with the results of other studies in suggesting that dream formation processes deal with only one event at a time and may impose a fixed window of about 3 days during which it is preferentially expressed in dream content, to the exclusion of other events To further clarify this possibility, future studies of stimulus incorporations into dreams may need to present these stimuli at a range of different times and vary their relative self-relevance.

5.1.1.1. Day-residue effect for LAB incorporations

The day-residue effect for LAB incorporations was most pronounced for dreams collected during the laboratory awakening for the morning REM sleep period (8 dreams, 53% of all dreams collected at that time). This strong effect is consistent with a wealth of previous research reviewed in the Introduction, although is somewhat higher than the values typically reported, e.g., 33% (W. C. Dement, E. Kahn, & H. P. Roffwarg, 1965) or 35% (Jouvet, 1999) . Rather, our effect is more similar to the finding (Fosse, et al., 2003) that 51% of dream reports from a home diary contain at least one reference to any type of recent experience at all. Thus, it may be that the LAB experience in our study had a particularly strong impact on participants.

The robustness of this effect links it to an equally robust effect on sleep and dreaming that is attributed to sleeping in the laboratory, i.e., the "first-night effect." REM sleep is preferentially sensitive to the experience of sleeping for the first time in the laboratory, as shown by dramatic changes such as ‘skipping’ of the first—and at times even the second—REM sleep period of the night, prolonged REM sleep latencies (Agnew, Webb, & Williams, 1966; Carskadon, Keenan, & Dement, 1987; Edinger et al., 2001), longer times between successive REM sleep periods (Lorenzo & Barbanoj, 2002), fewer REM sleep periods (Mendels & Hawkins, 1967), and reduced REM sleep% (Agnew, et al., 1966; Lorenzo & Barbanoj, 2002). Some have suggested that the first night effect may be a transient response triggered by a sensitivity to anxiety (Riedel, Winfield, & Lichstein, 2001), possibly even an adaptive response to the stress of sleeping in a laboratory (Lorenzo & Barbanoj, 2002; Schmidt & Kaelbling, 1971). Chronic nightmare sufferers are more sensitive to the first night effect than are matched controls (Nielsen et al., 2010). While some authors have cited changes in dream content as a central component of the first night effect (Browman & Cartwright, 1980), no one has yet linked laboratory incorporations specifically to this effect.

In sum, the high prevalence of first-night laboratory dreams may be but one indication of a strong, and possibly more general, response to sleeping in the sleep laboratory. While some have linked this response to the stress or anxiety linked to the laboratory, we suggest that a major component of the laboratory experience is the interpersonal dimension in which the participant is placed in a more passive role than usual. We expected to see this dynamic reflected in changes in the dream LoC measure (see later section).

5.1.2. Partial replication of the dream-lag effect

The two types of stimulus event used in this study both produced unexpectedly delayed dream-lag effects. The dream-lag effect for LAB elements was observed 9 days post-stimulus whereas the effect for the VR maze was observed 8 days post-stimulus. Both of these delays are longer than is usually seen in other studies (5-7 days) (Nielsen & Powell, 1989; (Nielsen & Powell, 1992); Blagrove, et al., 2010). Nonetheless, delays of this magnitude have been reported. Jouvet's (1979) analysis of samples of his personal dreams revealed that when he travelled to a new destination for any length of time, elements of the new environment did not peak in his dreams until 8 days after departure, whereas when he returned home from long trips, elements of his home environment did not reappear in his dreams until 8-10 days later. Other studies have observed delayed incorporations occurring 10 days after a stressful film (Nielsen & Powell, 1995) or 12 days after an emotionally negative daytime event (Nielsen & Powell, 1992) but, unlike the present study, the latter two effects were coupled either with a delayed day-residue effect (day 4) or normal day-residue (day 1) and dream-lag (day 6) effects respectively. One possible explanation for the delayed dream-lag effect for LAB elements is the same as the one previously suggested to explain the delayed (4-day) processing of the VR maze stimulus. Once the VR maze stimulus was successfully incorporated in dream content on day 4 (day 5 relative to the LAB experience) it, in turn, may have prevented the reoccurrence of the LAB experience for another 4 days. Consequently, the reappearance of the LAB stimulus was delayed from the usual 5-7 days, to the 9-10 days observed.

Another possible explanation for the delayed dream-lag effects for both LAB and VR maze stimuli is that around days 8 or 9 participants may have been reminded themselves that the end of the study was imminent and that they would be required to meet the experimenter again, receive their financial compensation, etc. The emotional salience of this reminder may have been sufficient to trigger a new round of incorporations of the LAB and VR maze stimuli around this time—a type of secondary day-residue effect. Such an 'end of study' explanation suggests that memory sources of dreams may be reactivated by salient reminders, an effect that has not yet been demonstrated in the literature. Nonetheless, it is an easily testable hypothesis which could clarify an important source of variability observed in studies of the dream-lag effect.

5.1.3. Relationship between dream locus of control and incorporation patterns

The second hypothesis of this study, that Dream LoC will be more external for days with peak LAB incorporations and more internal for days with peak VR maze incorporations, was partially confirmed. For dreams that were high in LAB incorporations, average Dream LoC was more external, whereas for dreams high in VR maze incorporations, it was relatively more internal. Moreover, when comparing Dream LoC scores for peak incorporation days with pre-laboratory averages (baseline), dreams that were high in LAB incorporations (day 1) had higher external LoC scores. This was not the case for dreams from day 9 however. Also, no change in Dream LoC was seen for dreams high in VR maze incorporations relative to baseline.

It might be argued that the observed changes in Dream LoC are due simply to a confounding of the incorporation and LoC measures, i.e., that LoC scores were simply reiterating the relative external or internal nature of the incorporated stimulus elements. By this explanation, incorporated LAB elements would influence scoring judges because they appeared to possess relative external control, i.e., control wielded by the experimenter, constraints of experimental procedures, acquiescence of the participant to numerous requests, etc., whereas incorporated VR maze elements would be seen as reflecting a relatively more active role by the participant, i.e., forming strategies, making decisions, and navigating through the labyrinth.

Analyses confirmed this consideration to some extent in that observed Dream LoC differences between dreams occurring on peak and nadir incorporation days were reduced to statistical trends when prior differences in LAB and VR maze incorporations (#elements) were controlled. However, the fact that trends still remained suggests that Dream LoC scores are at least partially independent of incorporation scores. They may, therefore, reflect more general changes in dream content that are brought about by exposure to the target stimuli. In the case of dreams that are influenced by the LAB experience, for example, this may mean that processing of the interpersonal relationships inherent to being a laboratory participant (presumably a more external LoC situation) occurs to some extent on a global level that affects the dream narrative as a whole.

Both the dependence and the independence of the incorporation and Dream LoC measures can be illustrated with examples from our dream sample presented in Table 1. Dependence between the measures is quite obvious in instances in which the Dream LoC score (external vs. internal) parallels the incorporation score (LAB vs. VR maze), with higher external scores for dreams with LAB incorporations and higher internal LoC scores for dreams with VR elements. For example, in the two first dreams with VR incorporations (see examples 1 and 2) both scored as relatively internal in LoC, participants referred to being "*…inside a computer game, it is a labyrinth. I turn left, then right, then right…*", and to "*…walking up and down various floors*". Similarly, in some examples of LAB incorporations, scored as external LoC, one participant reported being "*…in the laboratory bedroom"* while *"... somebody is taking electrodes off my head*", and another one dreamt of being "*admitted to a hospital"* where *"a team of doctors stands over the gurney, telling me that I must be hospitalized.*"

On the other hand, independence between incorporation and LoC measures is suggested by cases in which a LAB incorporation, in a dream scored high on external Dream LoC, cannot be easily accountable for simply by reactivation of the LAB situation. For example,: "*…A man and his son are discussing some action to take, perhaps how to roll over with all these wires attached (...) When they decide what to do, they march toward the point of my perspective, I feel omnipresent…*". In this dream, that occurred on day1 (peak of LAB incorporations), the high external Dream LoC score cannot obviously be attributed to a confounding with LAB elements (wires, bed) with LoC. Rather, these elements played only an enabling role in the other characters' intentions to act. In other words, the external LoC score stemmed from the characters' actions and not from the mere presence of the LAB elements in the dream. Similarly, consider this dream part: "*…Seascape. Night. Awareness of stars, but they were not clear. (…) Quite cartoonish. I don't remember whether I was on a boat or somehow a floating observer. There were some 'sharks'… something arrived… the sharks began their defensive movements. The attacking thing retreated. (…) They sat there, evenly spaced in front of me, (…) talking."* Here, the cartoonish quality, the nighttime and presence of stars were scored as indirect LAB incorporations because of their close resemblance to elements of the short animation film clip that the participant saw in the lab during the dream reporting training session. The high external Dream LoC here, again, was scored because the dreamer was an observer to external events and not simply because laboratory elements were present in the dream.

This partial independence between incorporation and LoC measures is consistent with our suggestion that dreams often respond to target stimuli in a variety of ways, including references to specific memory elements (direct incorporations), to quasi-disguised or transformed memory elements (indirect incorporations), and to global changes in the entire dream narrative (Dream LoC). These different types of effects may all reflect processes that subserve consolidation of the same memory feature or they may reflect processes directed at different features of the same memory or of different memories altogether. The latter is consistent with our observation of a partial independence of specific and general measures but also by the finding that dreams from days 5 and 9 differed in incorporation but not in LoC.

5.1.3.1. Dream locus of control may reflect general memory processes

Although the present LoC results need replication, they nonetheless support our view that dreaming reacts to significant daytime events with general as well as specific changes. This exploratory part of our study revealed that stimulus-driven general changes in dream content can be assessed adequately with a LoC scale adapted specifically for application to dream content. This LoC scale differentiates between dreams containing incorporations of laboratory and VR maze experiences yet appears to be partially independent of the these incorporation measures. As the examples discussed in the previous section demonstrated, the general changes in LoC are not mere reflections of incorporated elements from the LAB or VR maze, but they may well reflect more global changes that were set into motion by these target experiences.

Identification of more general changes in dream content would be a valuable advance in the emerging neuroscientific study of dreaming and memory. At present, investigators have relied primarily upon direct or indirect incorporations of tasks as evidence that dream content is reacting to these tasks. Wamsley et al (2010) found that dream content with direct references to a virtual maze task was associated with later improvements in performance on that task. Similarly, Pantoja and colleagues (Pantoja et al., 2009) found that elements in dreams related to a recently played computer game (‘Doom’) correlated with performance gains. Finally, Smith and Hanke (Smith & Hanke, 2004) reported that dream content incorporated indirect references to a mirror drawing task. Such approaches are based upon the reasonable assumption that the (direct or indirect) reappearance of elements in dream content, however minimal, reflects the operation of a more extensive, yet unseen, memory consolidation mechanism. To illustrate, Wamsley and Stickgold (2011) point out that in dream content elements of recent learning experiences are intermixed with remote memories, semantic information and other types of cognitions to produce sometimes bizarre scenarios and that this is due to ‘long-term potentiation–like plasticity in mnemonic networks’ and processes responsible for the ‘extraction of meaning’ (p. 104). In other words, dream incorporations reflect underlying memory processes of both encoding and integrating new experiences with previous knowledge, and the day-residue and dream-lag effects observed in the present study may partially represent these processes at a phenomenological level. These offline mechanisms are thought by many to be hippocampally-mediated, and one of their functions to be ‘integrative encoding’, a mechanism that enables a synthesis and a generalization of distinct yet related experiences (Shohamy & Wagner, 2008).

Our results can be taken to suggest that the yet unobserved processes taking place within dreaming may be detectible in general changes taking place in dream content such as a shift toward a more external locus of control in the basic structure of the dream. LoC is but one such general feature. Other possible measures have been reported. For example, DeKoninck and colleagues found that dreams reported in response to the wearing of inverting lenses included direct incorporations (e.g., upside down objects) but also general changes (e.g., misfortunes, confusion). Smith and Hanke (2004) found that dreams following a mirror tracing task contained more driving mistakes and mishaps.

5.1.3.2. Dream locus of control and dream formation

Taken together, findings for the two hypotheses of the study are consistent with the suggestion that dreams tend to deal with one impactful daytime event at a time—possibly even excluding other events from consideration—and that this reaction includes activation of a more general mechanism (than the incorporations per se) that is sensitive to the balance of self/non-self agency in the dream narrative.

The idea that the dream formation processes preferentially select one kind of stimulus among many, and that the dream narrative is structured around that dominant theme can be traced back to the beginning of the psychological study of dreams. Freud (1900) saw dream formation as subservient to a single wish-fulfillment drive, by which a specific affective concern is expressed in the dream narrative in a disguised form through processes of condensation and displacement. In a similar vein, other psychoanalytic theorists have argued for ‘dream distillation’(Sullivan, 1968), a dreamwork technique, whereas a therapist attempts at uncovering a single most significant element of a dream. Hartmann’s (2010) idea of a ‘central image’ posits that a single, most significant theme of a dream carries its affective load and personal meaning, in order to facilitate contextualization of impactful events. In a trained single participant study of sleep-onset dreams from our laboratory it was found that semantically similar (and often temporally distal) elements tend to cluster together in the same dream (Stenstrom et al, in preparation), which also suggests that dreams tend to incorporate one kind of stimulus at a time. The Dream LoC measure may be one way of addressing this generality in dream content by way of assessing a relative interpersonal weight of a dream.

Numerous other scales for evaluating potential memory-related content changes are available. A notable example is the Hall and Van de Castle (Hall & Van de Castle, 1966) content analysis scoring system which contains over 100 categories of general content and which has been found to be a valid instrument for discriminating among various groups of participants (e.g., men vs. women; children vs. adults). Any of the Hall and Van de Castle categories could be explored for their possible implication in memory consolidation processes.

5.2. Limitations of the study

The most obvious limitation of the current study is its limited sample size. The fact that missing observations is very common for protocols requiring dream recall over multiple days (average dream recall for the general population is 2-3 dreams/week; (Kramer, Winget, & Whitman, 1971) impeded our use of repeated measures designs. This obstacle was dealt with to some extent for the calculation of polynomial trends by combining results for adjacent days, but for other comparisons we were obliged to use less powerful independent sample t-tests. A second limitation of the study is the limited length of the dream diary for assessment of VR maze elements. We observed a peak incorporation for this measure on day 4 rather than day 1 but, because the diary duration was only 9 days, we could not evaluate whether a dream-lag effect occurred after about a week (day 11) or perhaps even later as would be expected, or whether it simply did not occur at all. A longer dream diary would have avoided this problem.

A third limitation is that some differences were observed only for parts of the dream report. For example, a Dream LoC difference between days low (day 2; external LoC) and high (day 4; internal LoC) in VR maze incorporations was only found only for the ‘last 60 seconds’ part of the dream. This finding may be artifactual in that 30% of collected dreams contained no ‘rest of dream’ report, thus substantially reducing the N for statistical evaluation of the latter. But the finding is also consistent with the possibility some LoC changes are quite ephemeral and their accurate identification dependent upon the use of a more structured dream collection procedure that focuses a participant’s attention on the most recently recallable material.

A final limitation of this study is that the dreams constituting the day-residue effect for LAB elements (day1 dreams) were reported in the laboratory. The presence of experimenters during dream collection may have influenced dream content in unknown ways, including producing more external LoC features, and may have increased laboratory incorporations (Schredl, 2008). However, there is evidence that dreams obtained in the laboratory and at home differ very little in content (Domhoff and Schneider, 1998). Also, in the present study the length of dream reports obtained in the laboratory did not differ significantly from that of dream reports obtained from the 10-day home diary.

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Appendix I. Study consent form

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CONSENT AND INFORMATION FORM

THE MEMORY SOURCES OF DREAMS

Development of self-observational and text-mining methods to assess dreaming

Investigator: Dr Tore Nielsen, Ph.D., Psychologist
Sleep Research Center, Hôpital du Sacré-Cœur de Montréal
Telephone: (514)

Study funded by the Social Sciences and Humanities Research Council of Canada

INFORMATION

We invite you to participate in a study concerning the memory sources of dreams. It is important that you understand certain general principals that apply to everyone participating in our studies:

- Your participation is on a voluntary basis,
- By accepting to participate in the study, you must respect its conditions. However, you maintain the right to withdraw from the study at any time and for any reason. By consenting to participate you do not give up your right to legal recourse if necessary.

1. STUDY OBJECTIVES

What determines the content of our dreams? That is a question that everyone has asked him- or herself at one time or another. Since Freud, researchers have known that the memories of the people, places, and emotions of daily life are reflected in dreams but are typically so fragmented and transformed that they cannot be predicted well. The aims of this study are to: 1) develop new, more reliable, methods of dream collection and content analysis, and 2) use these new tools to better identify the memory sources of dreams associated with a known experimental stimulus (immersion in a virtual reality maze).

A total of 60 participants (3 groups of 20 participants) will be recruited for this study who possess the following characteristics: aged 18-45 years, in good mental and physical health, low emotional distress, good dream recall (3 or more dreams per week for the last 2 months), access to a home computer with internet access, good typing skills and good language proficiency (English or French).

2. STAGES OF THE STUDY AND METHODOLOGY

The study is divided into 3 parts: 1) laboratory visit and completion of questionnaires, 2) sleeping one night in the laboratory and doing a virtual reality maze task the following morning, and 3) completing a dream diary and send it via email for 14 consecutive mornings.

LABORATORY PART:

1. At your convenience, you will meet with a research assistant for about 1 hour and a half to visit the laboratory and to fill out some questionnaires. After this meeting, your eligibility will be verified based upon your questionnaire responses and you will be informed by telephone whether or not you may participate. Subjects who participate will come for a 1-night stay in the laboratory. There are 3 groups in this study that differ only in the manner in which subjects are asked to reflect on and report their dreams. Your inclusion into one of these groups will be determined by a randomized selection process.
2. During your laboratory stay, your sleep will be studied by polysomnographic (PSG) recording for 1 night. The time required for the PSG recording is about 8 hours with an extra 4 hours required for electrode installation and removal (from 8 pm to 8 am the next morning). We will wake you at specific times during your sleep period for dream collection: at sleep onset (for a maximum of 4 times or a maximum of 2 hours) and a little before your usual wake-up time in the morning (1 time). We will give you specific instructions on how to report your dreams and we will ask you more specific questions which apply to your group. You will practice technique by watching a 5 min movie clip twice and then write a summary of what you remember from the clip. You will be given specific instructions on how to do this. You will have a private room, but your sleep will be recorded using a DVD recorder. The DVDs will be kept under lock and key for a period of about 5 years after the end of the study and will later be destroyed. You will be able to communicate with the night staff at any time. After removal of the electrodes in the morning, you will do a 20 minute virtual reality task.

HOME PART:

3. Each morning, as soon as possible after you wake up, you will complete a dream diary form that you will then email to us and this, for 14 consecutive days where we will ask you to type the content of your dream the same way you usually do for 4 days prior to your laboratory stay**,** and by using the same instructions that were given to you in the laboratory for the 10 days after your laboratory stay. We will also ask you a few questions regarding your sleep and your activities the day before.

3. RISKS, SECONDARY EFFECTS AND INCONVENIENCES

There are normally no risks associated with participation to this study. The questionnaires are non-invasive and do not present any risks. To minimize stress, the time required to complete the questionnaires will be less than 60 minutes and less than 15 min for the telephone interview. No risks or secondary effects are associated with recording your sleep using polysomnography. The electrodes may cause a slight irritation of the skin, the electrodes are small metal disks (not needles) that are glued (temporarily) to the skin of your head, face, legs and arms. You will have to agree in limiting your caffeine consumption and avoiding consuming alcohol 24 hours before the sleep recording. Exposure to the virtual reality environment does not pose any risk but you might feel dizzy or slightly nauseous for a few minutes. This has been seen in a few subjects. These sensations are similar to the ones felt after watching a 3D movie on a big screen (IMAX) and/or after actively playing video games (computer or game consoles) for prolonged periods of time.

4. BENEFITS AND ADVANTAGES

You will not benefit from participating in this study, however the results will help us to identify more specifically the memory sources of dreams and to develop new tools for the analysis of dream content.

5. MONETARY COMPENSATION

You will receive, by mail, a compensation of $25 for completion of the recording night and $100 for the 14 day dream diary via email, for a total of $125 for your participation in the entire study. Furthermore, we will reimburse you for travelling costs (either parking or public transit) during your visits to the Hôpital du Sacré-Coeur de Montréal. If you do not complete the study, you will receive compensation for the part that you completed.

6. CONFIDENTIALITY

All the information collected about you during the study will be kept confidential within the limits allowed by law and you will be identified only by code in order to preserve your anonymity. The results of this research study may be presented at scientific meetings or in publications; however, your identity will never be disclosed.

For verification purposes, your file could be consulted by a person representing the hospital's ethics committee. This committee observes a strict confidentiality policy.

7. COMPENSATION FOR ILLNESS OR INJURY

If you experience injury or illness as a direct result of your participation in this study, the necessary treatment will be provided without any cost to you. However, this fact does not prevent you in any way from seeking legal recourse concerning anyone implicated in the study for any faults resulting from the study or treatment.

By signing this consent form, you do not waive any legal rights you may otherwise have or liberate the researchers or institutions involved of their professional or legal obligations.

8. VOLUNTARY PARTICIPATION AND WITHDRAWAL FROM THE STUDY

Your participation is voluntary. You are free to refuse to participate. You may also withdraw from the study at any time by simply informing the researcher or research assistant of your decision, without having to give any reasons. You will be informed of any new findings concerning your condition obtained during the course of this study which may affect your willingness to continue participation.

Your decision to not participate or to withdraw from the study will not have any consequences on the quality of care you may receive from this hospital.

The investigator can decide to withdraw you from the study without your consent if you do not respect the conditions.

9. CONTACT PERSONS

If you have any questions regarding the study, if you would like to report an incident, if you like to withdraw from the study or if you have comments, you can contact us at any time:

Tore Nielsen, Investigator	**Telephone: (514)**
Tyna Paquette, Research Assistant	**Telephone: (514)**

If you would like to ask questions about the study to a researcher who is not implicated in the research, you can contact at any time:

Julie Carrier, Investigator	**Telephone: (514)**

If you wish to ask some questions concerning your rights as a study participant or if you have a complaint to report, you can contact at any time:

Hospital Administration	**Telephone: (514)**

CONSENT

Title: The memory sources of dreams: Development of self-observational and text-mining methods to assess dreaming

- The nature of the study, the procedures to be used, the risks and benefits of my participation in the study as well as the confidential nature of the information to be collected has been explained to me.
- I had the opportunity to ask all the questions I needed on the different aspects of this study and I received answers that were satisfactory to me.
- I acknowledge that I had enough time to make my decision.
- I, the undersigned, consent to participate in this study. I can withdraw from the study at any time without compromising my relationship with my doctor or other caregivers, and without prejudice of any kind.
- I was informed that I will receive a signed copy of this consent and information form.

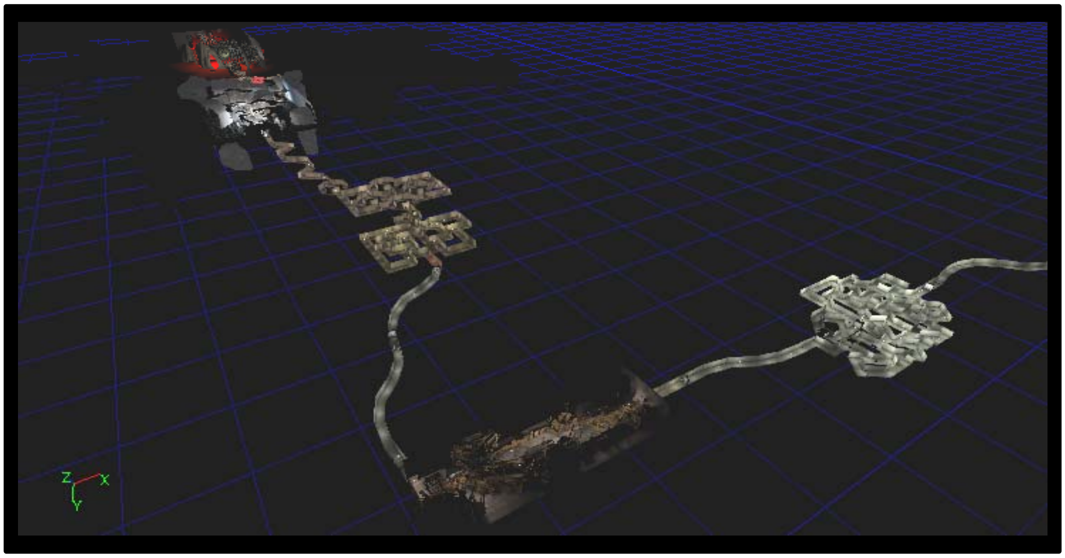
Name of subject (please print)	Signature of subject	Date

Name of the investigator or representative (please print)	Signature	Date

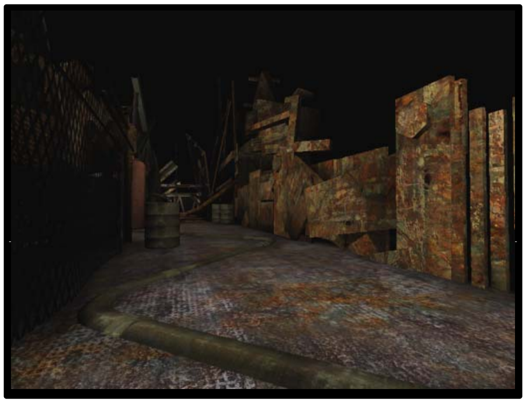
Appendix II. Images from the VR maze task

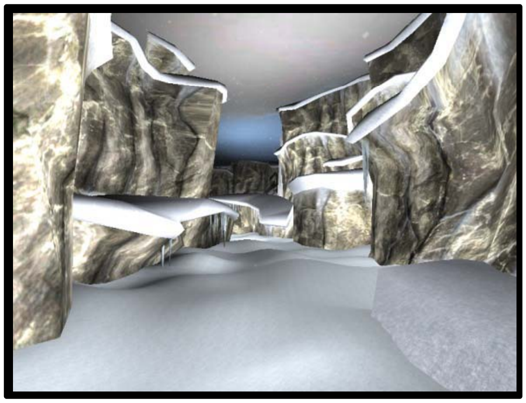
Appendix II. Images from the VR maze task

Bird’s-eye view of the labyrinth



Examples from the sequence of VR environments





Appendix III. Dream diary templates

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DREAM REPORT (MS-Word file to fill out and return via email)

Lie still with eyes closed and remember what you were dreaming during the last 60 seconds before you woke up. Scrutinize only this part first. When you are sure that you remember this part in detail, go back and recall what you were dreaming prior to this 60-second part in the same way. When you have recalled this thoroughly, please get up and type out the dream in the same order, i.e., the 60-second part first and the remaining part second.

1. **Remember to observe and report details about setting, characters, actions and emotions**
2. **Remember to use complete sentences, proper grammar and chronological order**
3. **Record any memories that seem to correspond to any of the details you have recalled**

Please type your dream experience here using the following categories:
Last 60 seconds:
[Please select this text and type in your answer to the question here]

Rest of dream:
[Please select this text and type in your answer to the question here]

Associated memories:
[Please select this text and type in your answer to the question here]

Today's date: "[Please select this text and enter today's date (Day Month Year: 19 june 2010).]"

Please send this document by email to the following address first: ____________________
and then please fill second part : Sleep Schedule

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DREAM REPORT (MS-Word file to fill out and return via email)

Lie still with eyes closed and remember what you were dreaming during the last 60 seconds before you woke up. Scrutinize only this part first. When you are sure that you remember this part in detail, go back and recall what you were dreaming prior to this 60-second part in the same way. When you have recalled this thoroughly, please get up and type out the dream in the same order, i.e., the 60-second part first and the remaining part second.

1. **Remember to observe and report details about setting, characters, actions and emotions**
2. **Remember to use complete sentences, proper grammar and chronological order**
3. **Review the dream a second time to recover any details that you may have missed:**
    - **first review the 60-second part from beginning to end, then the reset of the dream**
4. **Also, remember to recover any details that you may have missed about:**
    - **How you perceived events, including your own movements and actions**
        - i. How were you positioned in the scene and how did your perspective change?
        - ii. What perceptual movements did you make, e.g., turning/moving your body, head or eyes?
    - **Timing and order of events**
        - i. What was the exact order of your perspective changes of perceptual movements?
    - **Specific feelings and reactions you had during the events**
        - i. How did you react to each image?
        - ii. What emotions accompanied your experience?
5. **Record any memories that seem to correspond to any of the details you have recalled**

Please type your dream experience here using the following categories:
Last 60 seconds:
[Please select this text and type in your answer to the question here]

Rest of dream:
[Please select this text and type in your answer to the question here]

Associated memories:
[Please select this text and type in your answer to the question here]

Today's date: "[Please select this text and enter today's date (Day Month Year: 19 june 2007).]"

Please send this document by email to the following address first: ____________________
and then please fill second part : Sleep Schedule