The influence of the simulation environment on teamwork and cognitive load in novice trauma professionals at the emergency department: Piloting a randomized controlled trial

Alexandra Lapierre[1,2], Patrick Lavoie[1], Véronique Castonguay[2],
Ann-Marie Lonergan[2], Caroline Arbour[1,2]

[1] Faculty of Nursing, Université de Montréal, 2375 Chem. de la Côte-Sainte-Catherine, Montréal, QC, Canada, H3T 1A8.

[2] Research center, Hôpital du Sacré-Coeur de Montréal, 5400 Boul Gouin O, Montréal, QC, Canada, H4J 1C5.

Correspondence should be addressed to Alexandra Lapierre, Faculty of Nursing, Université de Montréal, 2375 Chem. de la Côte-Sainte-Catherine, Montréal, QC, Canada, H3T 1A8 ; e-mail: alexandra.lapierre@umontreal.ca; ORCID: https://orcid.org/0000-0002-8704-4940; Twitter: @Alexe_Lapierre

Conflict of Interest

The authors declare no conflicts of interest.

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Abstract

Introduction: This pilot study aimed to test the feasibility of conducting a randomized controlled trial to examine how simulation environments (in situ versus laboratory) influence teamwork skills development and cognitive load among novice healthcare trauma professionals in the emergency department.

Method: Twenty-four novice trauma professionals (nurses, medical residents, respiratory therapists) were assigned to in situ or laboratory simulations. They participated in two 15-minute simulations separated by a 45-minute debriefing on teamwork. After each simulation, they completed validated teamwork and cognitive load questionnaires. All simulations were video recorded to assess teamwork performance by trained external observers. Feasibility measures (e.g., recruitment rate, randomization procedure and intervention implementation) were recorded. Mixed ANOVAs were used to calculate effect sizes.

Results: Regarding feasibility, several difficulties were encountered, such as a low recruitment rate and the inability to perform randomization. Outcome results suggest that the simulation environment does not affect novice trauma professionals' teamwork performance and cognitive load (small effect sizes), but a large effect size was observed for perceived learning.

Conclusion: This study highlights several barriers to conducting a randomized study in the context of interprofessional simulation-based education in the emergency department. Suggestions are made to guide future research in the field.

Keywords: Feasibility study, interprofessional education, mental load, simulation, environment, traumatology

1. Introduction

In the emergency department, teamwork is essential for delivering safe and effective care to patients sustaining traumatic injuries [1]. Teamwork can be defined as the interaction between professionals who work interdependently toward the same goal [2]. Teamwork has an individual and group component; it depends on each member's contribution and team behaviors [2]. Deficiencies in teamwork have been linked to delays and deviations from evidence-based care, placing trauma patients at risk of death and avoidable errors [3]. This suggests that professionals' knowledge and technical skills are insufficient during trauma resuscitation. Instead, healthcare trauma professionals should be able to work together under intense time pressure to deliver coordinated and efficient care to these vulnerable patients [1].

Interprofessional training is strongly recommended to enhance teamwork in traumatology [4]. This is particularly true for novices who often have had little exposure working with professionals from other disciplines during their education. To this end, high-fidelity simulation—an interactive educational strategy—has become increasingly popular in trauma centers to develop teamwork skills, such as communication, leadership or situation monitoring [5]. Typically, simulation involves a scenario featuring a computerized manikin that mimics the physiological responses of a patient [6]. It includes a briefing to prepare and orient participants to the scenario and a debriefing where they reflect and discuss their individual and collective experiences afterwards [7]. Our recent systematic review shows that interprofessional high-fidelity manikin-based simulation enhances teamwork performance in trauma care in the emergency department [8].

High-fidelity manikin-based simulations can occur either in the clinical environment (in situ) or in a laboratory [8]. For trauma training, in situ simulations often happen directly in the resuscitation room, with the emergency department's equipment and contingents (e.g., noise and interruptions) [9]. In contrast, laboratory simulations are performed in a dedicated training space where educators control most environmental elements (e.g., equipment, personnel) [9]. From a practical point of view, in situ simulations involve more preparation and practicalities than laboratory simulations, e.g., scheduling according to patient volume, avoiding mixing equipment for care and training, and setting up the high-fidelity manikin in the resuscitation room [10, 11].

Despite these challenges, emergency department educators increasingly favor in situ simulation over laboratory simulation because it offers greater realism for teamwork training [8, 12]. However, the only two studies that explicitly compared in situ and laboratory simulation in pediatric and obstetric teamwork training do not support the added value of in situ over laboratory environments [13, 14]. Evidence instead suggests that sensory stimuli in high-acuity clinical settings may interfere with participants' learning during in situ simulations [15, 16], even more so for novice trauma professionals whose capacity to process new information is typically lower than experienced professionals [17, 18]. This phenomenon is associated with cognitive load—the load imposed on a learner's cognitive system when performing a task [19]. Cognitive load, which may run counter to the enthusiasm for in situ simulations, invites consideration of the effect of the simulation environment on teamwork and cognitive load. Conceptually, cognitive load provides insight into learning at the individual level and an opportunity to better understand its contribution to the development of teamwork skills.

To date, no study has compared the impact of the simulation environment on teamwork and cognitive load for novice trauma professionals. To answer such a question, a randomized controlled trial (RCT) is the research design that presents the highest level of internal validity. In education, RCTs are considered the gold standard for identifying an educational intervention that works and establishing a causal relationship between variables [20, 21]. This is because randomization reduces allocation bias and assures that participants' characteristics in the two groups are probabilistically identical from the start—ensuring that any differences in outcomes are caused by the intervention [22]. However, RCTs are complex and require extensive conceptual, methodological, and practical planning. As we were designing a RCT, we quickly encountered several challenges concerning the preparation, implementation, and realization of such a study. For these reasons, we deemed that a pilot study was warranted to test the feasibility of our proposed research design before initiating a larger, full-scale RCT.

This pilot study aimed to test the feasibility of a RCT protocol to examine how the simulation environment (laboratory versus in situ) influences teamwork and cognitive load in novice trauma professionals at the emergency department. Specifically, the primary objective was to assess feasibility in three areas: 1) recruitment, attrition, and randomization of participants; 2) implementation of simulations in the appropriate environment (laboratory or in situ); and 3) data collection using individual (cognitive load, teamwork) and group (teamwork) measures. A secondary objective was to calculate effect sizes for the main study variables to provide insight into the results that could be obtained in a future RCT.

2. Methods

Pilot studies are small-scale studies to test the feasibility and/or acceptability of a research design and methods [23]. The CONSORT extensions for randomized pilot studies [24] and health care simulation research [25] were used to ensure complete and transparent reporting of this study. Ethics approval was received from the institution's Research Ethics Board (REB) committee (Protocol N/ref.: 2021–2185).

2.1 Setting and participants

This study occurred in the emergency department of a Level-1 trauma center in Montreal, QC, Canada—during the COVID-19 pandemic. A purposive sampling method was used to generate an interprofessional sample of novice trauma professionals. Eligibility criteria were established in collaboration with a local clinical nurse specialist and two physicians involved in continuing education at the study site, considering trauma cases exposition and proficiency in team management during resuscitation. In accordance with the conception of novice health professionals proposed by Valdez [26] and the input of a clinical nurse specialist and two physicians involved in continuing education at the study site, all emergency department nurses and respiratory therapists with less than 18 months of experience in the resuscitation room were invited to participate—these professionals could hold college or university degrees, per Quebec's norm. To complete the sample, all emergency medicine third-year medical residents were invited (family medicine or emergency medicine).

***2.2** Recruitment*

Department heads organized virtual meetings with eligible professionals to promote the project. Participation in these meetings was voluntary. Department heads also

distributed a video summarizing the project to eligible individuals. Those that were interested were asked to email the researcher directly. Participation was voluntary, and individual compensation of $150 was offered. All participants provided informed consent before study initiation.

2.3 Sample size and group allocation

We used the stepped rule of thumb for pilot studies proposed by Bell et al. [27] to estimate the sample size, considering the larger trial's expected effect size and power. Considering the study of Patterson et al. [28] that showed a medium effect size (d= 0.30) of a simulation activity on self-reported teamwork in a pediatric emergency department, 10 participants per group were needed for β=80%. Considering a conservative attrition rate of 15%, the sample size was set at 12 participants per group.

We planned to operate double randomization for group allocation, i.e., randomizing each professional to a simulation team first based on a typical trauma team composition (three nurses, two physicians/residents, and one respiratory therapist per team), and then each team to a simulation environment, using an independent statistician.

2.4 Scenario development and review

The researchers developed the scenario (**Table 1**). They validated it with a clinical nurse specialist and a physician, both simulation experts, to ensure that the difficulty matched the participants' expertise to avoid cognitive overload due to the scenario (rather than the simulation environment, which was the focus of the study).

Table 1. Trauma simulation scenario

Learning objective	– Demonstrate teamwork skills during the initial assessment and management of a polytrauma in the resuscitation room

Scenario summary	– A medical dispatcher calls the emergency department advising that a paramedic team is on its way with a patient who has sustained a traumatic injury following a bicycle accident. The patient is conscious in the ambulance but becomes unconscious upon arrival in the resuscitation room. An E-FAST exam shows free fluid in the abdomen. The patient shows early signs of hemorrhagic shock, calling for emergency surgery.
Material	– In situ: real equipment from the study site resuscitation room. – Laboratory: training equipment (e.g., expired medications, non-functional ultrasound machine) mimicking the material in the study site resuscitation room.
Briefing	– Review of learning objectives and roles. – Orientation to the simulation environment: • Explanation of the environment and equipment available • Explanation of the specificities of the manikin and the monitoring • Answer questions, if any.
Debriefing	– Based on the PLUS\DELTA method [29] – Duration of 45–60 min – Conducted by the principal researcher (without video support) – Focused on teamwork skills as recommended by the Canadian Patient Safety Institute [30] Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) training program – A cognitive aid summarizing the principles of teamwork as discussed during the debriefing was given to all study participants at the end of the session.

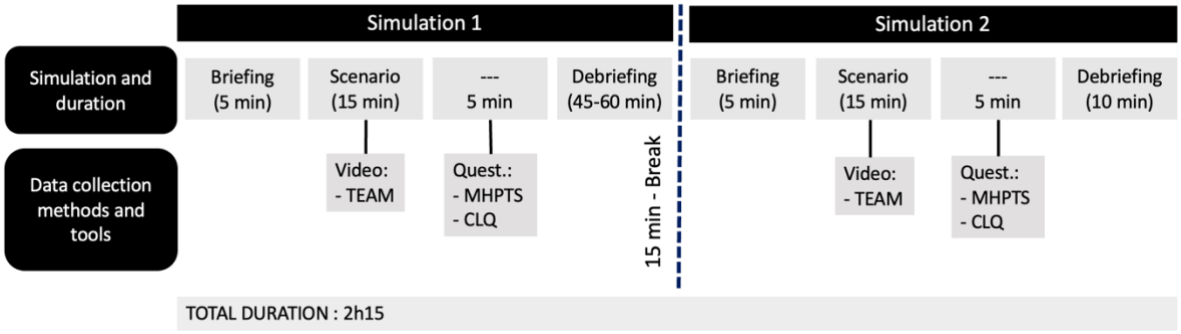
2.5 Procedure

Upon arrival, participants were introduced to their simulation team. Some had worked together before, while others did not know each other. They completed a sociodemographic questionnaire and received a chest tag with their name and role in the simulation (i.e., nurse, respiratory therapist, resident, team leader). Participants were asked to play their own professional role. Then, they attended a 5-minute briefing, followed by the first simulation scenario (15 min – **see Table 1**). Immediately afterwards, they completed the teamwork and cognitive load questionnaires. A debriefing focused on interprofessional teamwork (45–60 minutes), and a 15-minute break followed. The same

scenario was repeated for the second simulation, followed by the same questionnaires and a shorter debriefing to finalize the reflection (10 min). Between the simulations, participants kept the same role. Study participation ended after the second debriefing. The total duration of the activity was 2 hours and 15 minutes (**Figure 1**).

The simulations either occurred in the resuscitation room (in situ) or the simulation laboratory. The same scenario and manikin (Laerdal SimMan 3G) were used in both simulation environments. The same two simulation educators facilitated each scenario, one providing guidance and verbal cues and the other controlling the computerized manikin's responses. The same confederate orderly took part in each simulation to increase realism. All simulations were video recorded (Sony HDRCX405, HD Video Recording Camera) to facilitate teamwork assessment by external observers.

Figure 1. Simulation steps and data collection procedures



Note. Quest.: questionnaire; TEAM: Team Emergency Assessment Measure; MHPTS: Mayo High Performance Teamwork Scale; CLQ: Cognitive Load Questionnaire.

2.6 Measures and instruments

Self-reported individual teamwork performance was considered the primary outcome of this study. The French version [31] of the Mayo High Performance Teamwork Scale [MHPTS; 32] was used to assess it after participating in the first and second simulations. The MHPTS consists of 16 items, scored on a three-point scale (never,

sometimes, constantly), measuring four aspects of teamwork: (1) cooperation/communication, (2) leadership, (3) situational monitoring, and (4) decision-making. With a total score ranging from 0 to 32, the French version of the MHPTS demonstrated an acceptable internal consistency (Cronbach's alpha = 0.74) [31].

The French version [33] of the Team Emergency Assessment Measure [TEAM; 34] was used to measure group teamwork performance (analysis of video recordings) as a secondary outcome. The TEAM consists of 12 items (11 items on a scale of 1 to 4, one on a scale of 1 to 10) measuring different aspects of teamwork: leadership, task management, situation monitoring, and cooperation [35]. With a total score ranging from 0 to 54 for the first 11 items, the TEAM is the most validated tool for trauma teamwork assessment. The French version of the tool demonstrated excellent internal consistency (Cronbach's alpha> 0.89) and satisfactory inter-rater reliability (ICC = 0.60) [33]. The two observers partook in a 2-hour online training adapted from Eppich et al. [36] which included: (1) a review of teamwork concepts based on the TeamSTEPPS model, (2) a brief introduction to the tool, (3) an overview of the user guide, and (4) exercises—independent scoring of team performance videos and discussion of divergent scores. Then, the two observers independently rated the teamwork performance from the video recording of each team.

The Cognitive Load Questionnaire [CLQ; 37], translated into French and adapted for simulation research with novice healthcare professionals [38] was used to assess self-reported cognitive load as a secondary outcome. The CLQ consists of 12 items on a 10-point Likert scale. The CLQ measures intrinsic and extraneous cognitive loads separately and the perception of learning. Conceptually, the intrinsic load is associated with the demands of the learning task (e.g., simulation scenario). In contrast, the extraneous load

relates to the demands imposed by elements that have the potential to distract the learner from the learning task (e.g., noise, interruptions, unclear instructions) [39]. Four items are used for each concept, for three sub-scores of 0–40. The tool has excellent internal consistency (Cronbach's alpha = 0.91 for intrinsic cognitive load; 0.82 for extraneous load; 0.94 for perception of learning) and good structural validity (χ 2/df <3) [38].

2.7 Analyses

Statistical analyses were performed using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, N.Y., USA). For sociodemographic characteristics and descriptive data, categorical variables are reported as frequencies and percentages, and continuous variables are reported as means and standard deviations (SD).

The feasibility of the recruitment was assessed with: (1) the recruitment rate and (2) the attrition of participants. The criteria for successful recruitment was 75% of eligible participants agreeing to be enrolled in the study, which is the most frequent rate in simulation-based studies in emergency departments [40]. The criteria for acceptable attrition was 10% or less [41]. Reasons for the attrition of participants were documented.

The feasibility of the randomization process was access with the capacity: (1) to randomize each professional to a simulation team based on a typical trauma team composition (three nurses, two residents, and one respiratory therapist per team), and then (2) to randomize each interprofessional team to a simulation environment (in situ or laboratory).

The feasibility of the interventions was assessed by the capacity: (1) to deliver the first and second simulations in the same environment separated by a debriefing, and (2) the capacity to deliver four in situ and four laboratory simulations over the study. In situ

simulations can be cancelled at the last minute if patients are admitted and require urgent care, representing a major feasibility problem for research involving in situ simulations. [12]. Barriers to the implementation of the simulations were documented.

The feasibility of data collection was assessed based on 95% completion of the self-reported questionnaires and an inter-rater agreement > 0.75 [42] for the TEAM observation tool. Intraclass correlations (ICC) for the TEAM scores were calculated using a two-way mixed-effects model. These criteria were selected to have minimal missing data and a good inter-rater agreement. Mean scores for each variable are reported for descriptive purposes.

Effect sizes were calculated on all study variables to inform future research. We used a two-way mixed ANOVA to analyze self-reported teamwork performance and cognitive load through simulation times (simulation 1 vs. simulation 2) and environment (in situ vs. laboratory). Partial η^2 were computed to assess the effect sizes of the results. Values of 0.01, 0.06, and 0.14 were considered small, medium, and large effect sizes, respectively [43]. For TEAM scores, we used descriptive analysis (means and SDs), as the sample size was too small (n=2 teams per group) for inferential analyses. The French version of the CLQ being a new adaptation of the original tool, we calculated Cronbach's alphas for each subdomain.

3. Results

3.1 Participants' characteristics

Participants' age ranged from 21 to 38 years (mean 27.8). Most identified as female (79.2%) and had a university degree (75.0%). All participants had previous experience with high-fidelity simulation, ranging from 1 to 15 experiences. The two groups appeared similar regarding their sociodemographic characteristics—see **Table 2.**

Table 2. Sociodemographic characteristics and clinical experience for the entire sample and each simulation group

	Total (n=24)	In situ (n=12)	Laboratory (n=12)
Age (year)			
Mean ± SD	27.8 ± 4.6	28.2 ± 4.8	27.4 ± 4.7
Min.-Max.	21-38	24-28	21-38
Gender, n (%)			
Female	19 (79.2)	9 (75.0)	10 (83.3)
Male	5 (20.8)	3 (25.0)	2 (16.7)
Educational level, n (%)			
College	6 (25.0)	3 (25.0)	3 (25.0)
University	18 (75.0)	7 (75.0)	9 (75.0)
Profession, n (%)			
Nursing	12 (50.0)	6 (50.0)	6 (50.0)
Respiratory therapist	4 (16.7)	2 (16.7)	2 (16.7))
Medicine	8 (33.3)	4 (33.3)	4 (33.3)
Emergency care experience (year)			
Mean ± SD	1.9 ± 1.5	2.33 ± 1.7	1.5 ± 1.1
Min.-Max.	0.2-6	0.2-6.0	0.2-3.5
Resuscitation room experience (month)[†]			
Mean ± SD	6.8 ± 7.1	8.2 ± 9.9	5.5 ± 2.7
Min.-Max.	0.0-36.0	2-36	0-10
Job-status, n (%)[†]			
Part time	17 (70.8)	9 (75.0)	8 (72.7)
Full time	6 (25)	3 (25.0)	3 (27.0)
Shift, n (%)			
Day	6 (25.0)	3 (25.0)	3 (25.0)
Evening	5 (20.8)	3 (25.0)	2 (16.7)
Night	5 (20.8)	2 (16.7)	3 (25.0)
Rotation	8 (33.3)	4 (33.3)	4 (33.3)

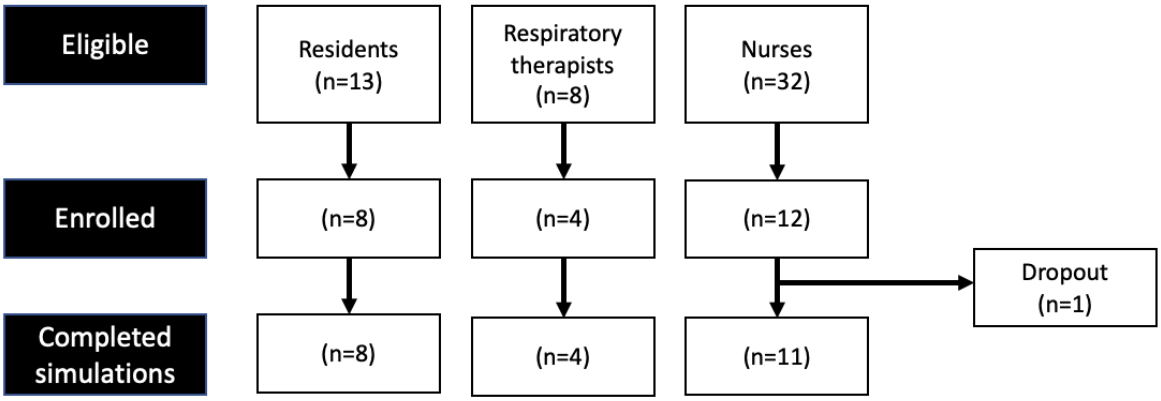
[†] missing data (n=1)

3.2. Recruitment, attrition, and randomization

Recruitment started in May 2021 and ended in July 2021. To form four teams of six professionals representing the minimal composition of an interprofessional team in the resuscitation room, our goal was to recruit 12 nurses, four respiratory therapists, and eight

residents. Of all eligible professionals (n=53), 24 (45%) agreed to participate and were enrolled in the study (see **Figure 2**). Consequently, the recruitment criterion was not met.

Figure 2. Participation flow chart



Randomization was not possible because of the limited availability of the simulation laboratory and staff, the limited availability of medical residents who were only available one-half day per week, and the incompatible schedules of professionals who worked on different shifts. Thus, with REB approval, the team constitution and allocation were modified just before the recruitment. Based on participants' work schedules, we formed four teams of six professionals (three nurses, two residents, and one respiratory therapist) to capture the composition of an interprofessional team admitting a trauma patient to the resuscitation room [1]. Allocation to the study group (in situ or laboratory) was based on the availability of the resuscitation room on the day of the activity. If the resuscitation room was unavailable, the team was directed to the simulation laboratory. Participants and the research team were unaware of group allocation until a few minutes before the activity. Consequently, the randomization criterion was not met.

Regarding attrition, a nurse withdrew a few days before one of the simulation activities because she was no longer available. Due to a lack of interested novice nurses

who met the inclusion criteria, she was replaced by a nurse with 36 months of experience, allowing us to carry out the activity as planned. Since only one participant withdrew, the attrition criterion (<10%) was met.

3.3 Implementation of simulations

Regarding the implementation of the interventions, two teams were assigned to in situ simulations in the resuscitation room (n=12 participants) and two other teams to laboratory simulations (n=12 participants) by the end of data collection, as planned in the study protocol. Since randomization was abandoned, we had planned to perform the two in situ simulations first and complete the data collection with the two laboratory simulations. However, this was not possible due to the unavailability of the resuscitation room during the first simulation. Still, we managed to perform two consecutive simulations in the same environment in each team and in the following order: laboratory (team 1), in situ (team 2), in situ (team 3), and laboratory (team 4). Of note, during one of the in situ simulations, the second simulation of the day was almost cancelled due to the imminent arrival of patients requiring urgent care. Despite all of this, the criteria for implementing the interventions were met.

3.4 Data collection

Regarding the outcome data collection, all questionnaires were fully completed by all participants (100%). The TEAM instrument's inter-rater agreement was good (ICC = 0.77; CI 95% 6.67, 0.85). Accordingly, the criteria for data completion of the self-reported questionnaires (>95%) and the TEAM inter-rater agreement (> 0.75) were met.

3.5 Effect sizes

Table 3 presents the descriptive results of the self-reported teamwork and cognitive load measured at two-time points and simulation environments.

Table 3. Descriptive outcome measures

Variables	In situ (n=12)			Laboratory (n=12)		
	SIM1	SIM2	MD	SIM1	SIM2	MD
Teamwork						
MHPTS (0-32)	23.8 (3.6)	26.8 (3.5)	3.0	21.8 (4.4)	27.3 (3.4)	5.4
Cognitive load						
Intrinsic (0-40)	16.4 (6.2)	14.6 (5.9)	1.8	18.3 (9.9)	15.9 (10.1)	-2.4
Extraneous (0-40)	9.2 (6.8)	8.1 (5.8)	-1.1	9.4 (8.4)	8.6 (6.9)	-0.8
Perceived learning (0-40)	17.3 (7.6)	19.6 (9.7)	2.3	23.0 (6.6)	26.3 (8.1)	3.3

Notes: Data presented are means and standard deviations; MD: mean difference

Figure 3 shows the scores for each team, depending on the simulation environment. Interestingly, one of the teams exposed to in situ simulations (team 3) showed decreased teamwork performance between the first and second simulations.

Figure 3. Fluctuation in TEAM scores from the first to second simulations

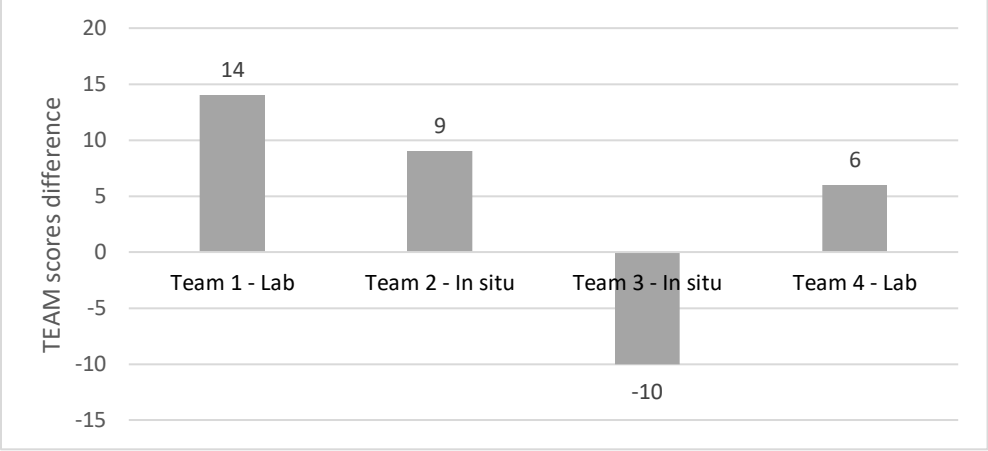


Table 4 presents each variable's effect sizes and power based on a two-way mixed ANOVA. The main effect of time showed a large effect on self-reported teamwork performance and intrinsic cognitive load (partial $\eta^2 = 0.561$, partial $\eta^2 = 0.258$) and a

medium effect on perceived learning (partial $\eta^2 = 0.078$). The main effect of group showed a large effect on perceived learning (partial $\eta^2 = 0.208$). The interaction between group and time showed only a medium effect on self-reported teamwork performance. All other effect sizes were small.

Table 4. Two-way mixed ANOVA for the self-reported teamwork performance and cognitive load

Variables	F	Partial η^2	Power
Time (Time 1 vs Time 2)			
MHPTS	28.09	0.561	0.99
Intrinsic cognitive load	7.63	0.258	0.75
Extraneous cognitive load	0.85	0.037	0.14
Perceived learning	2.32	0.078	0.26
Group (in situ vs. laboratory)			
MHPTS	0.30	0.013	0.08
Intrinsic cognitive load	0.23	0.010	0.06
Extraneous cognitive load	0.02	0.001	0.05
Perceived learning	5.79	0.208	0.06
Time*Group			
MHPTS	2.32	0.095	0.31
Intrinsic cognitive load	0.11	0.005	0.06
Extraneous cognitive load	0.02	0.001	0.05
Perceived learning	0.05	0.002	0.06

Note. Partial $\eta2 = 0.01$ indicates a small effect; $\eta2 = 0.06$ indicates a medium effect; $\eta2 = 0.14$ indicates a large effect.

Although it is not always recommended to calculate a sample size from the data of a pilot study [44], we opted to do so to orient future studies. To have 80% power to detect a significant effect with the MHPTS (the primary outcome of this study), 39 subjects per group would be required, with an alpha of 0.05. Cronbach's alphas for the CLQ showed acceptable to excellent internal consistency for each CLQ subdomain ($\alpha = 0.926$ for intrinsic load; $\alpha = 0.738$ for extraneous load; $\alpha = 0.862$ for perceived learning).

4. Discussion

This study aimed to test the feasibility of a RCT design to examine how simulation environments influence teamwork and cognitive load in novice trauma healthcare

professionals. It also aimed to compute effect sizes for the main study variables to inform future research in the field. Indeed, authors of systematic reviews recommend conducting more RCTs in trauma simulation-based education [8, 45].

4.1 Is it feasible?

The current study results are informative regarding the feasibility of such studies, as we aimed to assess the recruitment, randomization and attrition of participants, the implementation of the simulations as planned in the allocation sequence, and the collection of data using individual and group measures.

Our results demonstrate a low participation rate of novice trauma professionals (45%). Recruitment can be challenging and requires multimodal strategies to convince the target healthcare professionals to participate [46, 47]. Since the data collection was done during the COVID-19 pandemic and we could not meet participants directly, we put forward several strategies to increase the project outreach (i.e., asking department heads to contact eligible professionals, distributing of a video summarizing the project, and financial compensation), which had little effect on the recruitment rate. Remote and non-personalized recruitment, as we have done, seems to be an inefficient way to recruit professionals [47]. In addition, another interdisciplinary research project had just been conducted at the same emergency department, which may have interfered with professionals' motivation to participate in this study. The low recruitment rate could also be explained by the fact that the study professionals were particularly exhausted due to the effect of the COVID-19 pandemic, a phenomenon that has been well documented [48]. Therefore, as an RCT is highly dependent on participant recruitment, much emphasis will need to be placed on this aspect when setting up a larger study.

We were unable to perform randomization for several reasons, including the limited availability of the simulation laboratory and staff, the limited availability of medical residents, and the incompatible schedules of professionals working on different shifts. In contrast with our experience, a recent systematic review of RCTs evaluating simulation interventions in the emergency department (68 studies) shows that randomization of professionals in control and intervention groups is possible [40]. However, most of these studies (n=65/68, 96%) involved individual simulations (a single participant), which can facilitate the randomization process. In the only three studies that used interprofessional simulations, the teams were composed of only two to three professionals from different disciplines [49-51], whereas for our study, we had six professionals to randomize. In terms of randomization procedures, two studies were randomized by block (i.e., by teams), and only one conducted double randomization as we had initially intended (i.e., randomizing individuals to the team and then teams to the control and intervention groups). This demonstrates that randomization in interprofessional emergency department simulation studies is uncommon, probably because of numerous logistical challenges.

The ability to perform the first two simulations in the resuscitation room twice on the same day was also challenging. Indeed, we could not perform the first two in situ data collections as planned because the resuscitation room was too busy. Although we managed to carry out half of the activities in situ and half in the laboratory, replicating this in a larger-scale study would probably result in the cancellation of some simulation activities. Indeed, one of the simulation activities almost got cancelled due to the arrival of a critical patient, and we observed the crowded conditions of the resuscitation room—a well-known challenge of in situ simulation [12]. Limited access to the resuscitation room could also be

explained because the study was carried out in a large tertiary hospital. Moreover, one of the three resuscitation rooms was unavailable for in situ simulations as it was dedicated to caring for COVID-19 patients.

Data collection was carried out successfully throughout the study since the participants entirely completed the questionnaires. The video analysis by two independent observers was also successful, demonstrated by a good inter-rater agreement. However, as we only had four teams, it was impossible to perform inferential analyses with the team data since our sample size was based on individual data.

4.2 What are the effect sizes?

The results suggest a small effect size between the simulation environment and novice professionals' self-reported teamwork skills. However, the self-reported teamwork skills results are not consistent with those obtained by the observations of two external observers with the TEAM instrument. The use of the MHPTS could explain these results. Although this tool has been validated [31, 32], the response scale offers a narrow range for participants to self-assess, as it consists of only three choices (0—never or rarely, 1—irregularly, and 2—consistently). For this reason, and in line with other teamwork tools that have been criticized for similar reasons [52], we believe that the MHPTS is not optimal for identifying whether there is a change in teamwork skills following a simulation activity. Alternatively, the discrepancy between the perceived and observed teamwork results could also be due to the Dunning-Kruger effect, a cognitive bias whereby those less skilled in a domain may overestimate their competencies [53]. Despite this, we decided to use the MHPTS since it was the only individual teamwork measure relevant to trauma care in the emergency department.

The environment did not appear to influence either the intrinsic or extraneous cognitive load of the novice healthcare professionals in traumatology since effect sizes were relatively small. While preliminaries, these results are not consistent with those of Tremblay et al. [16], who compared two simulation environments on cognitive load and emotions in undergraduate pharmacy students and showed that a highly stimulating environment increased intrinsic and extraneous loads. Regarding cognitive load and expertise, it is recognized that improving expertise results in more knowledge, experience, and cognitive schema to rely on when faced with a clinical situation [17, 18]. Thus, these results may imply that our participants, who were relatively new to the resuscitation room, may not have been novice enough in the emergency department to be affected by the environmental stimuli as students in training would be. Otherwise, these results could also be explained because the in situ simulation environment was not sufficiently stimulating as it can be in the real world (i.e., no patient in the resuscitation room and no professionals not involved in the simulation activity were present during in situ simulations). We decided to carry out the simulations during the day and in the summer to favor the possibility of carrying out the simulations in the resuscitation room. However, consequently, this decreased the presence of stimuli in the environment. Another critical consideration that these results highlight is that most studies focusing on novice professionals' cognitive load in simulation settings, such as Tremblay et al. [16], have been conducted in an individual rather than a group learning context [54]. This is an important point, as the cognitive load of the learning activity can be distributed among the individuals composing a group, thus decreasing the individual load of each person [55]. Therefore, this aspect should be studied further.

Another interesting result is that the simulation environment seemed to influence the perception of learning as we found a large effect size. More precisely, the participants exposed to in situ simulations felt they had learned less than those in the laboratory since they had a lower understanding of the clinical case encountered and perceived they had poorer abilities to reason and take action. This element may speak to simulation educators, given that perception of learning often correlates with participants' satisfaction with the educational activity [56]. Although perception is an essential aspect of learning, our results also show a discrepancy between perception and observation of teamwork performance which was also observed in a previous study [57]. According to Persky et al. [53], perceptions of learning may not reflect learning gains, and perception data should be used with caution to substitute for evidence of actual learning in research. However, in this study, we used self-perceived measures since no objective measures of individual teamwork exist, and cognitive load is an individual concept.

4.3 Strengths and limitations

The strengths of this study were our capacity to obtain two similar interprofessional groups with homogeneous characteristics, perform pre-and post-test measures and compute effect sizes for the main variables. However, one important limitation is our incapacity to process the randomization as planned. Another limitation is that the effect sizes obtained may be overestimated due to our relatively small sample size.

5. Conclusion

This study was the first to test the feasibility of a RCT to examine how simulation environments influence teamwork and cognitive load in novice trauma professionals and to compute effect sizes for these variables. Results showed several considerations for

researchers in simulation education in trauma care. More importantly, we presented our experience in conducting a randomized study in the context of interprofessional simulation-based education in the emergency department—which demystifies the barriers we encountered and may lead to reflections on strategies to implement such a research design in this context. Effect sizes obtained could also orient sample size calculation in future studies.

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