Can We Trust Virtual Simulators for Health Education? A Study on Evaluation and Indicators of Accuracy and Reliability

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Abstract: Virtual simulation is capable of computationally recreating real environments and interactions. The goal of this study is to analyze papers on virtual simulations for health training to understand how educational and software quality assessments occur and how they can impact the reliability of these tools. It was observed that the participation of specialists in the elaboration of the requirements is common and can significantly collaborate with the detailing of information and with the educational approach of the virtual simulator. The evaluation of the simulators occurs considering almost exclusively aspects related to the application interface and through questionnaires. Researches related to long-term effects of skill acquisition mediated by simulators are necessary. Finally, it also observed that interdisciplinarity in development teams is essential to ensure the reliability of virtual simulators.

Keywords: *Virtual Reality, Health Education; Computer Simulation; Simulation Training.*

1. Introduction

New technologies have driven changes in the learning and training of healthcare professionals [1]. Traditional training performs simulations with mannequins, models, and corpses. However, these practices require on-demand preparation, raise ethical issues, and often do not allow the learner to experience more significant variability and complexity of clinical cases. In addition, another reported difficulty is the insecurity of professionals with no experience when working with patients for the first time [2]. In this sense, virtual simulators have shown how it is possible to explore new paths for training in Health and benefit fields of action, such as Medicine [3], Dentistry [4], and Nursing [5].

Virtual Reality (VR) and Augmented Reality (AR) are two main technologies for simulated and interactive learning. They enable user interaction with a virtual environment, reproducing visual, sound, and tactile sensations through computational devices, favoring the development of systems to support teaching, training, and therapies [1] [6]. It is important to emphasize that interpersonal skills training, in addition to technical skills, is also the goal of many of these applications [1]. The use of virtual simulators can reduce the costs and risks of traditional training and provide more training opportunities for students before practice and real-time evaluation of their performance.

The present study aims to analyze studies on virtual simulators for training clinical procedures to understand how the evaluation of educational aspects and software quality occurs and how these aspects can impact the reliability of these tools. For this, this integrative review was carried out.

2. Extended Reality Applied to Health

Extended Reality (XR) is the extension of human experiences through technology. It offers interactions that explore all human senses through virtual simulators. Tools based on XR explore immersion and interaction, providing real-time responses to user actions and through the realism of virtual simulators, with visual, tactile, sound resources, among others. Thus, VR, AR, and Mixed Reality are inserted in the context of XR [7].

The starting point of these technologies is the real environment. By inserting computational elements into the real world, we have AR. AR moves towards Augmented Virtuality (AV) as more virtual elements are superimposed on the real world. The literature discusses little AV and many studies approach it as AR. Mixed Reality consists of combining elements from the real world with the virtual. In this way, AR and AV are part of this concept. VR, in turn, allows the user to immerse himself in a three-dimensional environment, where it is possible to manipulate objects and perform a series of actions from the real world. Figure 1 shows the characteristics of each of the technologies mentioned.

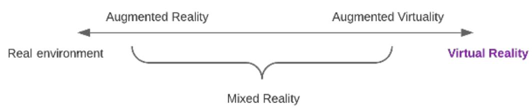

Figure 1. Representation of "Virtuality Continuum" [7].

Over the years, XR has been successfully used in different fields of knowledge, such as engineering, design, architecture, business, and entertainment [8]. In the field of Health, it has contributed by showing possibilities of exploring new ways to leverage treatments, clinical training, and tools for professional assistance. XR tools use computational devices for interaction. These devices represent, with increasing fidelity, the real interaction in virtual environments. These tools are realistic and safe, as they do not pose any risks to the patient's health and assist in the technical training of professionals, enabling them to obtain real-time feedback about their clinical practice.

3. Research Methodology

The integrative review was chosen as a methodology for selecting and analyzing studies related to the topic. The steps and results obtained are detailed below.

3.1. Research Questions

The development of virtual simulators must include the educational evaluation and the evaluation of the quality of the software to ensure the reliability of the tools. Therefore, this study seeks to answer:

1) How the evaluation of virtual simulators occurred?
2) What are the reliability and accuracy indicators?

3.2. Conduct Search

After defining the research questions, the next step was to select the papers for analysis. For this, terms commonly present in studies on virtual simulators for Health training were used to cover the most significant number of papers and obtain a broad view of state of the art. As a result, we arrived at the following search string:

(“augmented reality” OR “virtual reality” OR “simulation” OR “simulator” OR “haptic” OR “haptics”) AND (“medical education” OR "medical training").

The term "haptic" was included in the search string due to its importance in manual dexterity training through virtual simulators. A haptic device is a computational device used to interact with and manipulate 3D objects in a VR environment. It makes it possible to insert the user into the virtual environment and track their positions in it, and it can also provide tactile feedback through force feedback.

The searches took place in the digital libraries ACM Digital Library, IEEE Xplore, and PubMed, important publications in Engineering and Computing, in the case of the first two, and Medical Informatics. Studies from 2010 to 2021 were collected based on a title/abstract search using the previously defined search string. In addition to the cited databases, papers were included that the authors of this study considered relevant or mentioned in the returned papers' bibliography. Based on the search string and reading the titles of the papers, 252 papers were initially selected.

3.3. Papers Screening

Studies that met the following criteria were included in this study:

a) Approaching virtual simulations in Health. Be reported in a workshop, conference, or journal in Portuguese or English.
b) Address the development of skills for health professionals.

Accordingly, 68 papers were selected in this last step as relevant to this study goal.

4. Results and Discussion

The selected papers mainly address the medical area, such as specialists (38.2%, 26 of 68 studies), residents (20.5%, 14 of 68 studies), and especially students (55.8%, 38 of 68 studies). Some studies address more than one audience. It was noted that anesthesia was the most current topic in Medicine (4.4%, 3 of 68 studies) and in Dentistry (3%, 2 of 68 studies). We present a table with the selected studies, as well as the year and vehicle of publication, at this link: https://bit.ly/3xcMwXj. The following sections answer the research questions and discuss the results obtained.

4.1. How is the Evaluation of Virtual Simulators Occurred?

Educational Assessment

Aspects of interface (usability), content and educational effectiveness were analyzed for the educational evaluation. Most of the studies evaluated usability aspects (48.5%, 33 of 68 studies), and the most used instrument was the questionnaires applied to the target audience after using the virtual simulator (44%, 30 of 68 studies). Among the papers, it was common to develop their questionnaires [4] [9] [10]. However, standard questionnaires, such as the NASA Task Load Index [11] [12] and the iGroup Presence Questionnaire [13], were also used, in whole or adapted. Games and Web applications had their evaluations focused, almost exclusively, on interface aspects.

The evaluation of the content of the reported simulators was carried out through interviews with specialists in the area during the tool’s development process. The assessment of educational effectiveness took place through questionnaires applied to students, whether pre-test or post-test, defined by the team of researchers. The results were given by comparing the performance before and after using virtual simulators. In addition, some of the studies also considered the performance reports automatically generated by the virtual simulators themselves to verify and track the acquisition of clinical skills throughout the training sessions.

When it comes to educational effectiveness, it must be considered that knowledge acquisition can be short, medium, or long term. What we observe in the studies is the effects of single-use. The tools can help, both for the tactile/visual resources and for the motivation in carrying out the activity that until then is new and, therefore, offers potential for the acquisition of knowledge [6]. However, it is crucial to analyze how this construction of knowledge occurs over time and its effects on the work process.

Software Quality Assessment

Ensuring software quality consists of using techniques to identify deviations that may compromise the final quality of the system. Its role involves verifying compliance with criteria and methods throughout the operational processes to ensure the correct functioning of the software and identify opportunities for improvement. Among the analyzed studies, three types of software testing were identified: the performance test [14] [15], whose objective is to attest to the performance of the system in terms of data processing (the most frequent in the researched studies); the acceptance test [16], in which the tool is tested in a real environment with real users and; finally, the functional test [17], which seeks to ensure that programmed the virtual simulator functionalities according to the project.

The evaluation of software quality was the type of evaluation least present in the studies, corresponding to approximately 20% (14 of 68 studies). It is worth noting that part of the researched papers deals with functional prototypes, and few explicitly address this test stage. The incorrect functioning of virtual simulators during training can compromise the reliability and accuracy of the process. For this reason, software testing cannot be treated as an optional step in the production of virtual simulators.

4.2. What are the Reliability and Accuracy Indicators?

This study used the definition that characterizes reliability as the degree of fidelity of information related to the original. That is, how precise the selected studies parameters are. Thus, the level of reliability of the simulations influences their accuracy. The selected papers have as their main indicator of reliability and accuracy the participation of specialists [5] [14], either as part of the team or as guests at specific stages, in the development of virtual simulators. Also, used data from real patients to configure the virtual simulators, bringing even more accuracy to the parameters adopted and the content and evaluation [18].

Another reliability indicator identified was the use of the literature to define the contents of virtual simulators [19] [20]. However, the literature may have limitations related to the variety and granularity of data, which practical experience could better model. Among the analyzed studies, in approximately 8%, the requirements and validation occurred, considering the medical literature or scientific papers exclusively. Therefore, it is observed that this is not the standard since most studies also included the knowledge of specialists in this process [4] [12].

Also identified were validation tests performed with subjects from areas not related to Health and the non-characterization of the sample [10] [19] and studies that did not specify or suggest ways to infer reliability and precision. These are studies focused on engineering aspects whose contribution is to advance a specific computer simulation technique.

5. Conclusions

It was observed that students are the target audience of virtual simulators in the selected studies. However, improving knowledge throughout professional life is essential to ensure an updated and effective performance. Therefore, professionals working in their respective specialties must access this type of permanent education tool. It is a point that deserves further investigation due to the educational potential of virtual simulators [6].

The evaluation of the tools occurred considering almost exclusively aspects related to the application interface and through questionnaires (originals or standards available in the literature). The evaluation of educational efficiency, in turn, was carried out mainly through the application of questionnaires before and after the use of virtual simulators. However, studies commonly describe a single use of the tool, and it is essential to verify the long-term effects of skill acquisition mediated by virtual simulators. Software quality was an aspect that little evaluated in the selected studies. It is worth noting that the incorrect functioning of the virtual simulator compromises the reliability and accuracy of the training. When the simulation does not serve the purposes for which it was developed, it becomes irrelevant to clinical/educational practice. For this reason, software testing cannot be treated as an optional step in the production of virtual simulators.

The participation of specialists in elaborating the requirements to guarantee the reliability and accuracy of the virtual simulators was common. The process of training health professionals is based on evidence documented in the literature. Thus, relying exclusively on information provided by experts can limit the reliability and accuracy of the virtual simulator. The developers and researchers must consult both sources in a balanced and complementary way. The participation of the specialist will be able to collaborate with the detailing of information and with the educational approach of the virtual simulator.

Finally, to ensure the reliability of virtual simulators, interdisciplinarity in the development teams of these tools is essential. It is common to identify studies that design solutions that, for clinical practice, become irrelevant, complex, and technologically inaccessible. Communication, as well as the frequency of interaction between employees, are the main obstacles to interdisciplinarity. Therefore, in developing virtual simulators, each area's contributions must be considered to create solutions that are not within their reach individually.

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