Extended Reality Simulations in Surgeon Education – a literature review

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Introduction

With current technological developments the complexity and achievable realism of computer simulations increases each year. Extended Reality, a technology increasing in popularity, has already proven to be an effective learning-tool in practical applications and in the school environment (Tang et al., 2020). Extended Reality allows for the creation of immersive worlds, providing the ideal opportunity to get practical experience while being in a controlled environment. Complex degree courses require thorough supervising and personal-tailored study material to prepare students to work safely. Working in the healthcare industry requires experience to safely treat patients. Surgeons currently undergo training simulations using mannequins in role-play scenarios before treating actual humans. These mannequins, however, require much imagination and help from trainers, as their visual elements are limited to their robotic properties (Zhao et al., 2021).

Virtual simulations could introduce a new dimension to the simulations, giving complete freedom in their visual style while removing the need for direct narration from trainers when scenarios are pre-made. Virtual reality in its current state has limitations (Nakai et al., 2022). Consequently, virtual reality might lack the technological advances needed to provide a realistic training simulation for surgeons. Therefore, the goal of this paper is to research *the effectiveness of Virtual Reality as a learning tool for surgeons during training simulations.*

This paper consists of three parts, first stating the factors considered during surgical training simulations. The second part focusses on the extent to which Virtual Reality could aid in practical learning. The third section covers research on the user friendliness of Virtual Reality, also focusing on scenarios where users would need to use it for prolonged periods of time.

Surgeon Training Aspects

To find the important aspects of surgical training, a view on how surgeons are assessed after graduation is crucial. There are seven elements on which surgeons are assessed to determine their skills. The OSATS, the objective structured assessment of technical skills for surgeons, define seven skills on a Likert-scale: respect for tissue, time and motion, instrument handling, knowledge of instruments, use of assistants, flow of the operation and knowledge of the procedure. This system is often used in research to indicate effectiveness of learning, as it provides a measurable way to compare skill (Park et al., 2007; Larsen et al., 2008). Martin et al. (1997) proved the reliability of the method and validated the relation

between the scoring and technical skills. Furthermore, Jakubowski et al. (2021) supports the validity of this tool to still be reliable as an objective assessment tool, demonstrating a correct correlation between skill and score. Thus, to provide a proper training for surgeons the training must include the seven skills defined by the OSATS.

Besides the objective skill assessment using a standardized method for the assessment of skills, a very important factor in surgery training is teamwork and communication between students. Kotsis and Chung (2013) claim that teamwork and working in a team is of upmost importance when learning to become a surgeon. Being able to communicate efficiently with other surgeons and being able to calmly organize the procedure can result in more time-efficient and safer procedures and is often added as a separate score to assess surgeons upon (Park et al. 2007; Nicksa et al. 2015). This results in simulations often being done in a setting with other trainees in order to give them the skills necessary to communicate in an efficient manner.

With communication being of utmost importance, communication between the trainee and the mentor is an important matter in the training of a surgeon. Haluck and Krummel (2000) state that close, physically present mentoring is important in order to carefully observe and provide constructive feedback as students may not be proficient in everything and might lack skills in certain areas. They further state the importance of mentors setting specific goals and learning outcomes for each training session to balance overall improvements. Kotsis and Chung (2013) back this by showing the importance of tight communication in their “See one, do one” experiments in teaching methods for surgeons. Although being physically present is preferable, Hu et al. (2017) proved that video-based coaching is a further tool to assess work done by surgeons in training and has great benefits in their studies. Thus, a mentor being present virtually or physically is crucial to fit the study to surgeons in training to provide a complete study and hone their skills in all regards.

Besides communication, the main concern when student surgeons participate in role-playing simulations is the immersion level of the students in the regard of realism. Zhao et al. (2021) and Kotsis and Chung (2013) argue that the current simulation technique using mannequins is often too unrealistic and results in less effective role-playing scenarios. Having a realistic scenario is important for students to recognize what to do in stressful situations, giving them the skills needed for communication and teamwork. This is supported by Waran et al. (2014) who demonstrate the positive effects of the addition of realistic 3D prints to the learning program which students can use to practice, leading to better

results and participation. To conclude, a simulation must feel realistic to get the most efficient role-playing sessions which results in a better quality of education.

Extended Reality as a learning aid

Given the aspects a simulation requires, the next step is to look at how Extended Reality could aid in learning. Extended reality can be effectively used as a medium to train student surgeons. Haluck and Krummel (2000) argue that Virtual Reality provides a controlled learning environment, allowing situations to be changed to suit each student's needs and altered on a real-time basis which leads to overall less stress. This is further illustrated by Larsen et al. (2009) in their test showing significant improvements to the overall OSATS scoring after introducing Virtual Reality to beginning surgeons. Others like Al Janabi et al. (2020) and Logishetti et al. (2020) showed comparable results, also considering time and teamwork. Although Virtual Reality might work for some, Kaplan et al. (2021) concluded that Virtual Reality has no different results compared to the normal curriculum, getting equivalent results in the OSATS. Thus, Extended Reality can work as an effective learning tool to better perform at the OSATS or score similarly to a normal training simulation.

Student surgeons see benefits from adding Extended Reality to their curriculum, but Extended Reality also works as an effective tool as preparation for experienced surgeons. Park et al. (2007) proved this by having surgeons undergo a simulation before surgery and noticing significantly higher results in those who first ran the simulation compared to those who did not. Lohre et al. (2020) demonstrated a similar outcome, concluding that Virtual Reality as a learning tool demonstrates improved translational skills and knowledge acquisition skills when comparing to traditional learning methods in teaching complex surgical procedures. Extended Reality can thus not only be used as a tool for surgeons in training but can also aid in preparation for surgeons in later stages of their career.

Virtual Reality thus can aid in learning, but one major aspect in which it differs from traditional methods is the virtual environment and its portability. As stated by Hamuck and Krummel (2000) Virtual Reality allows for a controlled environment, but although it is controlled there are some things lacking in current technology. A study by Bernardo (2017) demonstrates how the lack of haptic feedback removes a lot of its potential, with students achieving higher results using tectile simulators like cadavers or physical models. This is backed by Overtoom et al. (2019) which demonstrated the benefits of adding simple haptic feedback, leading to better overall results, but not having the realism needed to replace traditional methods completely. When regarding the portability of Virtual Reality, one major benefit is

the possibility of it to be used anywhere with a stable internet connection. This is however not a reason to replace current methods as shown by Singal et al. (2021) in a test during the Covid-19 pandemic. They surveyed students after using Virtual Reality and the majority found face-to-face lectures better, mainly due to factors as bad internet, bad gear, and low self-motivation. Thus, Virtual Reality as a learning tool can have some benefits when it comes to the environment, but the current technology limits its potential due to little feedback or bad conditions.

Extended Reality in use

Extended Reality can cause several negative side effects after prolonged use. Al Janabi et al. (2020) surveyed that after prolonged Virtual Reality usage 10% of the participants experienced mild problems. The problems consisted of eyestrain, neck strain, headaches, and nausea. Virtual Reality can however differ in quality, and lower quality leads to less realistic movement which can give more negative effects. Moro et al. (2017) demonstrated that Virtual Reality headsets with three degrees of freedom had significantly more side-effects than a modern six degrees of freedom headset. Time also plays an important role, as Kourtesis et al. (2019) demonstrated in their study finding that the maximum training time in Virtual Reality should be 55-70 minutes to minimize negative effects, also showing that age and education does not play a role in side-effects. Virtual Reality is thus not a medium that works for everyone and can have unwanted effects after prolonged use.

Conclusion

The goal of this paper was to review the effectiveness of Extended Reality compared to traditional simulation methods in surgical training. To provide a good simulation, Extended Reality must provide the skills as described by the objective structured assessment of technical skills for surgeons, with a focus on communication and teamwork. While Virtual Reality can have benefits to the education of both junior and senior surgeons, the environment is insufficient for a complete replacement of traditional methods. It lacks the tactiles and realism needed to provide proper simulations and can lead to negative side effects after prolonged usage such as nausea or headaches. While it may not fully replace traditional methods, it is an effective medium to aid in learning besides the normal curriculum.

While a general overview on surgeon education is given, each specific study has their own needs and curriculum, which was not researched thoroughly. There are many regards in which more research can be done on the topic. Extended Reality is currently in an early stage, with many developments in the past few years. While Extended Reality may not be suited right now for a full transition in surgical

education, further research could go more in depth into haptic feedback and its current developments which might make the difference between a partial or full transition to a virtual working space. With technological advancements, the tactile simulations might also grow in terms of realism and effect which could also be a topic worth researching.

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