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LANA PLUMANNS
IMA/ZLW & IfU of RWTH Aachen University, Germany

THORSTEN SOMMER
IMA/ZLW & IfU of RWTH Aachen University, Germany

KATHARINA SCHUSTER
IMA/ZLW & IfU of RWTH Aachen University, Germany

ANJA RICHERT
IMA/ZLW & IfU of RWTH Aachen University, Germany

SABINA JESCHKE
IMA/ZLW & IfU of RWTH Aachen University, Germany

INVESTIGATING MIXED-REALITY TEACHING AND LEARNING ENVIRONMENTS FOR FUTURE DEMANDS: THE TRAINERS' PERSPECTIVE

Abstract:

The first three industrial revolutions were characterized by the invention of water and steam engine, centralized electric power infrastructure and mass production as well as digital computing and communications technology. The current developments caused by the fourth revolution, also known as "Industry 4.0", pose major challenges to almost every kind of work, workplace, and the employees. Due to the concepts of cyber-physical systems, Internet of Things and the increasing globalization, remote work is a fast-growing trend in the workplace, and educational strategies within virtual worlds become more important. Especially methods as teaching and learning within virtual worlds are expected to have an enormous impact on advanced education in the future. However, it is not trivial to transfer a reliable educational method from real to the virtual worlds. Therefore, it is im-portant to adapt, check and change even small didactic elements to guarantee a sus-tainable learning success. As there is a lot of ongoing research about using virtual worlds for the training of hazardous situations, it has to be figured out which potential those environments bear for the everyday education of academic staff and which competencies and educational support trainers need to have respectively can give in those worlds. The used approach for this study was to investigate the trainers' didactic perspective on mixed-reality teaching and learning. A total of ten trainers from different areas in Germa-ny took part in this study. Every participant pursued both roles: the teaching and the learning part in a virtual learning environment. In order to assess the learning success and important key factors the experiment yields data from the participants' behavior, their answers to a semi-structured interview and video analysis, recorded from the virtual world. Resulting data were analyzed by using different qualitative as well as quantitative methods. The findings of this explorative research suggest the potential for learning in virtual worlds and give inside into influencing variables. The online gaming experience and the age of participants can be shown to be related to participants' performance in the virtual world. It looks like the barriers for the affected trainers are low regarding utilization of virtual worlds. Together with the mentioned advantages and possible usages, the potential of these setups is shown.

Keywords:

Education, Mixed-Reality, Teaching, Virtual World

Introduction

Recent examinations of 702 today's occupations show how many million tasks and areas are affected by the ongoing digitalization (Frey & Osborne, 2013). While some occupations will be ceased, others will change, and new ones will occur. Responsible for these change are today's concepts like e.g. "Industry 4.0" (Federal Ministry for Economic Affairs and Energy, 2015; Geissbauer, Schrauf, Koch, & Kuge, 2014; Jeschke, 2013; Schuster, Groß, Vossen, & Richert, 2015) or Internet of Things (IoT). The ongoing globalization will not end and therefore, employees have to follow the trend. Occupations like e.g. teachers and trainers change through the trend to massive and remote teaching as e.g. massive open online courses (MOOCs) (Sursock, 2015). Powered by serious games (Moreno-Ger, Martinez-Ortiz, Freire, Manero, & Fernandez-Manjon, 2014) and gamification concepts, virtual worlds push into the teaching and training activities. Further, the produced data by the usage of these technologies is an enabler for learning analytics (Baker, 2014) and general analysis-driven methods.

Regardless of these possibilities, a teacher and trainer must be able to reflect those options. The potential usage of media and technology depends on the learning subject (Tesar et al., 2013). Thus, for some learning subjects virtual worlds are suitable. Today, virtual worlds are used to train uncommon scenarios e.g. major incidents (LeRoy Heinrichs, Youngblood, Harter, & Dev, 2008) or can be used to teach invisible processes e.g. the basics of a calculator. Besides incidents and inaccessible or non-existing places, also the training of dangerous activities is a possibility for such virtual worlds (Encarnação, 2008). Researchers identified effects and advantages of virtual worlds as method for trainings, e.g. in some cases an increase of team performance of about 50% or the fact that in case of 62%, the usage of a virtual worlds had the same effectiveness as traditional methods (LeRoy et al., 2008).

Further, remote work is constantly pushing forward. Working remotely whether from home, a coffee bar or another place is booming. Research suggests that more than half of today's office-based employees will regularly be working remotely within the next decade, thanks to technological advances in the workplace (Sawers, 2012). Advantages are among others more efficient agreements due to avoided travel time and a reduction of costs and the enhanced comfortability for the user (Ubell, 2010).

Due to current technological capacities it is possible to control machines and even whole factories remotely, so that no instructor has to be in place (Höpner, 2012). This technical development obviously shows the future requirements for such employees: While in the past an engineer was responsible for handling a specific local machine, tomorrow's engineer can control multiple factories remotely across the world. Hence, the remote collaboration is an important part of future companies and engineers might be confronted with e.g. intercultural issues. Prospectively, the future engineers must be aware of all processes, which are running at a factory instead of controlling one single process step locally. Further, the engineer has to understand and know all kind of machines at a factory and must be empowered to know their limits in order to control the whole factory.

Therefore, with the advent of Industry 4.0, a large market arises in the field of virtual training and settings for collaboration and schooling. But not every approach that is technically feasible improves users' learning outcomes; hence the danger of designing expensive virtual learning environments without having a positive effect on the users' learning is obvious. Thus, in order to ensure sustainable learning outcomes in virtual learning environments, people who provide professional skills in the physical world have to be involved. Based on previous studies about students' perspective on virtual education (Schuster et al., 2015), this study analyses the trainers' perspective of teaching and training using a virtual world for educational purposes with immersive hardware.

Before such technologies can be used in everyday training, teaching and learning with groups, further research regarding the transfer of common methods is necessary. Is it suitable for a trainer to moderate a group of students in a virtual world just like in the real world, even if the simulated area is huge? Is it possible to transfer well-known methods such as e.g. think-pair-share into a virtual reality setting? Currently, answers to questions like this are unknown and object of further research activities.

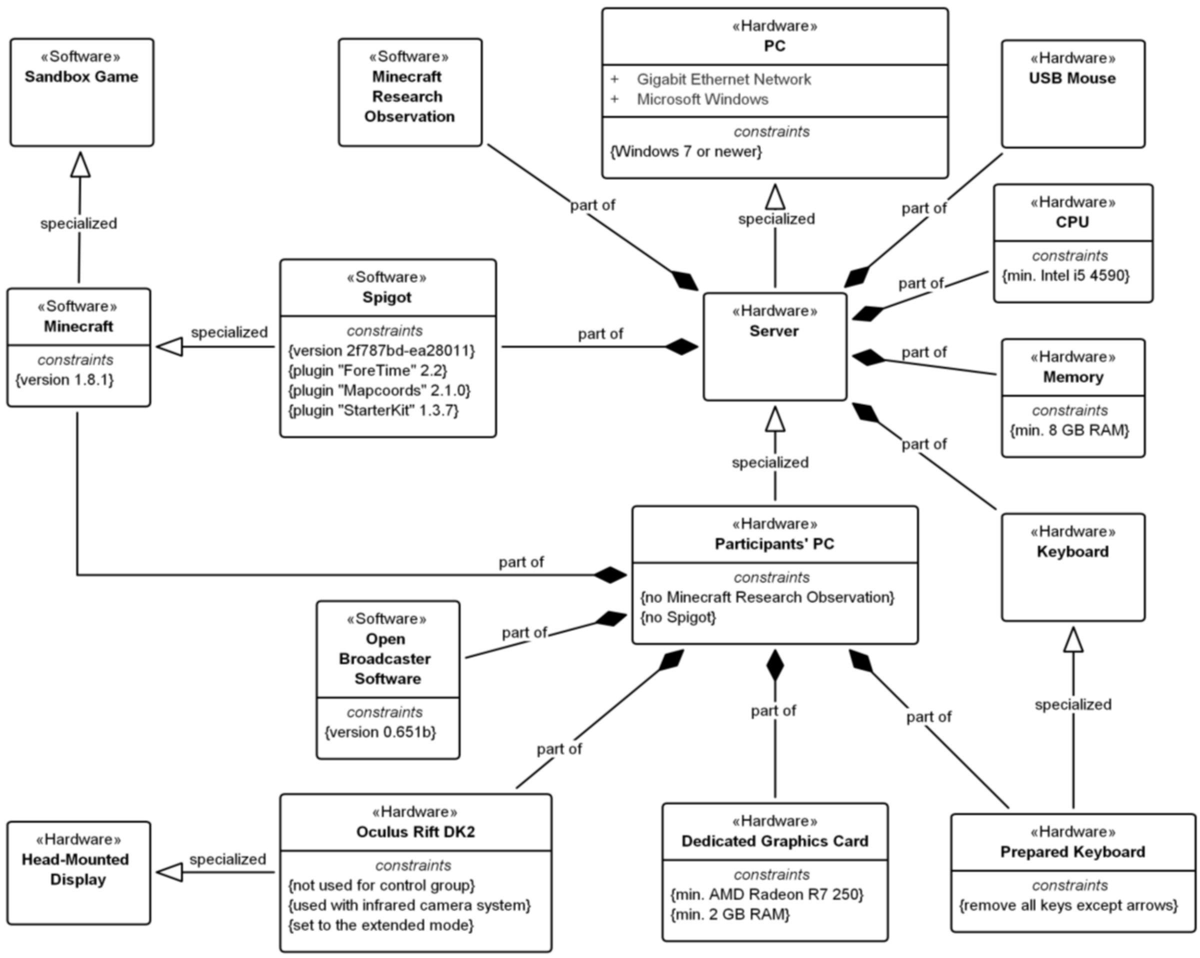
Following the high expectations regarding learning and working within virtual worlds, this research assessed trainers' behavior in and opinion about virtual learning environments. Hence, this experiment yields data from the participants' spatial behaviour and movements, their answers to questions regarding education and their experience within mixed-reality virtual learning environments to answer the question: Is today's society ready for remote training by using these technical possibilities? This study tries to give a first answer to this question by investigating the trainers' perspective inside the mixed-reality with virtual learning environments by a threefold purpose. First, an overview of the experimental setup is given; then the experimental study shows the challenges that tomorrow's trainers have to face and variables that might affect their performance. Finally, some technical and conceptual limitations are shown to guide further research in this field.

Setup and virtual environment

In order to get inside of technological details of this investigation, this section gives an elaborate description of the setup, the used environment, and the technical conditions. Hence, today's minimal technical requirements to provide an immersive virtual learning environment are shown. As the essential structure of this study, only one location was used in which two persons were participating for each pass. Thus, no headset was required for the verbal communication. A head mounted display (Oculus Rift DK2) served as immersive hardware to enter the virtual learning environment. Head-mounted displays had been used successfully in previous studies and the usage of these displays within virtual worlds is connected to strengthen sensations of immersion, flow, and spatial presence (Schuster, in press). Due to users' attention allocation processes while wearing these displays it is possible to blend the physical with the virtual world and hence design virtual interaction and knowledge transfer as naturally as possible.

The hardware requirements for this investigation are almost standard, as the model in figure 1 shows. A few components, however, need further consideration: Since this study was investigating trainers perspective on virtual education with the aid of immersive hardware, specifically the Oculus Rift, the participant's PC needed a dedicated graphics card in order to work with the head-mounted display. Further, for the convenient control of the participant's avatar in the virtual learning environments with equipped head-mounted display, a prepared keyboard was used. Except the arrow keys, all other keys were dismounted to prevent participants from pressing wrong or undesired keys. This modification is necessary because the participants cannot see the physical world while the head-mounted display is equipped. Additionally, a standard-sized USB mouse was used to enable a 360-degree turn, while sitting on in front of the PC.

Figure 1 The UML (Unified Modeling Language) model about the hard- and software requirements for this study.



Source: Self-created model

The head-mounted display was used with the infrared camera system and was set to the extended mode. Thus, it behaves like an additional display. However, this setup is not the optimal setting regarding lowest system response time; it is very stable and durable. In comparison, the direct mode offers a lower response time, which should prevent the simulator sickness better, but it appears to be not very stable within forgone pre-tests. For the optimal immersion into the virtual world, the system was calibrated regarding participants' individual interpupillary distance (IPD) and their body height.

As setting for the virtual learning environment, the open-world and sandbox game Minecraft was chosen (Short, 2012). This program has been used successfully for learning and teaching purposes beforehand and allows participants among other things to freely explore a virtual environment (Schifter & Cipollone, 2013). With Minecraft, the creation and manipulation of virtual worlds are efficiently possible. For this study, two virtual worlds respectively virtual learning environments were necessary: The first world comprised a tutorial to teach the basics of Minecraft, which was the participants' trainee part. The second world served as the task that the participants should solve as a trainer. To prevent simulator sickness (Höntzsch, Katzky, Bredl, Kappe, & Krause, 2013) as good as possible, both worlds are designed to be usable without jumping and climbing.

Figure 1 also shows, that "Spigot" was used on the server-side to provide the worlds. Its configuration was also important to make the worlds useful for scientific studies and virtual learning environments. The difficulty was changed to be friendly, which means that eventually present non-player characters do not attack the participants during the experiment. Further, the appearance of any non-player characters and the participants' possibility to attack each other were disabled.

Method

Participants

Ten professional trainers aged between 24 and 60 years (M=40.7; SD=13.2; n=2 female) participated. Participants were recruited from different areas in Germany and active in various domains of personal development to cover a broad range of professions.

Assessment of participants' objective behavior

A screen capture tool recorded participants' behavior within the virtual learning environment. The assessment of these objective data is important to clarify whether the basic competencies for learning within virtual learning environments are given and to track participants' performance during the experiment (Wilson et al., 2008). A calibration with subsequent validation procedure was conducted prior to the experiment. To assess participants attention allocation processes, their gaze fixations, collaboration behavior, communication as well as fluency and speed of movement during the experiment was assessed with the OBS (figure 2). These assessments were invisible to participants. Participants' movement fluency and speed allowed assumptions about their habituation progress, whereas the kind of communication and the progress of solving the subtasks reflected the efficiency as a trainer.

Participants' way of movements within the virtual learning environment was also assessed and extracted using Minecraft Research Observation tool to investigate whether they were e.g. rather following or autonomous and leading in the trainer part. These psychomotor skills can be classified into seven different categories, ranging from simple to complex: (1) perception, (2) readiness to act, (3) imitation, (4) habitual movement patterns, (5) complex overt response, (6) adapting the movement pattern to reach an aim and (7) creation of new movement patterns (Simpson, 1972).

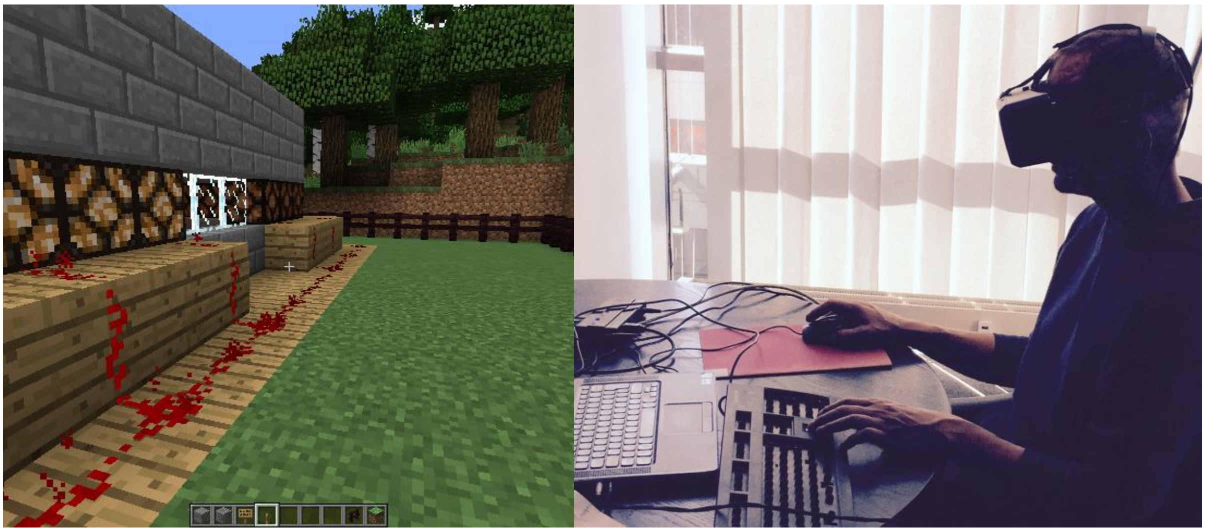
Semi-structured interview

In order to assess trainers opinion and experience within the virtual learning environment, a semi-structured interview was conducted after the experiment. The quantitative questions were assessed anonymously on a laptop and covered items as questions regarding simulator sickness, sensations within the virtual world, potential use of these worlds as a training method and benefit of these (rated on a 5-point Likert scale with 1=not helpful at all to 5=very helpful). The qualitative questions of the expert interview covered among other things questions like the trainers experience within the virtual learning world, advantages, and disadvantages of this kind of mixed-reality education, further fields of application. Data of the interview were recorded for further transcription (see analysis section).

Procedure

Upon arrival, all participants signed the informed consent and filled in their demographic data (among other age, gender, previous gaming experience and used gaming modus, specific field of expertise). Each experiment started with a short introduction into the virtual learning environment to get the trainer habituated to the environment and the hardware. During the experiment, the participants' spatial behavior within the virtual learning environment was assessed with a screen capture tool and documented by a scientific researcher. In order to focus on modern engineering education, an engineering task was given to the participants, who entered the virtual environment by wearing a head-mounted display, displayed in figure 2 (right side).

Figure 2: Screenshot of the teaching scenario (left side); participant entering the virtual learning environment (right side).



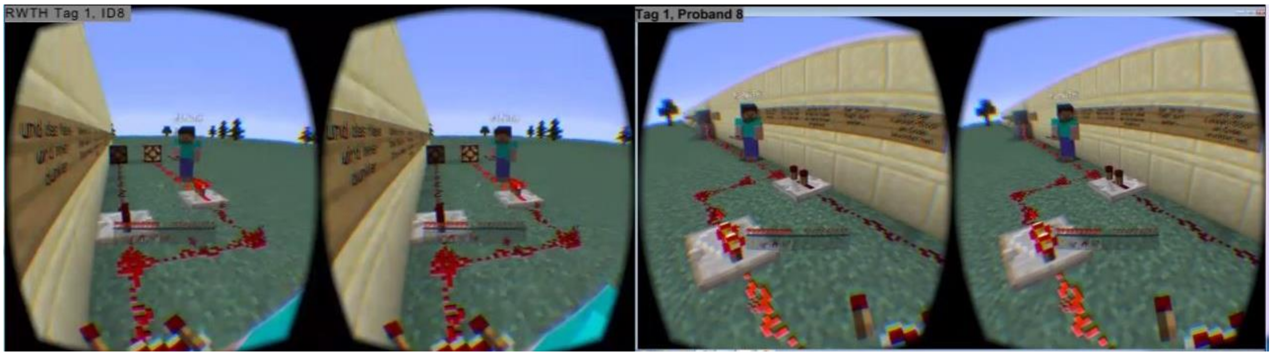
Source: Own figure

In order to get a deeper insight into the trainers' perspective of this new way of education as well as the discrepancy between learning and teaching within the virtual environment, every trainer pursued two roles: first the trainee and then the trainer part. The participants entered the virtual environment in groups of two. During this virtual meeting, both participants (the trainer and the confederate) were represented by avatars. In the first part of the experiment (trainee-part), the participant was instructed by the research director to restore a broken electrical circuits based on the "Redstone" system (Dezuanni, O'Mara, & Beavis, 2015). This part of the experiment also enabled the trainer to get comfortable with the virtual learning environment and the handling of the unknown hardware. In the second part of the experiment, a similar problem was stated, but this time the participant had to instruct the confederate about how to solve the stated problem, without anticipating the problem-solving process (the trainer part).

This second world provides a small area with a house and a lighting system. The issue was similar to the first world, but, in this case, the electrical circuit was bigger, and the light was partially working. The participants must repair the circuit to activate all the lightings. This task can be divided into several sub-tasks: (1) Get an overview of the electrical setting of the building. (2) Find out, at which spots the electrical circuit is broken. (3) Remember the necessary steps to repair the electrical circuit. (4) Find the spot within the building from where the success of the problem solving can be controlled (Schuster et al., 2015).

Starting with the briefing of the handling of the simplified keyboard and the mouse, the participants had to make sure that the other person (the trainee) feels comfortable within the virtual learning environment and solve the stated problem without further instructions. During the experiment, both screens (trainers and trainees) were recorded and gathered by the mentioned video capture tool for assessing the trainer's and the trainee's behavior in the virtual learning environment (figure 3).

Figure 3 Screenshot of the OBS recordings with the trainees view (right side) and the trainers view (left side).



Source: Own figure

Analysis

The quantitative data were analyzed by using IBM SPSS, version 22 (www.spss.de). Three independent scientific raters coded all qualitative data and scored from 1=low to 6=high. Since the interrater variability was high the scores of the three rates were collapsed into one score for each variable and analysed by using SPSS, results of Spearman correlation (two-sided) are displayed in the parentheses below.

Results

The screening of the gathered video data indicates that age and online-gaming experience were shown to be related to participants' spatial coordination within the virtual learning environment (r_{age}=-.60, p<.05; r_{gaming} =.78, p<.01). Older participants, and those who had no gaming experience showed initial difficulties with the hand-cursor coordination in the habituation phase, which was indicated by more questions, slower and less fluid movements and spatial problems when it came to entering the buildings or reading instructions that were hanged on a wall. Furthermore, these participants were shown to stay longer in the more simple psychomotor categories as proposed by Simpson (1972). However, most difficulties diminished after around the first minute (*M*=43.4 seconds; *SD*=23.8 seconds) by all participants.

This study showed that participants who reported higher sensations of immersion, got used to the virtual world faster, as seen by their objective behavior within the virtual learning environment (e.g. number of gaze fixations (r_{gaze} =.92, p<.01), spatial coordination ($r_{spatial}$=.94, p<.01), general task performance (efficieny) as trainee, respectively trainer ($r_{trainee}$ =.91, p<.01); ($r_{trainer}$ =.92, p<.01)). However, whether this is a consequence of participants precondition and mixed-reality devices could not be analyzed in this study and deserves further investigation. All participants were able to solve the stated problem as a trainee and were capable of instructing another person verbally within the second virtual learning environment. Thereby, it was shown that participants who documented their course of action out loud as trainee performed more efficiently; hence they finished the sub-goals faster and transferred their knowledge into their role as a trainer. This behavior was particularly seen by trainers with extended working experience. However, the amount of work experience as trainer does not predict efficiency within the virtual world solely.

Table 1: Inter-correlation matrix with Cronbach's alpha at the diagonals

	1	2	3	4	5	6	7	8
1. Age	1							
2. Gaming	-.65**	1						
3. Gaze	-.63*	.86**	.91					
4. Spatial	-.60*	.78**	.98**	.92				
5. Work	.62	-.25	.02	.06	1			
6. Immersion	-.82*	.74	.92**	.94**	-.35	.87		
7. Efficieny Trainee	-.72*	.84**	.98**	.95**	.04	.91**	.94	
8. Efficieny Trainer	-.50	.77*	.87*	.85**	.31	.92**	.93**	.90

Source: Own analysis

Other factors that seemed to influence the success of the trainee phase were among others the self-confidence appearance to the trainer within the virtual learning environment and the time they spend on reading the instructions. No participant got sick due to the simulation. The experimental session took around 35 minutes per participant. After the experiment, the participants were asked to evaluate their previous learning experience in the virtual learning environment anonymously. The participants' overall conclusion was very positive.

It was shown that even the barriers for the affected trainers are low regarding utilization of virtual learning environments for teaching. The benefit of virtual worlds in teaching got a mean score of 4.5 (*SD*=1), rated on a 5-point Likert scale (with 1=not helpful at all to 5=very helpful). In reply to the question concerning the potential use of these worlds as a training

** Correlation is significant by level 0.01 (two-sided).

* Correlation is significant by level 0.05 (two-sided).

method, all trainers answered with the highest rating (5=very helpful). The additional expert interview yield more insight into the gathered data and the trainer's perspective. The training was rated as very adaptive, and the participants pronounced the feeling of immersion into the virtual world. The trainers' particularly mentioned the possibility to represent and adapt specific learning content and their feeling of deep and conscious learning as well as the fast familiarization with the virtual learning environment. The speed of movement and the visualization of the environment within the scenarios were stated as pleasant just like the navigation after the habituation phase. The level of difficulty was rated as appropriate for the purpose, and the setup of the virtual learning environment was rated as immediately intuitive for those with gaming experience (n=8).

As possible fields of further application the trainer called among other things fields like emergency services, schooling of security staff and training of techniques, which are too hazardous for the training in field, as well as everyday schooling for higher education and development. As a particular advantage of learning in virtual worlds, the resource efficiency and flexibility, as well as the targeting of many senses at once and the consequential deep learning, were emphasized. Also, the possibility to change or adapt single parameters for training or learning success were mentioned as benefits of virtual learning environment as well as the exploration of environments or settings that are hard to visualize on plane surfaces.

The trainers emphasized the chance to visualize learning success immediately. Also, they told that it is forward-looking, to develop academic and personal needs with the aid of gamification of learning content. To the question of potential difficulties with virtual worlds for trainees and trainers, initial problems with the usage and the acceptance of technology were mentioned as well as a partial negative delay when looking into depth. However, the benefits exceeded the possible adverse effects. When asked about further suggestions, the trainers emphasized the importance of virtual learning environment for learning and future work forms and mentioned their interest in the progressive interlocking of economy and research due to the ongoing digitalization.

Conclusion and Outlook

This research gives an insight into trainers view on virtual education. Often, teenagers' and young adults' opinions are positive regarding modern technologies. However, the average age of the participants was relatively high (M=40.7 years; SD=13.2 years). Nevertheless, their opinion regarding training in virtual worlds with immersive hardware was positive. Though, a representative study would be interesting to get an average result from the trainers' and therefore, the teachers' cohorts. A shortcoming of this study was the cross-sectional design, a longitudinal investigation could be useful to give additional insight. Furthermore, a larger sample size would be needed in order to verify the current findings.

After the initial minute, the participants had no major problems with the hand-cursor coordination and everyone was able to show the necessary spatial movement patterns to complete the task. The possibility to verbal communicate within in the virtual learning environment was perceived as beneficial in the trainers self-report for both parts, the trainer, and the trainee part. Thus, the process of pointing toward e.g. an issue was possible by using the verbal communication as well as the avatar's gaze direction and arms. Furthermore, due to real-time communication any issues could be resolved directly. The trainers mentioned as an advantage of this setup that multiple senses are targeted at once. It would be interesting to investigate effects regarding learning, caused by targeting multiple senses in longitudinal studies.

The experience with this study shows possible improvements for further studies: The so-called "spawn point" is the point, where participants enter the world. Although the spawn point was predefined, the virtual worlds do not guarantee a particular point. Instead, a probable spawn area is used. The consequence was that the most participants enter at the right position, but some enter the world e.g. on the roof of the building. For further studies, the usage of an appropriate plugin is planned which allows the definition of a single static spawn point where also the point of view (the angel of the head) is pre-defined.

It is going to be a new challenge for trainers and users to teach, learn and work in the virtual world. Next to nowadays-required competencies, tomorrow's trainers need technical expertise to support users in case of technical problems, malfunctions, and digital literacy to tutor and collaborate appropriately within virtual environments. These requirements represent a major challenge for trainers especially when it comes to groups of users instead of a single one. Also, trainers must be aware if this technology is the right method for a particular subject and if they can transfer their didactic methods into these worlds.

For the successful usage of mixed-reality virtual learning environments for everyday teaching, training and learning for suitable topics, the corresponding industry must provide efficient programs for the creation of such settings. The creation and preparation of suitable worlds must be able and time-efficient as the creation of today's presentations. Some concepts are already promising: For example, some police restricts in Germany got already a suitable solution (Herkersdorf, 2013; Lecon & Herkersdorf, 2014): They can utilize a predefined world with an editor that is customized for the police training to easily setup suitable scenarios. Sandbox games like Minecraft are another approach, which affords the changeability and openness of a suitable tool. However, often, these games are limited regarding related learning topics like e.g. physics, mathematics and training of major incidents, which is often caused by missing mechanical systems at the virtual worlds.

Regardless of the tooling, the virtual reality hardware needs more research regarding usage for training and teaching purposes: Currently, it is not suitable for the students to take or read notes while they are wearing the virtual-reality headsets. One promising approach is the usage of today's speech recognition to take notes. Reading of notes is potentially possible with the right tooling. Another approach is the upcoming augmented reality hardware. They combine the physical world with the virtual reality, respectively can blend the physical world with virtual elements. Because the students can also perceive the reality, notes can be written and read. Nevertheless, for both technologies are topics and scenarios suitable.

Due to new technological developments, the integration of activating learning elements in virtual environments is possible, even as working remotely and controlling machines from afar, offering training with the aid of avatars and many more. This study showed the potential of nowadays-recent progress regarding the ongoing digitalization, but it is necessary to take care that everyone can be involved in this developments. Therefore, continuing this kind of research is an important contribution towards tomorrow's proliferous and digitalized world.

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