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Advancing immersive virtual reality-based simulation practices: developing an evidence-based and theory-driven pedagogical framework for VR-based simulations of non-technical skills among healthcare professionals

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ABSTRACT

Virtual reality (VR) based simulation is emerging as an innovative tool for the training and education of healthcare professionals. However, pedagogical frameworks specific to this type of simulation are yet missing. This paper explores participants' experiences with VR-based simulation training in non-technical skills (VR-SIMI) and integrates them with established pedagogical theory. Non-technical skills refer to cognitive, social, and personal resource skills such as effective communication, relational competence, and stress management. An observational study was conducted involving 11 healthcare professionals in children and adolescents' mental healthwho attended four VR-SIMI sessions over one year. Data were collected through field notes during participant observation and informal conversations with the participants. Directed content analysis was conducted, informed by the established practice of VR-SIMI (including INACL standards of best practice simulation), Jeffries simulation theory, Kolb's experiential learning theory, and adult learning theory. The findings indicate that the participants positively evaluated the use of VR-SIMI. However, they also reported that the implementation and learning outcomes should be further refined. Based on these findings, an evidence-based and theory-driven pedagogical framework is proposed to guide and enhance the quality of VR-based simulations of non-technical skills for various of healthcare professionals, as well as inform future research.

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Introduction

Simulation training of non-technical skills

To improve situational awareness, anticipate possible consequences, and make correct decisions in different situations, skills like effective communication, relational competence, stress management, and effective collaboration with other colleagues—also known as non-technical skills (NTS)—are paramount for healthcare professionals (Flin et al., 2008). Flin et al. (2008) define NTS as "the cognitive, social, and personal resource skills that complement technical skills, and contribute to safe and efficient task performance". Training programs using simulation to strengthen NTS were initially introduced in the aviation industry, but later adapted to the healthcare system (Gaba et al., 1994)

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and referred to as *medical simulation*. Today, medical simulation is a well-positioned health care teaching methodology, in which professionals or students interact with each other, a simulator, and/or other technical devices (Dieckmann et al., 2007) to replace or amplify possible real-world scenarios with safely guided experiences in a fully interactive manner (Gaba, 2004). The purpose is to mimic a clinical environment where healthcare professionals can practice procedures and reflect using role-playing, games, video without the risk of doing any harm to patients (Jeffries, 2021). Medical simulations take place in safe environments where exercises can be repeated and mistakes are allowed (Rosen, 2008). Medical simulation has proven to be an effective learning activity (Farbu et al., 2020; Pottle, 2019), as it creates positive learning environments and contributes to greater self-confidence (Foronda et al., 2013).

In the past decades, pedagogical frameworks have been proposed to guide medical simulation and enhance the quality of the learning experience. A commonly used framework in medical simulation is The National League of Nursing (NLN) Jeffries Simulation Theory (Jeffries, 2022). Jeffries' theory offers "an evidence-based contextual learning-teaching strategy that facilitates experiential learning and fosters critical thinking and clinical reasoning". The theory is embedded within adult learning theory (Zigmont et al., 2011), also known as andragogy. In this context, it is paramount to consider that participants in medical simulation (either healthcare professionals or students) are adult learners and, hence, have different needs and characteristics than children. In particular, adults are independent in the learning process, striving for autonomy and self-directed learning. Unlike children, adults bring previous knowledge, experiences, and personal perspectives to new learning experience, which can (and should) be seen as a resource (Knowles et al., 2005). Intrinsic motivation is essential to support learning among adults, which is triggered when they believe that the learning outcome is relevant to their practice and immediately usable (Ryan & Deci, 2000) – in this sense, it is important that the learning is primarily task – and problem-centered. In this context, the role of the *facilitator* (a figure who guides the learning experience), rather than the *teacher* (a figure that unidirectionally communicates knowledge), becomes central in medical simulation.

Despite its extensive use, medical simulation presents several challenges. The planning and facilitation of sessions can be highly resource-intensive (Zigmont et al., 2011) because simulations should take place in customized rooms that mimic the surroundings of real-life scenarios, requiring large spaces to contain both actors and observers, as well as specific equipment. It can also be stressful, because the scenarios are mostly enacted by students/trainees, often recorded (Ødegården et al., 2015), and/or involves being professionally assessed by colleagues. Moreover, some find healthcare simulation to be of little practical utility (Lied, 2010). Virtual reality (VR) technology may address some of these challenges.

VR technology in simulation, training, and education

Gaddis (1998) defined VR as "a computer-generated simulation of the real or imagined environment of world." VR simulators may be divided into three main categories: (1) screen-based VR, showing images or videos displayed on any screen or desktop; (2) non-immersive virtual environments based on interactive and/or multiplayer online gaming including, for instance, avatars for trainees and "virtual" patients, etc.; and (3) immersive VR-environments, in which trainees are exposed to virtual environments whilst being disconnected from the real world through head-mounted displays (HMD) (Haowen et al., 2021). With respect to the latter type of VR, further elaborations need to be made relative to three aspects that characterize the technology and the way it influences the users' experience: immersion, presence, and interactivity (Mütterlein, 2018). While immersion refers to the extent to which the VR technology can provide "an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant", presence refer to the users' subjective "sense of being in the virtual environment" (Slater & Wilbur, 1997). Interactivity, on the other hand, refers to the extent to which the user can influence the virtual world, for instance moving objects or having the possibility to influence the storyline. The levels of interactivity often depend on the developmental techniques used to create the VR scenarios. For instance, while 360 videos (VR content created through special video cameras) normally only allow "passive" exposure to a predetermined sequence of scenes, where the user can only choose where to direct their vision within the 360 range of vision, digitally generated VR content (e.g. using 3D modeling and video-game techniques) often allow greater levels of interactivity, depending on the specific programming (Calogiuri et al., 2021).

An essential aspect of the simulation is that participants experience the same (or highly similar) feelings of being in a real-world setting (Gaba, 2004). In this respect, immersive VR technology can be particularly effective, as it is known to provide stronger feelings of presence than less-immersive technology (Slater & Wilbur, 1997), which can increase the interest in the learning itself (Kyaw et al., 2019; Pottle, 2019). Moreover, in VR-based simulations, the participants do not need to engage in role-playing as the scenarios are already being recorded and the high levels of presence may elicit greater feelings of situational awareness and empathy (Slater, 2018). Importantly, studies have demonstrated that VR is considered by many users to be equally (if not more) engaging and enjoyable compared to regular "blackboard" teaching (Mantovani et al., 2003; Radianti et al., 2020).

Recent advances in VR technology, including the introduction of relatively inexpensive and user-friendly HMD and 360 cameras (Fertleman et al., 2018), have opened new possibilities for the use of this technology in simulation training. VR-based simulation programs have recently emerged and are currently in use in different health trusts. VR is often referred as an experimental method with focus on the usability in short-term use (Jensen & Konradsen, 2018) and focus on the usability rather than the methodology and learning outcomes, is known gaps in the applications of VR (Radianti et al., 2020). Much attention has been given to the technology itself (hardware and software) rather than how to effectively integrate VR into training and education according to sound pedagogical approaches (Radianti et al., 2020). Hence, to generate meaningful learning experiences, it is important to acknowledge and address the specific challenges and requirements associated with the use of immersive VR technology within the pedagogical context. However, a pedagogical framework tailored for VR-based simulation, especially in the context of NTS training, is still missing.

Purpose of the present study

This study is connected to an overarching project titled *Mental Health Care for Children and Youth* (https://nbup.no/bup-prosjektet/) led by the South-Eastern Norway Regional Health Authority. Within this project, a VR-based simulation training program (VR-SIMI) was developed as an innovative solution to enhance and strengthen NTS among healthcare professionals within children and adolescents' mental healthcare services. The study presented in this paper aims to explore the practice of VR-SIMI to develop a novel pedagogical framework that can specifically address the needs and learning outcomes of VR-based simulation training of NTS. The following research question was designed: What is the participants' experiences of learning through the implementation of VR-SIMI in training of non-technical skills among healthcare professionals over a period of time, in light of Jeffries Simulation Theory, Kolb's Experiential Learning Theory and Adult Learning Theory?

Materials and methods

VR-based simulation Inland Norway (VR-SIMI)

VR-SIMI is developed at the Centre for Simulation an Innovation at SIMInnlandet, Innlandet Hospital Trust Norway based on general guidelines for medical simulation (Oslo Universitetssykehus, 2021). The VR scenarios are developed as 360 videos and viewed through HMDs. In the simulated scenarios, professional actors and/or volunteer healthcare professionals enact topical cases. As an example, one of the scenarios depicts a therapist having a difficult first conversation with a patient and their parents. The participants get to "participate" in 10 min of this conversation, as an invisible observer in the room. The scenarios are led by a trained facilitator leading groups of five to eight participants. The sessions lasting for one-and-a-half hours follow the Guidelines for the implementation of VR-SIMI [reported in an unpublished manual (SIMInnlandet, 2022 build on Kolb's Experiential Learning Cycle (1984) and include the following five steps:

(1) Clarification: Presentation of the case and related learning objectives, based on the selected pre-recorded scenario, desires, and/or needs of the participants/management.
(2) Pre-briefing: Include reading relevant research articles, attending a lecture, or other learning activities on the chosen subject.
(3) Viewing the VR scenario: Participants gather in a suitable room. The time, place, and situation depicted in the VR scenario are described by the facilitator (this information is also provided within the VR scenario). After a brief explanation of how to operate the device, the trainees wear the HMD and start the 360 video simultaneously. The facilitator is recommended to have seen the scenario in advance.
(4) Debriefing: After a brief summary of the events in the scenario, the group discuss and reflect on the case viewed in VR, with a focus on the learning objectives. The discussion follows procedures outlined by the International Nursing Association for Clinical Simulation and Learning Standards of Best Practice (INACSL Standards of Best Practice, 2016, December) and the Debriefing Assessment for Simulation in Healthcare (Simon et al., 2013).
(5) Apply in practice: The participants concretize the ways in which they can implement the learning in their clinical work. Often, the session is concluded with a written evaluation.

Design

This study adopted an overarching pragmatic qualitative design that involves a continuous alternation between empiricism and theory. Data were collected through observation performed by the first author. Through active participation, close observations of the participants attending the VR-SIMI sessions were conducted. This allowed informal conversations, or "field conversations" (Wadel & Fuglestad, 2014), spontaneously taken place during the sessions, generating knowledge through first-hand experience, which is considered as a valuable benefit of fieldwork (Fangen, 2004). Notes from field conversations and observations were recorded and transcribed following each observational session.

Sample and data collection

The participants were 11 healthcare professionals (registered nurses, social workers, social educators, psychiatrists, and psychologists) working within mental health services for children and adolescents in the Health Trust in Norway, who were attending the VR-SIMI sessions as part of the overarching project. The sessions took place at the Health Trust's simulation center. The participants were divided into two groups, one group was affiliated with the children's service and one with the youth service. Each group completed four sessions between February 2021 and December 2021. Attendance varied from three to five participants per session, with all the 11 participants attending at least one session. All participants were familiar with medical simulation from their work as they train from once a week to once a month on self-selected clinical situations with prepared learning objectives. A few of the participants had tried VR in connection to simulation before, but not VR-SIMI.

Participants received oral and written information about the research project and treatment of their personal data and provided written informed consent. The study was approved by the Norwegian Centre for Research Data (reference n. 661795). Due to the small sample, quotes were paraphrased to protect the participants' privacy.

Data analysis and development of the pedagogical framework

The analysis was based on directed content analysis (Hsieh & Shannon, 2005) guided by the Jeffries Simulation Theory as integrated with Kolb's Experiential Learning Theory, and Knowles' Andragogy. The analysis was deductive (Elo & Kyngäs, 2008), with the initial coding frame anchored in the core constructs of Jeffries Simulation Theory and topics associated with VR technology. Firstly, in the preparation phase, initial codes were selected (selected units of analysis; Table 1), and a structured categorization matrix was developed based on the empirical findings. Through reiterative reading, the final themes were further defined, including main categories and subcategories (Table 1). The categories were supported by direct quotes. The interpretations and understandings were corroborated by requesting feedback from the participants and discussions with the employees at the SIMInnlandet.

Result and discussion

Table 1 presents the analysis results, while Figure 1 depicts visually the proposed pedagogical framework. The main categories, with their respective subcategories, explanations, and participants' quotes, are presented and discussed below and construe the foundation for the pedagogical framework of VR-based simulation for the training of NTS (VR-SIMI Framework).

Contextual principles and participants

Safe environment

The participants preferred attending the VR-SIMI sessions at the Simulation Center instead of in their workplace, so they could fully concentrate on the sessions, avoiding being distracted by their responsibilities at the clinic.

> *"VR-SIMI wouldn't work so well in the clinic; I do not know where we could have trained in peace and quiet there."*

Table 1. Selected units of analysis, main categories, and subcategories of the directed qualitative content analysis, concerning the construct of the Jeffries Simulation Theory.

Selected units of analysis	Main categories	Subcategories
- Context - Mixed group of health professionals - Varying attendance	Contextual principles and participants	i. Safe environment ii. Feasible even with few participants iii. Learning from different professionals.
- Facilitator skills - Facilitator education	VR-SIMI Facilitator characteristics	i. Be confident in guiding toward learning goals ii. Formal facilitator education
- Purpose - VR-SIMI compared to medical simulation	Pedagogical principles	i. Meaningful learning goals related to practice. ii. Avoiding the role-play and Critical reflection on the scenarios
- Pre-brief - Vision of VR-scenario - Debrief - Apply in practice	Established VR-SIMI practice	i. Pre-brief: Not essential for a good learning outcome ii. VR-Scenario/ De-brief: presence, engagement and learning iii. Apply in practice: Combine with medical simulation
- Pros - Cons	VR-technology	i. User-friendliness, engagement ii. Cybersickness
- Non-technical skills - Engagement - Observational learning - Self-efficacy	Outcomes	i. Critical reflections ii. Observational learning and vicarious mastery (Preventing work-related stress)

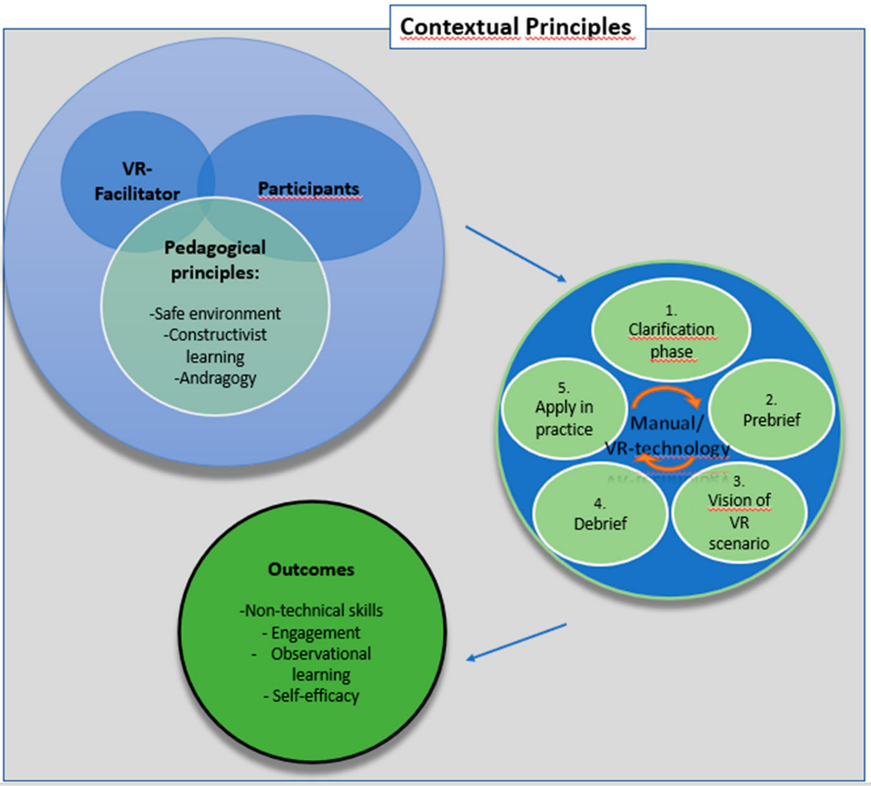

Figure 1. VR-SIMI framework. (Framework made by author Siv Lena Birkheim, inspired of Jeffries, 2021).

The participants preferred using swivel chairs, instead of normal chairs, to facilitate the exploration of the virtual environment, as you can turn around effortless. This emphasize how VR-SIMI does not require large spaces or complex equipment, but just a quiet room with enough space for some swivel chairs. However, the participants were paramount that they could feel safe and as comfortable as possible while wearing the HDM. These findings find correspondence in Jeffries Simulation Theory (Jeffries, 2022), where a safe environment is an important start for the effective implementation of simulation training. Mutual trust, respect, freedom of expression tolerance and duty of confidentiality were viewed as core elements in the practice of VR-SIMI training.

Feasible even with few participants

Challenges relative to attendance occurred, mainly because of restrictions and sick-leave related to the COVID-19 pandemic, although several of the participants experienced also lack of time, as their employers did not formally include the training within the health professionals' work schedules. This issue was discussed in the groups, with the participants agreeing that the training should be embedded within professionals' work routines, allowing time and resources accordingly. Despite these challenges, the training sessions were carried out as planned, even with only three participants (including the facilitator). The participants agreed that three people should be the minimum group size for a session. The fact that VR-SIMI can be conducted in such small groups was an advantage. For instance, one participant, who is also educated as a facilitator in medical simulation, described that they had used VR-SIMI instead of medical simulation when they experienced low attendance in their planned medical simulation. In this case, VR-SIMI may function as an alternative to healthcare simulation, and not just as a supplement like it was intended to be.

Learning from different professionals

VR-SIMI was seen by the participants as a useful method for achieving better collaborative learning across occupational groups, which was perceived as a shortage among the participants. Including a variety of health professionals in the same group was deemed as a positive element, as was well-depicted by the voice of this participant:

> *"It is interesting to hear how professions other than myself think about this problem. It is important to learn from each other".*

Although everyone viewed the same scenario in the HMD, they did not always have the exact same experience. In fact, the participants may have different perspectives of the 360 video through the HMD, or their perception may be colored by their professions, experience, and previous knowledge. Such an opportunity to notice and reveal different perspectives makes the VR-SIMI a useful method for increasing NTS in a way that is more comparable with clinical practice, where situations may often be perceived differently among professionals.

VR-facilitator characteristics

Being confident

The analysis revealed that patience, effective leadership, and genuine enjoyment for teaching, were perceived as important skills of the VR-SIMI facilitator. Additionally, VR facilitators need to be skilled and familiar with the use of VR. Commitment and interest, alongside the ability to facilitate the conversation flow during the debriefing phase, but still focusing on learning goals, were also considered important.

> *"We need someone who holds on to learning goals and asks Socratic questions. Without a facilitator, everything can quickly become like a big soup."*

There was consensus among the participants on not viewing the facilitator as someone who can provide answers: "*[The] facilitator shall dance together with the participants,"* This links to sociocultural learning theory (Vygotsky, 1978), which is central to the Jeffries Simulation Theory.

Formal facilitator education

According to the unpublished VR-SIMI manual, facilitators in VR-SIMI are recommended to complete a "train-the-trainer course" (SimOslo, 2022), or another certified course to become a facilitator in medical simulation. Those among the participants who had taken this facilitator course tended to recognize the value of requiring such a prerequisite in the context of VR-SIMI. As discussed by the participants, however, requiring a formal facilitator education comes with challenges, especially in relation to costs (both, the course itself and the "lost" work time required to attend the course over three days), which can be taxing to health trusts or individuals. This may result in a barrier to the effective implementation of VR-SIMI. The participants suggested that less resource-intensive courses may be provided as an alternative. The creators of VR-SIMI emphasize the need of maintain high-quality standards in the implementation of the method, including the need of adequately qualified facilitators leading the sessions, although this does not necessarily exclude the possibility of solutions that may lower costs. This issue is likely to be relevant concerning the use of VR-SIMI in an educational context, which is often already deficient in economic and staffing resources (Ødegården et al., 2015).

Pedagogical principles

Meaningful learning goals related to practice

The overarching purpose of VR-SIMI may vary depending on whether the method is used for professional training or education. In this study, specific learning outcomes were defined by the facilitator and/or the participants and adapted to the cases. This is in line within adult learning principles, as adults tend to prefer engaging in learning by a "need to know" principle, with focus on improving their work performance (Knowles et al., 2005). In such context, having concrete previous experiences offers the base for collaborative reflections, which can lead to new solutions to common challenges. As one participant expressed:

> *"It is great to have a 'place' to meet other adults who have a desire to understand and learn more … The scenario must be relevant, but the learning goal for the training is the most important."*

Avoiding the role-play and critical reflections on the scenarios

A perceived benefit that recurred among the participants was avoiding to role-play. This made participants feel more relaxed, spontaneous, and self-aware. Moreover, several experienced that, contrary to their experiences from traditional medical simulation, the use of the VR scenario allowed them to speak freely (even in critical terms) of the fictitious characters.

> *"I feel we can problematize a little more in VR-SIMI … I allow myself to be more critical and it allows for more learning than in a medical simulation."*

Breaking-up daily work routines with VR-SIMI was evaluated as fresh and regenerative, providing renewed motivation to work afterward.

> *"Training like that [VR-SIMI], gave me energy and motivation to go back to work … I learn something new every time and that gives me a boost in the daily work." Comparing this to medical simulations, where several of the participants expressed: "Role-playing is demanding, and I get so tired. It is often difficult to return to work."*

Established VR-SIMI practice

Pre-brief: not essential for a good learning outcome

It is important to consider what health professionals view as useful to their own learning. For instance, readings of relevant literature in the pre-briefing did not seem to be a priority, as expressed from several participants:

> *"When we practice as a part of our workday, it is not as important [to] pre-brief as when we are going to learn something new … [this] can be an obstacle to meet."*

Participants also expressed that they felt more open-minded and creative if they could meet without a pre-brief, although they expressed that the pre-brief should not be completely excluded from the procedure.

VR-scenario/de-brief: presence, engagement, and learning. Although in VR-SIMI, the participants do not have the opportunity to actively interact with the environment, this did not seem to limit the feeling of presence in the scenario, as exemplified by these quotes:

> *"I was drawn straight into something that was perceived as clinically relevant and I experienced it more intensely as if I were in the room."*

> *"It was good to avoid disturbances, I just needed to stick to my reactions, as I didn't see the others."*

> *"This was fun … I really felt it in my body"*

The sense of presence helped the participants to value the relevance and importance of continuous training and to find possible answers to everyday challenges (Jensen & Konradsen, 2018; Mantovani et al., 2003). The HMD triggered the participants' exploration, reflection, and learning. This highlights how, in VR-SIMI, the VR device can serve as a visualization tool, both in the form of vividly recalling situations previously experienced and preparing for situations that might come.

> *"The situation in the film was new to me, but I thought that this is also a way to do it. Now I feel more prepared."*

VR provides an opportunity for constructivist learning, as it emphasizes the combination of input from senses, existing knowledge, and new information to develop new meaning (Chen, 2010). Participants repeatedly reported feeling emotionally affected by the experience, and this was described as a focal element through which the VR scenario supported their learning. In turn, the emotional responses seemed to be amplified by the heightened perceptions of being present in the virtual world expressed like: "*I felt with my whole body that this was an activated patient*" *and* "*I felt like I was there*". Participants enjoyed meeting authentic problems presented in a novel and interesting way through the HMD. This is in line with previous studies showing that using VR in an educational context can elicit positive emotions and engagement (Allcoat & Mühlenen, 2018). Although entertainment does not necessarily translate into learning (Makransky et al., 2019), being engaged and motivated in learning is fundamental to repeating learning activities and achieving learning outcomes (Allcoat & Mühlenen, 2018; Mulders et al., 2020) and the engagement and enjoyment experienced during VR-SIMI sessions may support continuous learning and training among health practitioners. When it comes to the various phases of VR-SIMI, everyone agreed.

> "*It is in the de-brief most of the learning takes place*".

Apply in practice: combine with medical simulation

In VR-SIMI, as well as in traditional medical simulation, the concluding phase "Apply in practice" is rarely attempted. To increase the likelihood of this phase taking place, several participants suggested combining VR-SIMI with medical simulation.

"*What if we use VR-SIMI first, to get to know the scenario and discuss possible outcomes/solutions, and then try this out with role-playing games in a medical simulation? Then we get to try in practice what we are talking about during the debriefing in VR-SIMI.*"

Although requiring more resources, this was perceived by participants as a potentially effective strategy, which may rely on already planned activities within the professionals' training.

VR-technology

User-friendliness

The participants appeared to quickly learn how to operate the HDM, in spite several of them had no previous experience with such devices. This is likely facilitated by people's ever-increasing familiarity with digital technology, as well as the fact that the participants were educated adults. As noticed by one participant:

> "*This was so easy, so self-explanatory.*"

Cybersickness

Cybersickness was not measured through any specific instrument, but all participants received information about it and were given the opportunity to express themselves on this topic. In general, cybersickness did not emerge as a noteworthy challenge. However, as cybersickness is a known and common challenge when using VR (Litleskare & Calogiuri, 2019), it is important to be aware of the possibility that some participants may experience it and be prepared to offer alternative means for viewing the scenario (e.g. viewing the video on a screen or tablet).

Outcomes

Critical reflections

In VR-SIMI, great emphasis is placed on the fact that there may be different solution to a specific challenge, by reviewing various solutions to the scenario viewed in VR. While in traditional medical simulations a great emphasis is placed on providing positive evaluations and feedback to the learners who role played a scenario, VR-SIMI provides greater opportunities for critical evaluations and, perhaps, even suggest alternative solutions in the way the actors handled the situation in the scenario. Then, participants in the group can engage in a lively and honest discussion without risking hurting anyone's feelings.

All participants agreed that VR-SIMI is a suitable method for training NTS. However, several participants noticed limitations in the implementation of the methods, especially with respect to specific learning outcomes.

> *"VR-SIMI, as it stands now, is too similar medical simulations. It should be adapted and developed even further in line with the learning objectives." Participants shared general feedback on what can be further developed, such as, "I think the scenarios are for similar medical simulations and should be better adapted in terms of technology, such as how the camera is placed, etc."*

Observational learning and vicarious mastery (Preventing work-related stress)

> *"What a good example of a conversation with a patient, exemplary actually."*

This spontaneous statement links to Bandura's Social Learning Theory (Bandura, 1977), which emphasize how learning results from observing the behaviors of others. Comments like "*I don't know if I would say or do it like that. But seeing this example allows us to reflect on own expression,*" captures how VR-SIMI may act through modeling and vicarious mastery experience (Bandura, 1977). Such vicarious experiences may contribute increasing the participants self-efficacy, the individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments, relatively to similar situations in real life (Bandura, 1994). For this to happen, it is essential that learners identify themselves with the social model they are observing (i.e. the actor in the VR scenario). This process seems to be reflected in the VR-SIMI sessions. All participants appeared to relate to the events in the VR scenario, which provided a base for subsequent discussions in plenary. Positive reinforcements like confirmations or constructive feedback from colleagues was considered important and necessary by the participants to feel secure in their work. Moreover, similarly to medical simulations, VR-SIMI appeared to increase the participant's confidence in critical thinking and problem-solving abilities (Jeffries, 2014).

Strengths, limitations, and recommendations for future research

The present study provides valuable insights, informed by established theory on medical simulation, into the way healthcare professionals experience and value VR-based simulation as a way to train their NTS, which can guide the use of this methodology in other contexts. By doing so, to the authors' best knowledge, this is the first study addressing the lack of specific pedagogical frameworks that can fully satisfy the unique requirements and learning outcomes that characterize VR-based simulation (such as VR-SIMI). By including the voice of healthcare professionals who used VR-SIMI as part of their regular training routines, the evidence-based and theory-driven pedagogical framework proposed in this paper provide valuable contribution to the advancement of VR-based simulation practice. This study, however, has several limitations that should be taken into account.

This study had a relatively small sample, which made it vulnerable in terms of drop-out. All participants in this study were familiar with and regularly train with medical simulation as part of their work schedule, which may have influenced the way their overall evaluation of VR-SIMI. Although the pedagogical framework proposed in this study may be flexibly applied to other VR-based simulation training, adjustments may be needed. The study focused primarily on the practical implementation of and learning processes during VR-SIMI, while the evaluation of the actual learning outcomes was limited. It is, hence, recommended that future research further evaluate effectiveness of VR-SIMI in achieving the set learning outcomes, as well as include larger samples, to obtain a more representative result.

Conclusion

VR-SIMI emerges as a simple, engaging, and educational method for training NTS, which can serve as a supplemental or alternative tool to traditional medical simulations. The proposed theory-driven and evidence-based pedagogical framework addresses the current lack of specificity in VR-SIMI (and other VR-based simulation training), especially with respect to the challenges and opportunities provided by VR technology, highlighting challenges to the effective implementation of this methodology, generally contributing advancing the practice of VR-based simulation.

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