Lights. Camera. Action. Debrief.

ENGLISH SUMMARY

Simulation-based education is a powerful learning method that prepares healthcare students and professionals for clinical practice. Immersive simulation allows the learner to practice tasks relevant to future practice within a realistically simulated clinical environment. In immersive simulations, learners rehearse clinical skills, followed by a debriefing period during which they analyze the performance. The simulation and the debriefing are complementary; combining them is essential for optimal learning.

Immersive simulations were first mostly used with more advanced learners with some clinical experience, which enabled them to cope with the unexpected and messy clinical context of authentic situations. Given the limited clinical experience of a novice, it is likely that the messiness of an authentic clinical setting overwhelms them and prevents them for fully reaching the intended learning goals of the simulation. Educators must adapt both the learning task and the learning environment to account for the learner's level. However, the cognitive impacts of these two features on an inexperienced learner remained vastly unexplored, making it more difficult to accurately adapt the simulations to account for the learner's level.

In **Chapter One**, we disentangle the effects of task and environment complexity on novice learners. We also acknowledge that the role played by the learner in a simulation, whether passive or active, influences their cognitive load and learning experience. We illustrate that evidence is still scarce as to what constitutes in practice a complex clinical task for novice students—even more so in specific disciplines such as pharmacy. By understanding how complex environments and tasks influence the learning experience of novices in simulation, we could design simulations specifically adapted for them, and provide guidance that promote learning. This state of affairs led to the development of two central research questions:

1. What are the effects of task and environment complexity in immersive simulation on novices' learning experience?
    a. What are the differences between immersive simulation and simulated patients in terms of cognitive load and emotions for undergraduate healthcare students? (Study 1)
    b. What are the effects of simple and complex tasks in immersive simulation in terms of cognitive load, self-perceived learning, and performance for undergraduate pharmacy students, and how does task complexity influence students' perception of learning? (Study 2)
    c. What is the impact of modulating the complexity of the task and of the environment on novices' cognitive load and performance in immersive simulation? (Study 3)

2. How to support the learning experience of novices in immersive simulation when they observe a peer perform in simulation?
    a. What are the similarities and differences between collaboration scripts, checklists, the combination of both, and no guidance in terms of intrinsic and extraneous cognitive load, and self-perceived learning for novice observers during a simulation-based training, and how do these tools influence the observers' learning experience? (Study 4)

The study presented in **Chapter Two** focuses on the cognitive and emotional impacts of the learning environment in immersive simulation for novices. In this mixed-methods study, we compared two different settings in a crossover design for 143 undergraduate pharmacy students: an *immersive simulation* in a fully authentic environment and a *simulated patient* activity in which participants did not need to use elements of the environment to solve the problems, such as telephones, electronic patient records or actual medications. After both simulation activities, participants rated their cognitive load and emotions using validated questionnaires. Thirty-five students met in focus groups to explore how features of the learning environment influenced their perception of learning. We found that intrinsic and extraneous cognitive load and negative-emotion scores, such as stress, in immersive simulation were significantly but modestly higher compared to simulated patients. Our qualitative findings revealed that the physical environment in immersive simulation generated more stress than with simulated patients. With simulated patients, students concentrated on clinical reasoning, while immersive simulation turned their attention to data collection at the expense of the problem-solving process. This study helped us demonstrate that the learning environment in which novice students experience the simulation influences what and how students learn. Immersive simulation was reported as more cognitively and emotionally demanding than simulated patients. More importantly, our findings emphasized the urgent need for the development of adapted instructional design guidelines in simulation for novices.

In **Chapter Three**, we investigated the effect of task complexity on undergraduate pharmacy students' cognitive load, task performance, and perception of learning in immersive simulation. In this mixed-methods study, 167 pharmacy students experienced consecutively one simple and one complex learning task. Participants' cognitive load was measured after each task and debriefing. Task performance and time-on-task were also assessed. As part of a sequential explanatory design, semi-structured interviews were conducted with students showing maximal variations in intrinsic cognitive load, in order to understand their perception of learning when dealing with complexity. Although the complex task generated significantly higher cognitive load and time-on-task than the simpler one, global performance was high for both tasks. Qualitative results revealed that a lack of clinical experience, an unfamiliar resource in the environment, and constraints—such as time limitations—inherent to simulation hindered the clinical reasoning process and led to poorer self-evaluation of performance. Simpler tasks helped students gain more self-confidence, while complex tasks further encouraged reflective practice during debriefings. Although complex tasks in immersive simulation were more cognitively demanding and took longer to execute, students indicated that they learned more from them as opposed to the simpler tasks. Complex tasks constitute an additional challenge in terms of clinical reasoning, thus providing a more valuable learning experience from students' perspective.

Building on the results presented in the previous studies, in **Chapter Four,** we designed a study that sought to determine the impact of modulating both task and environment complexity on novices' learning experience in immersive simulation. Second-year pharmacy students (N=162) were randomly assigned to one of four conditions (two-way factorial design) in an immersive simulation session varying in complexity: simple or complex tasks in simple or complex environments. Using video recordings of the simulation, two raters assessed students' performance. We measured intrinsic and extraneous cognitive load with questionnaires after the task, and tested knowledge after task and debriefing. Performance during the simulation remained good in all conditions, but we found an interaction between task and environment complexity, which indicated that performance of simple tasks decreases as environment complexity increases. When novices struggled with the environment during the simulation, their focus seemed to shift from the task and was redirected towards managing the environment, hence the decrease in performance in more complex environments. We also found that the higher the task complexity, the higher the intrinsic cognitive load. As complexity increases in simulation, students seem to strategically manage their own cognitive load to maintain an appropriate performance and learn something relevant. However, although this strategy prevents students from experiencing cognitive overload, it might also impede their capacity to meet all the intended learning goals.

In **Chapter Five**, we explored the learning process in immersive simulation of students with the role of observer. We designed a mixed-method study that aimed to understand similarities and differences in cognitive load and learning outcomes while comparing observers' use of collaboration scripts and checklists. Second-year pharmacy students (*N*=162) were randomly assigned to one of four conditions when observing a simulation: collaboration scripts (heuristic to analyze in dyads while observing), checklists, a combination of both instruments, and no guidance. We measured observers' intrinsic and extraneous cognitive load, and self-perceived learning, and conducted focus group interviews. Collaboration scripts imposed the highest intrinsic cognitive load because collaborating and co-constructing knowledge with a peer seemed more complex. Checklists, which generated the lowest scores of intrinsic cognitive load, were perceived as a simple exercise that did not require them to reflect on the relevance and quality of the box to check. Extraneous cognitive load scored significantly higher when both tools were combined, although scores remained very low in all four conditions. Observing the simulation, with or without guidance, was a meaningful learning experience resulting in moderate scores of self-perceived learning. With collaboration scripts, students learned more thoroughly about one specific aspect of the simulation, whereas checklists gave them a general overview of all possible options for the problems encountered in the simulation. Combining both tools seemed a bit overwhelming for students, as they had to deal with too many tasks at the same time. Without support, observers were free to reflect on their observations, but could easily be distracted or focus on irrelevant parts of the simulation. With or without guidance, we showed that observers were actively learning during the simulation, but our findings showed that their effort differed depending on the tool they used.

In **Chapter Six**, we answer our research questions by synthesizing the results of our studies and situate them in relation to the existing literature. We also discuss practical implications, strengths and limitations of this research, and provide suggestions for future study. In answer to our first research question, we can conclude that both environment and task complexity influence the learning experience in simulation. Without careful planning of all features involved in the simulation, the learner can be easily diverted from the initial learning objectives. They can strategically decide to pursue smaller goals more reachable or, undesirably, fail to detect the appropriate problems. Moreover, the environment and the task act in synergy and directly influence what students will learn and how they will perform in simulation. For novices, complex environments appear more complex than clinical tasks, partly due to their lack of awareness and mastery of the clinical setting, which inevitably induces a certain amount of stress. It is therefore advisable to prepare students to deal with complex environmental features before introducing complex concepts in the learning tasks, in order to facilitate students' capacity to manage all information.

With regard to our second research question, we can conclude that providing instructional support for students with an observer role in simulation ensures that they are actively engaged in the simulation and focus on relevant aspects. Throughout our research program, students often reported that they really appreciated acting the role of observers as it provided them a wide perspective on the simulation without experiencing performance anxiety. Some participants even proposed that they were more able to analyze the situation. For novice learners, varying their roles and having them observe occasionally should not be overlooked, as it seems meaningful for them.

The research presented in this thesis contributes to our understanding of effective instructional design of immersive simulation for novices. Providing authenticity and complex problems are essential to stimulate learning, but careful consideration must be paid to not overwhelming the learner during the simulation. Like a theatre director, designers must manage the combination of all the features involved in the simulation, from the environment in which the scene takes place, the task that will be performed, up to how the audience will respond to this performance. Our findings support the use of immersive simulation for novices and stress the importance of managing complexity to promote learning.