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INSTRUCTIONAL DESIGN MAP FOR IMMERSIVE FENCING TRAINING IN VIRTUAL REALITY

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ABSTRACT

Education and learning are evolving because of the rapid speed of technological advancement in the 21st Century. Virtual Reality (VR) has emerged as one of the high-potential learning technologies for education and training purposes across a vast range of fields. In sport education VR has been utilised to enable learners to access learning environments and experiences for drill-training, complex conceptualisation and problem-solving skills. This paper presents an instructional design map for developing and improving fencing skills utilising VR technology. This interactive fencing training simulation is aimed to help to develop a solid en garde position, balanced movements, correct weapon and body position, as well as providing tactical advice and support for advanced principles of performance. Fencing is a combat sport where fencers compete in three weapon disciplines. This study focuses on one of these weapon disciplines – the foil. To develop a proposed solution three main tasks were undertaken – study of current scientific literature as well as analysis of existing VR fencing training solutions and expert interviews with professional coaches and the professional athletes. This research addresses the lack of a systematised knowledge base by examining scientific literature and analysing case study experience in order to design the basic criteria that will be used in the development of a VR learning experience for fencing training in an immersive VR environment.

Keywords: *education, fencing, instructional design, training, virtual reality*

Introduction

In recent times, Virtual Reality (VR) technologies have been actively incorporated into education, teaching, and training in various applications (Radianti et al., 2020) and this has happened to fencing which has been an Olympic sport discipline since 1896. It is a combat sport where fencers compete in three weapons: epee, foil and sabre (Meyer et al., 2017). These weapons differ from each other in blade type, valid target area and scoring technique (Bieniek et al., 2017). This research focuses on foil and in the context of this study, VR has been used and studied. VR can be explained as:

a completely digital environment, closed off from the physical environment (Dreimane, 2020b).

The aim of this research is to develop a VR learning experience design map to aid the development of fencing skills. To achieve this, the following steps were undertaken:

1. Exploring the scientific literature on studies already carried out, using VR as a tool for fencing skills development;
2. Exploring existing VR learning experiences with fencing elements;
3. Interviewing professional fencing coaches;
4. Devising an instructional design map for a VR learning experience in order to ensure the development of fencing technique.

Coaches and athletes are constantly looking for new possibilities to improve performance, training process, analyse results of performance and therefore gain edge over competitors (Mackenzie & Cushion, 2013; Farley et al., 2020; Holly et al., 2021). In order to develop athletic performance, coaches typically analyse athlete movements using performance analysis methods (Farley et al., 2020). In gaining an edge over competitors, it is very important to record information about athletes' performance (Mackenzie & Cushion, 2013; Farley et al., 2020). As Farley noted: "Enhanced performance data (such as the physical demands and technical aspects of a sport) better equip coaches and trainers as to the skills, movements and physical qualities of their athlete" (2020, p. 2). As highlighted in various scientific articles (Bieniek et al., 2017; Meyer et al., 2017; Farley et al., 2020; Holly et al., 2021), VR can contribute to the development of the skills and increase athletic performance in different sports (Farley et al., 2020), including fencing. The last decade has seen significant advancements in technology, especially within the development of VR (Farley et al., 2020).

Virtual Reality technologies allow interaction with the virtual environment with a high intensity of immersion (Holly et al., 2021). Scientific articles of (Slavova & Mu, 2018; Holly et al., 2021) concluded that when using VR as a tool combining with traditional learning methods, athletes gained better results of understanding and recognising concepts of sport performance and overall motivation in the learning process increased. Two other articles explained, that VR technologies support the design of training programmes by simulating real game activities and introducing effects which are not easily replicated in real training conditions, allowing athletes to gain 'mental repetitions' and increase track performance (Appelbaum & Erickson, 2016; Holly et al., 2021).

In order to achieve good results, any learning process, including fencing training, needs to be constantly updated by introducing new methods and techniques (Turner et. al., 2013), including new technological solutions. The fundamental role of speed, co-ordination and sensory-motor skills is

indisputable in fencing; however, merely rapid and correct accomplishment of a movement does not ensure success. An outright bout against an opponent requires a high level of perception, information processing and strategic decision-making and precise execution. Thus, in fencing, as a 'game of anticipation and deception', technical abilities are a tool used to execute chosen strategy and tactics (Bieniek et al., 2017). When teaching fencing, not only technical, but also pedagogical aspects need to be considered (Ruffaldi et al., 2011). The education sector and learning as a process are continually changing as a result of the technological impact.

Methodology

The aim of this research is to develop a VR learning experience design map to aid the development of fencing skills. The study took place in 2021 and was divided into four phases:

1. Study of current scientific literature;
2. Analysis of the existing VR fencing training solutions;
3. Expert interviews, and
4. Developing concept of instructional design map to enhance learning experience in fencing in VR.

Currently, technology has an immense impact on people's lives, including individual, societal, organisational and systematic levels. Technology has redefined our communication, work, leisure, even sports and our learning (Kaimara et al., 2020). Technology can make the learning process interesting and exciting, but at the same time the concept of "fascination" must be taken into account (Daniela, 2020), because pupils may want something interesting all the time. This, in turn, risks poor development of sufficient long-term attention as attention will be switched from one technology to another (Kaimara et al., 2020). The use of technology has great potential in promoting the interest of pupils, as it stimulates immersion in the educational process (Hwang et al., 2008). The efficient use of technology in the learning process depends on how strong the learning process is and how clearly the technology task is defined (Hadlington, 2017). At the same time, it has also been seen that technology is often being put at the forefront rather than a technology enhanced learning process (Surma & Kirschner, 2020) and technology enhanced learning is often used as a synonym for improving technological infrastructure in education (Daniela, 2020). Pedagogical principles should be considered when developing Virtual Reality educational platforms to avoid a fascination effect by utilised technology (Daniela, 2020). Pantelidis outlined various reasons to use Virtual Reality in education: "At every level of education, virtual reality has the potential to make a difference, to lead learners to

new discoveries, to motivate and encourage and excite. The learner can participate in the learning environment with a sense of presence, of being part of the environment" (2009, p. 61). Therefore, this study presents an instructional design map for a VR learning experience to help in developing and improving fencing skills.

To develop the proposed solution three main tasks were undertaken – a study of current scientific literature as well as analysis of the existing VR fencing training solutions and expert interviews with professional youth coaches and the Latvian national team of professional athletes.

Many studies have been conducted (for example, Mackenzie & Cushion, 2013; Appelbaum & Erickson, 2016; Farley et al., 2020; Holly et al., 2021) which have studied and explained the importance of VR in sport, but only three were about fencing (Baek et al., 2003; Bieniek et al., 2017; Agosti & Autuori, 2020). There is very little scientific evidence and advice on how to create a design for the development of fencing skills in virtual reality, which in turn justifies the potential impact of this study.

The collection of VR learning experiences was carried out using the social networking analysis method – Nodes (Robin, 2015). The Nodes method is based on a claim that a network is interrelated. Finding one VR learning experience or a case study leads to the next one. AR learning experiences were analysed using a VR learning experience evaluation tool developed by Dreimane (2020a) There were three criteria groups:

1) Purpose of learning experience;
2) Instructional strategy and
3) The design of experience, with a total of twenty criteria and eighty-eight sub-criteria.

The tool was designed primarily for evaluating virtual reality experiences, but it has broader aims:

> "The proposed VR experience evaluation tool was essentially developed to serve as a purposeful quality control or a design development instrument that would inform instructional designers, educators, learners and VR content and technology professionals by providing a clear and multi-purpose framework that outlined the alignment between the instructional, pedagogical and VR learning environment in order to ensure and strengthen the efficiency of the VR learning design and instructional strategies (Dreimane, 2020b, p. 64)".

Learning experiences were tested to primarily assess whether the learning experience was related to fencing, followed by analysis of this experience. As a result, only one learning experience was analysed.

Finally, to specify the needs for such a VR solution, three semi-structured interviews with professional coaches who train children and the national team of Latvia were held.

Discussion

Many recent studies (Pantelidis, 2010; Kapp & O'Driscoll, 2010; Coimbra et al., 2015; Dreimane, 2020a) indicate that VR has emerged as one of the most important and effective tools for education and training. The fencing training programmes in VR are not commonly used as part of the traditional training programmes' curriculum in 2022. However, there are only three scientific studies on this topic. For instance, Baek et al. wrote about applications that were used for fencing training and a dance imitation game (2003). Meanwhile, Agosti & Autuori suggested apreliminary methodological approach to an ad hoc functional training for fencers of all three weapons (2020).

Focusing on the VR itself, there were several studies conducted where VR has been used to improve skills or to evaluate the training results. A study conducted by Bieniek et al. in Poland in 2017, explains that frequently repeated movements create stable movement patterns which are individual for each of the participants (2017). According to the individual character of the performed actions, the animation database should contain the highest possible number of recorded athletes (Agosti & Autuori, 2020). By widening the database of animations, the solution can provide an expected level of diversity for fencing training and prevent the effect of 'training with' just one opponent (Bieniek et al., 2017).

In VR environments for training, the advancement of visual and haptic technologies play an important and innovative role in the context of sports training (Ruffaldi et al., 2011), and this is especially true in fencing. Developing a fencing training platform in VR includes some challenges, one of which is the identification of specific elements that compose sport skills and which can benefit from training in VR. In addition, it is challenging to identify the best combination of training protocols and multi-modal feedback that can be employed to improve these skill elements in a given task (Ruffaldi et al., 2011).

Fencing is a sport which requires both immense concentration and tactical ability in order to outwit an opponent, so much so that it has often been compared to a game of chess. Maintaining mental and physical endurance is a crucial part of succeeding at the highest level, as well as rapid reactions and explosive power (Bottoms, 2011).

Results

As a result of the analysis, it was concluded that the tested learning experiences lack an important immersive aspect for fencing training – haptic feedback. In real life a fencer bands his sword while making a touch and

this develops a sense of pressure in fencers' movements. This is important because it helps to develop a sense of right distance and right force that should be applied while one is making a touch. One solution that could be tried to address this issue would be a virtual glove which would allow to feel the pressure when actions are taken in the VR environment. Another issue is the lack of foot exercises that would help a fencer to learn and develop the fencer's en garde position, steps forward and backward, lunges and fleche (special movement in fencing to thrust fast forward). This is a good and much needed solution to take fencing into an e-games environment. It gives a feeling and understanding of basic fencing skills. Addressing more complex movements and skills would offer a great advantage to explain fencing to even more people. This shows how hard it is to bring fencing into e-games and VR environment with a sense of reality, because complex issues such as haptic feedback, bending of a touch, foot movement, correct technique and pedagogical feedback all need to be solved.

To discuss the need for such a VR solution, three interviews with professional coaches who train children and the national team of Latvia were held (see Table 1, 2). Authors asked three questions:

1. What are the main skills in fencing which needs to be developed in the training process?
2. Do you see benefits of development of such tool to improve fencing learning skills?
3. What functions should a learning tool have in order to be useful in the training process?

These experts emphasised that it is very important to train with different athletes in order to improve fencing skills and experience. So, from a pedagogical point of view, an effective VR learning software with different skill levels would help to gain the necessary strategic experience. For simple movements, such as steps forward and backward, reaction and precision can be trained with such a solution; however, it requires some basic knowledge about fencing, such as the correct en garde position, from the user. Experts emphasised that haptic feedback was crucial in order to learn the correct touch and movements that involve feeling the pressure on the blade. In addition, pedagogical feedback would help the user to understand if the movement is executed correctly. Of course, gaming elements and a sense of competition with other users from the same club or other part of the world would help to build a platform and each exercise should serve a clear educational purpose, for example, a solid en garde position, a strong lunge or fleche, balanced movements, correct weapon and body positions. These would be the important skills that a user needs to focus on (Wojciechowski, 2019). It has already been stressed that the use of such VR software would require the user to have some basic knowledge about fencing. Indeed, it

would be advisable to have several real-life practices with the assistance of a coach, to learn the correct en garde position, and basic foot and hand movements and positions such parry (defence) and lunge (attack).

Table 1. Experts' views on the benefits of VR technology in fencing

No.	Experts' views on the benefits of VR technology in fencing
1.	Possibility to train with different athletes in order to improve fencing skills and experience
2.	Gain strategic experience and improve psychological resilience
3.	Possibility to train without assistance of a coach and to train also at home or any other place
4.	The gaming elements could increase the overall performance of athletes
5.	Diversify the process of the training

Table 2. Experts' views on main functions which a learning tool should have

No.	Experts' views on functions which a learning tool should have
1.	Gaming elements and different level exercises
2.	Haptic feedback to learn the correct touch and movements that involve feeling the pressure on the blade
3.	Feedback on the completed exercises
4.	Examples of correct performance of the task
5.	Assessment in real-time with right or wrong signals, scores, points and completion time

The aim of this research is to offer a VR learning experience design map to aid the development of fencing skills. Therefore, this study proposes a design map (see Figure 1) based on the framework of evaluation tools for VR developed by Dreimane (2020a). This will allow the design of instructional design criteria (including technology aspects) that could be used in the development of a learning experience for fencing training in VR environment.

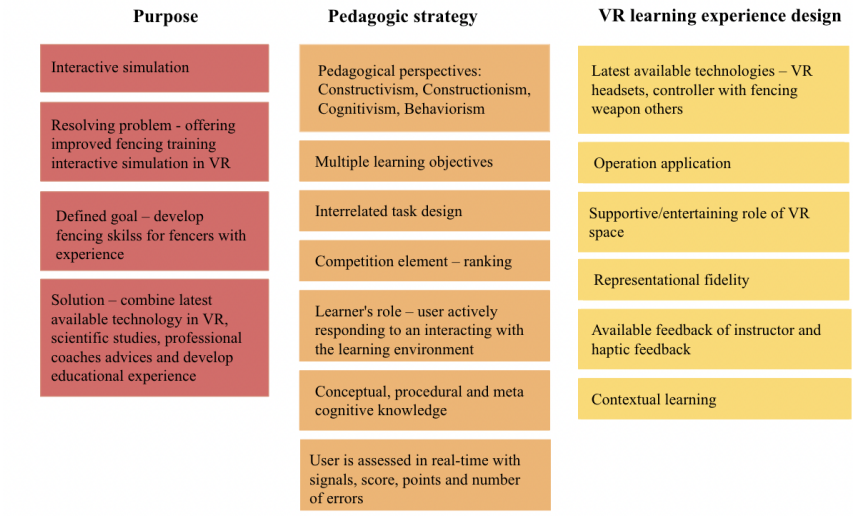

Figure 1. Instructional design map to enhance learning experience in fencing in VR

Instructional design map consists of three sections, which are developed based on VR learning experience evaluation tool developed by Dreimane (2020a), analyses of the existing VR fencing training solution and expert interviews:

1. Purpose (where the purpose of learning experience is explained);
2. Pedagogic strategy (explains pedagogic principles which are used at this learning experience);
3. VR learner experience design (explains aspects of design experience using VR technologies).

The target audience for such learning experience are users with a basic understanding of correct fencing movements and positions and an understanding of the rules. The relevant instructional strategy based on the typology proposed by Kapp and O'Driscoll, for the fencing training VR learning experience is operational application in that: "learners are challenged to apply physical world rules to objects in the virtual world" (2010). The purpose of such learning experience is to develop solid en garde position, balanced movements, correct weapon and body position, tactical advice and advanced principles of performance by using interacting VR simulation.

In 2022 there is no known solution available on the market that offers haptic feedback for touches and in-depth learning of advanced fencing movements. Such a solution would address the issue with the limited availability of advanced fencing coaches and their restricted time to teach only a certain number of students. Therefore, the VR learning experience

in fencing would increase the number of students who could access the knowledge of elite fencing.

Second section of the instructional design map explains pedagogic principles which are utilised in this learning experience which is based on the learning of a number of pedagogical theories – Constructivism (Piaget, 1956; Vygotsky, 1978; von Glasersfeld, 1974), Constructionism (Papert, 1993), Cognitivism (Gagne, 1985; Bruner, 2020) and Behaviorism (Watson, 1913; Malone, 2014). Within each of these learning theories, there are important aspects that explain the importance of technology in education and can serve as a justification for selecting a specific digital tool and developing a certain learning design. The framework of Constructivist learning explains that learning is an active process and knowledge is constructed on the basis of past experience (Piaget & Cook, 1956). Constructivism is one of the most important of all the applied theories (Anderson, 2016), which constitutes an understanding of learning through technology (Garzón & Acevedo, 2020). Another fundamental theory explaining the potential benefits of using immersive technologies is Constructionism, developed by Papert (1993). This theory highlights the potential for practical tasks during learning or learning by doing (Papert & Harel, 1991). It was considered that by integrating technology with traditional constructive activities, pupils themselves create new experiences and new ways of thinking (Papert, 1993).

Behaviorism equates learning with changes in either the form or frequency of observable performance (Winn, 1990). Main assumption of behaviorism theory – "correct instructional stimuli will elicit the desired learning outcomes, with an emphasis on practice and performance" (Dreimane, 2020, p. 55). In other words, learning is accomplished when a proper response is demonstrated following the presentation of a specific environmental stimulus (Ertmer & Newby, 1993). Behaviorism imply that the job of the teacher and instructional designer is to (1) determine which cues can elicit the desired responses; (2) arrange practice situations in which prompts are paired with the target stimuli that initially have no eliciting power but which will be expected to elicit the responses in the "natural" (performance) setting; and (3) arrange environmental conditions so that students can make the correct responses in the presence of those target stimuli and receive reinforcement for those responses (Gropper, 2018; Schunk, 1991; Winn, 1990).

Cognitivism stress the acquisition of knowledge and internal mental structures and, as such, are closer to the rationalist end of the epistemology continuum (Gagne, 1985; Bower & Hilgard, 1981). Learning is equated with discrete changes between states of knowledge rather than with changes in the probability of response (Ertmer & Newby, 1993). Cognitivism focuses on the conceptualization of students' learning processes and address the issues of how information is received, organized, stored, and retrieved by

the mind (Ekkekakis & Zenko, 2016). Learning is concerned not so much with what learners do but with what they know and how they come to acquire it (Jonassen, 1991). Knowledge acquisition is described as a mental activity that entails internal coding and structuring by the learner (Schroth, 1987). The learner is viewed as a very active participant in the learning process (Ertmer & Newby, 1993).

Therefore, this learning experience design is based on such pedagogical perspectives such as Constructivism, Constructionism, Cognitivism and Behaviorism. The learning experience design proposes a variety approach to differentiate different learning objectives such as developing different solid and correct touches from different positions and distances, balanced foot and body movement and tactical advice and experience for fencing with different types of fencers. A user should be able to choose interrelated tasks. The experience design suggests involving a competition element, where users can perform different tasks and get results which are ranked against other users who perform the same tasks and previous user's own results. The results would be summed up on a ranking list where a fencer can measure their performance against others. A user should be able to actively respond to and interact with the learning environment, as it would be important for developing conceptual, procedural and meta-cognitive skills, such as the correct timing of an attack and defence, anticipate adversaries' actions, use right tactical solutions and develop psychological stability.

For an effective feedback, the performed actions and their sequences should be assessed in real-time with right or wrong signals, scores, points and completion time. Right or wrong signals should be used in a task to assess users' ability to learn actions, tactics and speed. Points should be awarded if correct actions are taken strategically and precisely technically executed. The achieved results and data which can be obtained later can be used to discuss with the user's instructor. The development of learning experience proposes using a VR headset, controllers with fencing weapon for foil in the right weight and size, haptic technologies for feedback and more immersive interaction.

Conclusions

In conclusion, VR has the potential to support the acquisition of fencing skills, since it improves reaction and attention, allowing athletes to gain 'mental repetitions', building of muscle memory and developing attack and defence skills through the repeated practice.

As a result of the analysis, it was concluded that the tested learning experience for developing fencing skills lacks haptic feedback, which was highlighted as a crucial component from the interviewed coaches and

professional athletes. In real life a fencer bands his sword while making a touch and this develops a sense of pressure in fencers' movements. This is important because it helps to develop a sense of right distance and right force that should be applied while one is making a touch.

Based on the results of the study, a design map to enhance learning experience in fencing in VR has been developed. This is an ambitious project with many challenges and potential difficulties, including technological aspects. Nonetheless, this study shows that in practice this could be a significant tool for developing fencing skills for advanced fencers within a safe and individualised immersive environment. VR technology can become an important tool for improving different skills which are needed for high level athletes, starting from simple movements – a solid en garde position, a strong lunge or fleche, balanced movements, correct weapon and body positions and continuing with fencing experience with different partners and level of exercises to improve psychological resilience as well.

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