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SHORT COMMUNICATION

Usefulness of augmented reality in radiological protection education and training for interventional radiologists

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Objective: The aim of this work is to evaluate the usefulness of using augmented reality (AR) to train medical professionals in radiological protection (RP) in fluoroscopy.
Methods: A Microsoft HoloLens 2 device has been used to simulate a fluoroscopic device. The teaching scenario considers a Philips Azurion able to rotate to pre-defined gantry positions,a dorsal decubitus patient and a ceiling shield. Radiation exposures were simulated using the FLUKA Monte Carlo code. 11 radiologists were asked to reproduce their positioning as per a clinical procedure and to correctly position the ceiling shield. Then, they were presented with the radiation exposure of their choices and were able to further optimise it. After the session, they were asked to complete a questionnaire.
Results: Users rated the AR educational approach as Intuitive and relevant to RP education (35%) and inspiring to deepen their knowledge (18%). Nevertheless, a negative aspect was mainly the difficulty in dealing with the system (58%). Although the participants were radiologists, a minority recognised themselves as having accurate knowledge of the RP (18%), indicating a relevant knowledge gap.
Conclusion: The usefulness of using AR in RP education for radiologists has been shown. The visual aid of such technology is likely to improve the consolidation of practical knowledge.
Advances in knowledge: The use of interactive teaching techniques has the possibility to both help radiology professionals consolidate their radiation protection training and confidence in their practices.

INTRODUCTION

In recent years, several countries underwent a review of the radiation protection legislation as a result of findings of studies such as ORAMED on the issue of accumulated dose to the eye lens by interventional practitioners using X-ray.[1,2] One of the big changes in this review was the modifications to the eye lens' dose limits which went from 150 to 20 mSv/year.[1,3]

Often in this scenario, the medical team is the most critical group, due to its inevitable proximity to the source of scattered radiation, the patient, and the X-ray tube itself. This includes occupations such as neurologists, radiologists, cardiologists, orthopaedists, urologists, etc. The backgrounds of these professionals are different regarding the depth and width of their education in radiological protection, especially the one that must be applied when using such equipment. To perform the medical procedures under safe conditions a series of protective materials are often available such as lead aprons and glasses, movable lead acrylic ceiling and table lead shields.

Different international organisations have fostered educational actions, such as the IAEA radiological protection guidelines.[4] Additionally, local teams are expected to invest part of their time in annual staff refresher training, where this topic should always be addressed, given the risks to which these professionals are subjected. Several studies on teaching methods have shown that active learning gives a greater retention of knowledge than in the case of traditional lectures, even when audiovisual resources are used.[5]

Augmented reality (AR) has been used as a visual aid in different fields, including healthcare, architecture and civil engineering, manufacturing, defence, tourism, automation and education. Although AR is not necessarily a new technology, it is gaining momentum in medical education and simulation through different commercial devices.[5]

The objective of this work is to evaluate the usefulness of using AR to train medical professionals in radiological practices forfluoroscopic examinations.

METHODS AND MATERIALS

HoloLens 2 and scenario development

For improved flexibility with respect to future developments, the scenario was produced for Microsoft HoloLens 2. The HoloLens is a head-mounted display (HMD) equipped with cameras and different sensors to accurately track the environment. Due to its see-through nature, virtual objects are overlaid onto the physical environment (instead of a video feed). It allows training in full virtual AR mode, as well as with the possibility to have it integrated with the real fluoroscopy device. The application was developed with the game engine Unity (v. 2021.3.11f1) and uses the Mixed Reality Toolkit (v. 2.8.2), a Microsoft-driven plugin which supports all essentials such as occlusion culling with real-world objects and interaction with virtual objects. Real objects cover what is behind them: occlusion culling ensures the same for digital objects. The simulated scattered radiation values for all defined angiography device angulations are pre-imported and displayed to a 64 × 64 texture with a point distance of 0.1 m to achieve accurate coverage. A gradient going from red via purple to blue denotes the intensity of the radiation (Figure 1). Users can move the protective ceiling shield with simple grab and drag gestures. Its position is checked at runtime dynamically reducing the radiation levels in the covered areas.

Augmented reality scenario

The scenario has been created considering a fluoroscopic room with a Philips Azurion (Philips Healthcare, Amsterdam, the Netherlands) and a patient on the examination table in a dorsal decubitus position. The radiation beam axis has been positioned towards the heart in all projections. Different simulated projections have been included that can be used within the teaching: anteroposterior - AP, left anterior oblique - LAO, left anterior oblique cranial - LAO CRAN, left anterior oblique caudal - LAO CAUD, right anterior oblique cranial - RAO CRAN, right anterior oblique caudal - RAO CAUD, caudal-CAUD and cranial-CRAN. A Mavig lead-acrylic protective ceiling shield (Mavig GmbH, Munich, Germany) was also simulated. Radiation exposures, for the before-mentioned projections, were simulated using the FLUKA Monte Carlo code,[6] which accounts for the emissions used in real examinations. The device's angular positions and Monte Carlo simulation characteristics have been previously described.[7] The visual representation of the radiation exposure can be switched on and off. The actual teaching scenario consisted of asking individual radiologists to position themselves as they would have done during cardiac catheterisation using a femoral entry point, then they should position the ceiling protective shield and indicate where they would position an assistant. Once these steps were performed, the radiation exposure display would be switched on to discuss the chosen positions.

Figure 1. Generated scenario with overlaid scattered radiation with ceiling shielding (a) and without (b). In both figures, there is shown the modelled device, patient in the patient bed, controls and ceiling shielding. In the left figure, it can also be seen the protective effect of the shielding positioning. The Microsoft HoloLens 2 (c) and a participant using the HoloLens and visible scenario displayed on the television (d).

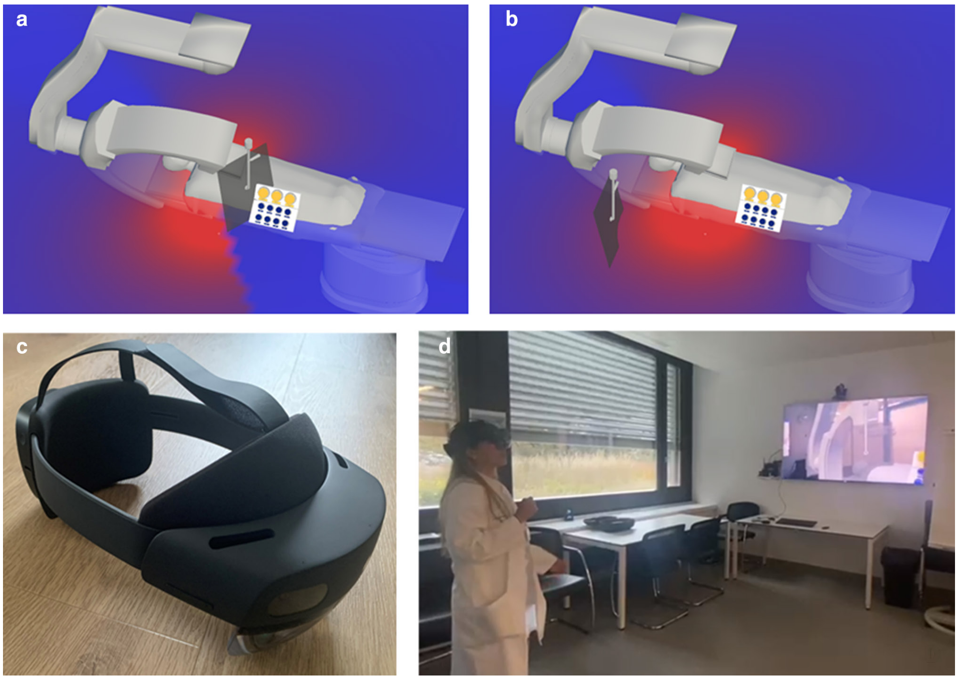
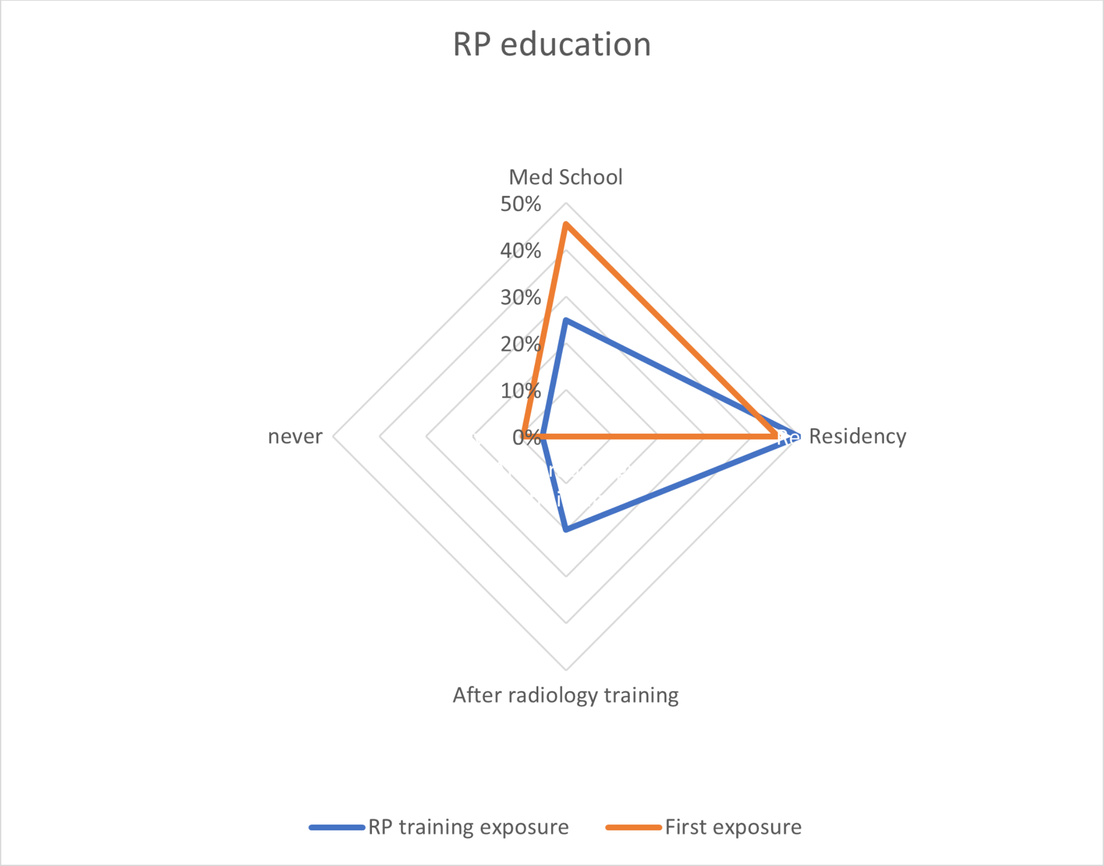


Figure 2. Exposure of the participants to radiological protection education by stage of their career. RP, radiological protection.



Participants

The participants included 11 radiologists with different levels of experience from first-year residents to the head of the department (five residents, six radiologists). Out of the participants, three of them were not interventionalists. Participants included one Head of neuroradiology and one Head of vascular interventional radiology. All the residents underwent or were to undergo, a rotation between the different modalities within the radiology and nuclear medicine department.

Analysis

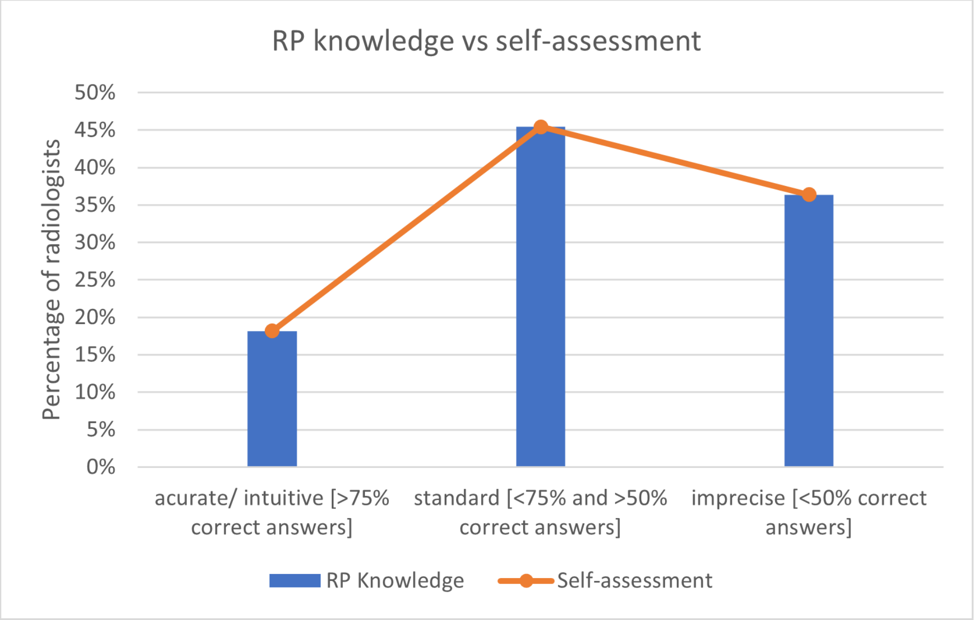
The participants were presented with the AR scenario previously described and with a questionnaire. Prior to undergoing the AR scenario example, the participants had to complete the initial part of the questionnaire (available in the supplementary materials) that included questions about their level of education, basic questions about radiation protection in fluoroscopic examinations and self-evaluation of their radiation protection knowledge.

Once these questions were answered, the participants tested the AR scenario. After undergoing the AR scenario example, the participants answered two further questions about the tested scenario and the use of AR in their teaching. In the first question, the participant was asked to select three positive aspects from the scenario from a list of six (easy to handle, inspire me to deepen my knowledge, easy to pay attention to, intuitive and relevant to RP education, easy to understand the task, help me gain confidence) and order them from best applicable to least applicable. The most applicable aspect received three points, the second two and the third received one point. On the second question, the participant had to select up to three aspects of the AR scenario (difficult to handle, no new information, not relevant to my needs, does not apply to my role, complicated to follow the task, I didn't understand what I need to learn). Once again when more than one negative aspect was selected, the participants were asked to rank them. From the rank, the aspects received three, two or one point from the highest rank aspect to the lowest one.

RESULTS

For the first part of the questionnaire, radiologists reported at which stage of their education or career they received their respective knowledge on radiological protection (RP), as shown in Figure 2. Most of the radiation protection education exposure (50%) happened during residency, followed by during medical school (25%) and as part of their continuing education once they had finished their specialisation in radiology (20%). Looking at where this first exposure to RP training started, almost half of the participants (45%) received their first training during medical school while another large group (45%) only received their training during residency. Only one of the participants reported having never been exposed to the theme, a first-year resident in her first month.

Figure 3. RP knowledge of the participants and their self-evaluation. RP, radiological protection.



Secondly, in this first part of the questionnaire, the participants were asked some basic questions about RP with fluoroscopic equipment. The results of this were subsequently compared to their self-assessment of their knowledge of this theme. Figure 3 shows that there is good agreement within this sector of radiation workers' knowledge of RP and their performance in the questionnaire. The range obtained is also compatible with the range of experiences of the participants.

The second part of the questionnaire was directed at evaluating the usefulness of AR in RP training. The results were divided into positive and negative aspects. Figure 4 presents the positive aspects listed by the participants. Considering the weight of relevance, two aspects accounted for more than half of the choices: Intuitive and relevant to RP education (35%)/inspire me to deepen my knowledge (18%). Another three aspects were related to the usability of the device and developed scenario, representing around 33% of the relevance. The other 14% of the relevance was attributed to the confidence obtained after carrying out the activity.

Figure 5 presents the negative aspects listed by the participants. Considering the weight, the most relevant aspect was the difficulty to handle the system (58%). In second place was the complexity to follow the task (18%). These two added together represent approximately 3/4 of the relevance of the answers. The others added together represent 24% of the relevance indicated by the professionals.

DISCUSSION

In this work, we wanted to understand the uses of AR in the education and training of radiologists in RP applied to intervention radiology. The use of AR in education for medical and other fields has already been reported in the literature.[5] Some groups

Figure 4. Positive aspects based on the participant choices.

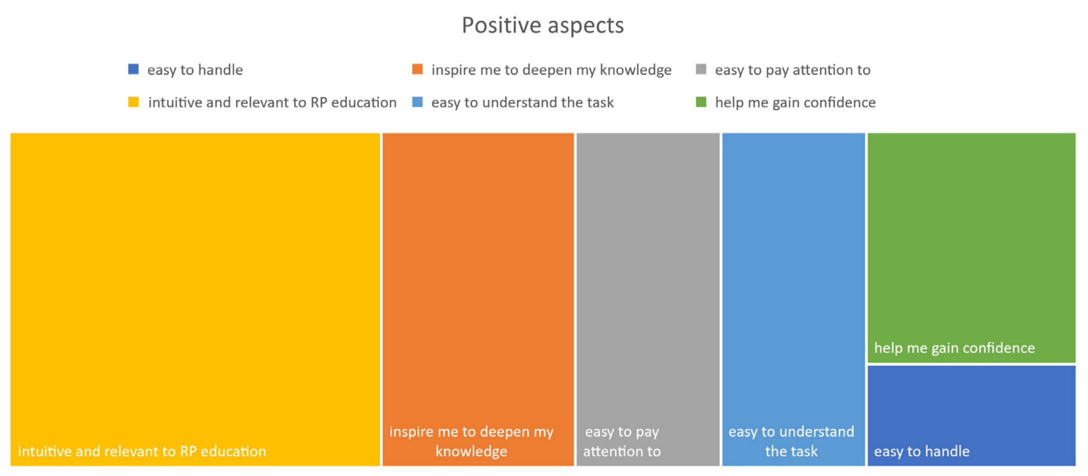
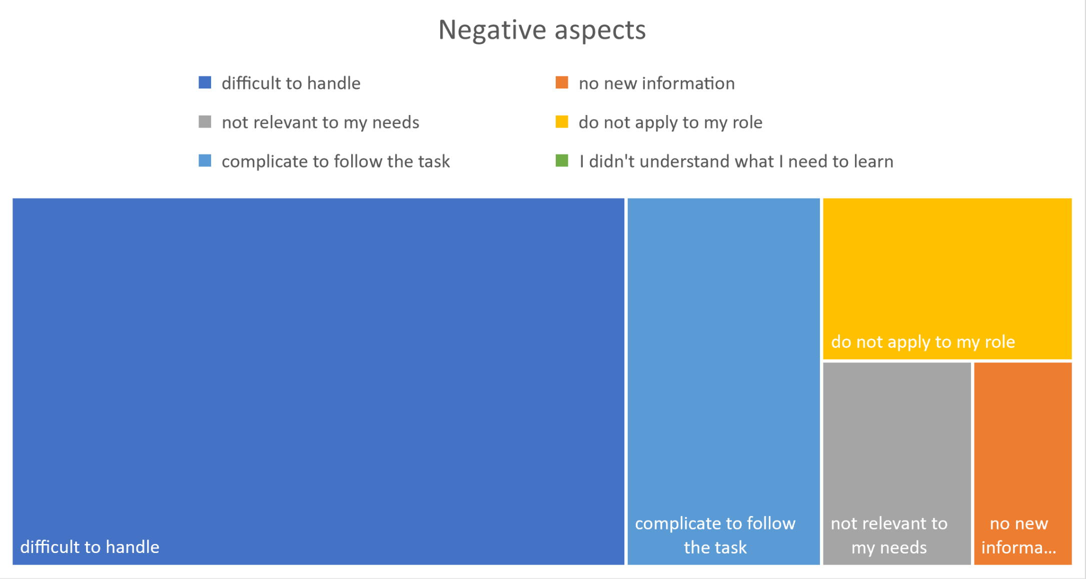


Figure 5. Negative aspects based on the participant choices.



have even evaluated the usefulness of AR for RP education and training, but this often includes only the response from students[8] never with radiation-exposed professionals.

As expected, the early stage of their careers is when most radiologists are exposed to their RP education (Figure 2). At this stage, new approaches to education and training can be a valuable tool to increase interactivity and consolidation of knowledge.

Although the participants were radiologists (either in clinical training or certified radiologists), a minority recognised themselves as having accurate knowledge of the RP (18%), indicating a relevant knowledge gap. RP education for professionals working in interventional radiology is decisive on the doses they will accumulate along their careers. As it enables the professional to make non-intuitive decisions allowing them to understand the changes within the examinations to systematically optimise the different protective measures. Studies have shown that staff training in good practices of RP is a critical component in risk management.[1,9]

Just under half of the participants reported having standard knowledge, which limits their ability to apply RP knowledge during routine clinical work. The two most relevant virtues pointed out by the participants were that the educational tool proved to be intuitive and relevant for RP education and inspired them to deepen their knowledge on the topic. These aspects are likely to improve the comprehension of those in the “standard knowledge” to the “accurate” level, as they seek to consolidate new knowledge compared to the other available positive aspects. Those with a higher level of RP expertise, on the other hand, are potentially benefited from the confirmation of their understanding, characterised by the option related to gaining confidence.

All these aspects are directly related to the added value of using AR in RP education: the visual description of the scattered radiation. The other positive aspects were related to the developed scenario which was intentionally chosen to be simple to try to minimise limitations within the HoloLens technology.

As can be seen in Figure 5, this handling difficulty was still not avoided even by using such a simple scenario, this can likely be overcome with the introduction of tutorial steps before the RP education. Some negative aspects were to be expected since some of the radiologists were not working directly with intervention procedures.

Limitations

There were some relevant conclusions from our study, although, the number of participants was relatively small. Some known limitations were highlighted within this study, the first being the simplicity of the proposed scenario that, especially for the more experienced professionals, seemed repetitive. Another limitation pointed out by some of the participants was related to the technology, like the small field of view of the HoloLens 2. Such technical limitation has already been discussed in the literature[5] and it is likely to be overcome by future technological iterations.

Future work

All participants were positively impressedby the study and the possibility of using AR in RP education. They made different suggestions from the before-mentioned improving handling difficulty and variability within scenarios, to extending to other modalities like nuclear medicine and radiation oncology.

CONCLUSIONS

The usefulness of using AR in RP education for radiologists has been shown. The added value of the visual aid of such technology is likely to improve the consolidation of practical knowledge for these professionals.

FUNDING

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