Virtual Reality in Health Care Education: A Study about the Effects of Presence on Acceptance and Knowledge Improvement among Health Care Students

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Abstract: With an ever-increasing need of skilled healthcare workers, efficient learning methods like Virtual Reality are becoming increasingly important. A VR simulation for endotracheal suction intervention was developed and tested.
The aim of this pilot study is to examine the VR simulation's acceptance and knowledge improvement. Furthermore, the effect of presence on acceptance and knowledge improvement was investigated.
A total of 51 students participated in the pilot study, using pre-post-test design. A modified Unified Theory of Acceptance and Use of Technology (UTAUT) and Igroup Presence Questionnaire (IPQ) were used. Correlation and regression analysis were performed. Pre- and post-tests showed a significant knowledge improvement ($p<0.001$). Correlation between presence and behavioural intention was highly positive ($r=0.52$, $p<0.001$).
Performance and effort expectancy are dominant in effect on behavioural intention of using VR learning simulation. The results indicate that a simulation, which conveys a higher sense of presence, is more likely to be accepted.

Keywords: Virtual Reality, Health Care, Education Technology, Acceptance, Presence, Knowledge Improvement.

1 Background and motivation

Like many other countries, the number of people in need of care in Germany has been rising steadily for decades [St18]. Since the number of personnel is not developing accordingly, a shortage of care workers is emerging [St18], [LF19]. This inevitably leads to a higher demand of nurses requiring more efficient education in large scale. In view of the tense personnel situation in health care, especially the practical instruction of students

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is increasingly becoming a burden. Activities under instruction can therefore only be practiced to a lesser extent, if at all. This often results in a lack of readiness and skills among nurses, which has a negative impact on the quality of care and can lead to life-critical nursing errors [Ai12]. For this purpose, new learning methods such as VR must be studied.

Little is known about VR learning in nursing. So far, only few pilot studies have been conducted [We18], [BC19]. In the context of home ventilation as an exemplary field of application, endotracheal suction and ventilation have shown to be particularly stressful [LK18]. If nursing staff can perform suction carefully and without injury, relatives and patients feel safe [LE20]. Hence, a VR simulator for practicing the endotracheal suction procedure was developed. The aim of this paper is to estimate the target groups acceptance, and to validate knowledge improvement using VR in a pilot study. Furthermore, insights on how the sense of presence affects behavioural intention and knowledge improvement are acquired.

2 Theoretical framework

2.1 Presence in VR and consequent potential for learning applications

According to psychological learning theories like constructivism, experiential and situated learning, practical, interactive and lively experiences are highly beneficial for acquiring theory knowledge and practical skills in specialized field like nursing [Lo15]. Due to its immersive nature, VR has the capability of absorbing the user in a virtual environment creating an imprinting experience, hence leveraging the idea behind these learning theories. One construct to measure this experience is called presence. There are various definitions of presence, most of them being similar, for example “Presence is a state of consciousness, the (psychological) sense of being in the virtual environment.” [SW97] or “presence is the subjective sense of being in a virtual environment” [Sc03]. Based on learning theories, this subjective state should enhance the learning process for acquiring the desired knowledge and skills [Sl17].
One assessment tool for measuring presence is the Igroup Presence Questionnaire (IPQ) which divides presence in three subscales that are (I) Spatial Presence - the sense of being physically present in the VE; (II) Involvement - measuring the attention devoted to the VE and the involvement experienced; (III) Experienced Realism - measuring the subjective experience of realism in the VE [Sc03]. Due to its multi-dimensional nature and confirmed validity, IPQ was used as theoretical framework for measuring presence in this work.

2.2 VR in medical technology research and assessing knowledge improvement

VR simulators in medicine are widespread and there are even ISO-standards for validation [Pa18]. A survey of 31 studies with 2407 participants [Ky19] found evidence suggesting that VR improves post intervention knowledge and skills outcomes of health professionals when compared to traditional education or other types of digital education such as online or offline digital education. In the survey paper, knowledge improvement is defined as learner’s factual or conceptual understanding measured using change between pre- and post-test scores. The definition was adopted for this paper.

2.3 Assessing technology acceptance

While knowledge improvement of a new learning tool is important, the tool also must be accepted and used by the target group. According to the unified theory of acceptance and use of technology (UTAUT) technology acceptance is defined as a process. A process that reaches from testing a technology, developing behavioural intention and eventually using the technology in the field [VMD03]. UTAUT is a validated model that combines eight technology acceptance models. The UTAUT model defines constructs, that causally affect behavioural intention. There are four key constructs: Performance expectancy, effort expectancy, social influence and facilitating conditions and constructs that have been identified to not significantly affect behavioural intention: Anxiety and self-efficacy. The constructs consist of multiple items, which are statements towards the technology. For example, one item for assessing performance expectancy would be “I would find the system useful in my job” [VMD03]. To apply UTAUT these items must be adapted to the setting and usage scenario of the technology being evaluated.

3 Material and methods

3.1 The VR simulation

The VR simulation has been developed at the Care and Technology Lab (Institut Mensch, Technik und Teilhabe), Hochschule Furtwangen. The simulation runs on the HTC Vive Head Mounted Display (HMD) with Vive controllers. The aim of the simulation is to execute the steps of endotracheal suction intervention, shown in **figure 1**, on a virtual home patient guided by audio voice records and text messages on a virtual tv screen. The steps followed by the learner reach from disinfecting hands at the beginning up to disposing the used equipment after the procedure. The order of steps follows the SOP of a German hospital.

Fig. 1: Screenshot collage of the VR simulation

The patient reacts in a realistic manner, looking at the learner, showing discomfort and coughing with a painful expression when the catheter is inserted in too deeply. Sound effects have been recorded from real medical equipment. After execution, the learner is presented an evaluation of his performance including time required for the suction procedure as well as number of faulty actions like contaminations. The simulation was developed iteratively and continuously checked by health care professionals and corrected accordingly. Moreover, a pilot study with nursing professionals who have had previous experience in endotracheal suction was conducted and usability of the simulation as well as correctness of the procedure were adapted based on the results.

3.2 Objectives

Due to the complexity of the endotracheal suction procedure, there is no standard tool yet for assessing performance in terms of skills (like OSCEs), which is why this study focused on knowledge improvement rather than skills improvement. Skill assessment will be a topic of further research. Since there has not been much research on VR in nursing education (see **chapter 1**), the conducted study's approach was based on a semi-explorative design, analysing many hypotheses, and revealing further research questions. The large number of hypotheses compared to the relatively low number of participants can lead to errors, however we do not draw final conclusions, but use the results to provide further insight on possible research topics. The first objective was to investigate if the UTAUT constructs in the special context of VR learning in nursing affect behavioural intention the same way as in general technological acceptance domains like bureau jobs.

Besides the four key constructs, anxiety and self-efficacy were included as these could play a role in the domain of acceptance of VR learning. This led to the following hypotheses:

h1: [a-f] has an effect on behavioural intention to use a VR simulation for learning.
h1a: Performance expectancy, **h1b**: Effort expectancy, **h1c**: Social influence, **h1d**: Facilitating conditions, **h1e**: Anxiety, **h1f**: Self efficacy

The second objective was to analyse how presence affects behavioural intention of using VR learning simulations. The presumption behind this idea was, that users who perceive a simulation as highly unrealistic, are more likely to not accept the simulation as a learning tool. Hence, user who feel more present should be more likely to accept the simulation as a learning tool.

h2: [a-d] has a positive effect on behavioural intention to use a VR simulation for learning.
h2a: Sense of presence, **h2b**: Spatial presence, **h2c**: Involvement, **h2d**: Experienced realism

The third objective was to investigate the effect of presence on knowledge improvement. Based on learning theories (see **chapter 2**) presence should have a positive effect on learning outcomes. This led to the following hypotheses:

h3: [a-d] in the VR learning simulation has a positive effect on knowledge improvement of the intervention.
h3a: Sense of presence **h3b**: Spatial presence, **h3c**: Involvement, **h3d**: Experienced realism

3.3 Study design and evaluation process

In order to evaluate the hypotheses and gain further insight, 51 physiotherapy students were acquired for a study. Three VR setups separated by visual covers were installed in a large room. The students waited outside and filled out a knowledge pre-test. They were told that this test does not influence their grade in any way and were observed by an instructor to not cheat in the test. The students were asked to enter the room separately by the instructor whenever a VR setup was available to use. Next, they were given a standardised scripted explanation of how to use the system by one of three more instructors next to each VR setup. After this, they were requested to go through the simulation twice, in order to make sure they could learn the controls during the first run and focus on the task during the second run. Finally, they were asked to fill out the knowledge post-test and a UTAUT questionnaire as well as the IPQ.

Knowledge improvement (see **chapter 2**) was measured with the percentage decrease of error of the post-test compared to the pre-test. The tests were equal and contained 14 items, which were the steps of the intervention, that had to be put in the correct order. Error was calculated using the mean of absolute deviation from each item’s put position by the learner compared to its correct position. Percentage decrease of error in the post-test compared to the pre-test was calculated and used as the score to measure knowledge improvement. Every student was taught the same knowledge about the intervention before the test. They learned from a theory lesson and an information sheet. To validate h1, a paired t-test was used on the students pre- and post-test scores.

In order to evaluate the hypotheses 2a - 2f, UTAUT (see **chapter 2**) was used. Items were translated into German and adapted to the context VR learning for students, trying to stay as close to the semantic meaning as possible. Internal consistency using Cronbach's alpha was measured to make sure constructs are reliable. To estimate effect of the constructs on behavioural intention partial least squared path modelling was performed as suggested by Venkatesh et al (2003). Calculations were performed with the PLS-PM library in R.

Presence was measured using the IPQ. The IPQ guide on how to calculate subscales was followed [Sc03]. In order to evaluate presence related hypotheses Pearson’s correlation analysis was performed. The standard significance level of 0.05 was used throughout evaluation. Statistical calculations were performed using R.

4 Results

4.1 Study sample and knowledge improvement

Out of the 51 participants, 47 filled out the IPQ and UTAUT questionnaires, while 45 filled out the knowledge tests.

category	participants	gender		age			experience in	
subcategory	overall	m	f	18-25	26-30	>30	VR	suction
n	47	7	40	43	2	2	18	5
rate	100%	14.9%	85.1%	91.5%	4.2%	4.2%	38.3%	10.6%

Tab. 1: Study sample

Table 1 summarizes the study sample. The sample was relatively homogeneous consisting of students with health care profession, mostly at ages <=25 (91.5%) and most being female (85.1%). 38.3% had previous experience in VR and 10.6% had previously performed endotracheal suction on a human patient. There was no significant difference in test performance between the group with and without previous VR experience.
As a requirement for further research questions, knowledge improvement through using the VR simulation had to be confirmed. Mean absolute error in the pre-test over all participants was 2.26 and 0.79 in the post-test. Mean percentage decrease of error was 65%. A paired t-test confirmed high significance ($p<0.001$)**.**

4.2 UTAUT constructs effect on acceptance

While four of the six UTAUT constructs reached at least a value of Cronbach's Alpha $\alpha>0.8$, which is indicates a construct with good internal consistency, *social influence (α=0.64)* and *facilitating conditions (α=0.37)* did not reach the $\alpha>=0.7$ border which is considered inacceptable reliability, Thus, the two constructs had to be discarded for further conclusions leaving **h1c** and **h1d** unanswered.

construct	mean	effect (f^2)	t-value	p-value
Performance expectancy	4.4/5	0.34	2.33*	0.025
Effort expectancy	4.03/5	0.25	1.80**	0.008
Anxiety	1.74/5	-0.10	-0.83	0.41
Self-efficacy	3.36/5	0.11	0.88	0.38
Behavioural intention	3.8/5	-	-	-

Tab. 2: UTAUT constructs mean and effect on behavioural intention (*p<0.05, **p<0.01)

Table 2 shows the mean score of the UTAUT constructs as well as their effect on behavioural intention and its significance. Overall**,** behavioural intention of using VR for learning was high (3.8/5 (76%)). The constructs performance expectancy (f^2=0.34, p=0.025) and effort expectancy (f^2=0.25, p=0.008) had a significant effect with a medium to large effect size on behavioural intention suggesting that **h1a** and **h1b** are likely to be true.

4.3 Effects of presence

The scores of the presence subscales were as follows. The general sense of presence was relatively high (4.5/6), spatial presence (4.3/6) and involvement (3.9/6) were in the medium range, while the expected realism was rather low (2.5/6).

construct	Correlation (r)	t-value	p-value
sense of presence	0.52	4.07***	0.000
spatial presence	0.39	2.86*	0.01
involvement	0.26	1.79	0.08
experienced realism	0.34	2.43*	0.02

Tab. 3: Pearson’s correlation between presence and behavioural intention (***p<0.001, *p<0.05)

Table 3 shows Pearson’s correlations between the presence subscales and behavioural intention. Correlation between sense of presence and behavioural intention was highly significant (p<0.001) and according to Cohen also has a large effect (r>0.5). Correlation between spatial presence and behavioural intention, as well as experienced realism were also significant with a medium effect. Thus, **h2a**, **h2b** and **h2d** were confirmed. The effect of involvement was not significant and had only a low effect size, which lead to **h2c** being rejected.

construct	Correlation (r)	t-value	p-value
sense of presence	-0,28	-1,89	0,07
spatial presence	-0,33	-2,31*	0,03
involvement	-0,15	-1,03	0,31
experienced realism	-0,16	-1,07	0,29

Table 4: Pearson's correlation between presence and knowledge improvement (*p<0,05)

Likewise, **table 4** shows correlations between the presence subscales and knowledge improvement. Correlation between spatial presence and knowledge improvement was negative with medium effect size (r=-0.33 p=0.03). **h3b** was not confirmed, due to the negative effect. The other presence subscales did not correlate significantly (p>0.05) which means **h3a**, **h3c** and **h3d** were not confirmed either.

5 Discussion

Like the UTAUT model suggests, performance expectancy and effort expectancy had a significant effect on behavioural intention. Although some participants showed fear during execution of the simulation and had to cancel it, anxiety did not have a significant effect and neither did self-efficacy. Due to their insufficient reliability, no statement about social influence and facilitating conditions can be made. Overall, technology acceptance in VR learning does not seem to differ from other domains considering the UTAUT constructs. However, the number of participants were small and further research needs to be done to verify this, especially regarding the anxiety construct, since our subjective observations contrasted this.

Sense of presence had a medium to strong size positive effect on behavioural intention that was highly significant (see **chapter 4**). A higher sense of presence in a simulation could lead to a higher behavioural intention by learners. This seems plausible, since a simulation that absorbs the learner into a virtual training scenario and feels subjectively more realistic, should be more likely to be accepted and used.

Out of the presence metrics, only spatial presence correlated significantly (p<0.05) with knowledge improvement. It seems likely that a user who feels more spatially present in the virtual training scenario would have a more imprinting experience and could therefore memorize more of it. However, against this presumption the correlation was negative.

Regarding the effects of presence on learning outcomes, there is no consensus in literature. While [SGL19] and [Ch18] found a positive correlation between presence and learning outcomes, [Ba12] found a negative correlation (like this research) and [Pe09] as well as [LPF19] found no significant correlation at all. There could be various reasons for this discrepancy. The first reason could be that there are various survey instruments for assessing presence and learning outcomes which could lead to not measuring the same constructs. Another more complex explanation includes viewing presence from two different perspectives. First, presence can be seen from user perspective suggesting that each user has a different sense of presence towards one simulation. Second, presence can be seen from simulation perspective suggesting that the same user feels different degrees of presence in different simulations. This leads to two different study designs. In the first study design, differences in the degree to which user perceive presence in the same simulation are measured. In the second study design different simulations are compared by having the same users participate in multiple simulations and measure the differences in degrees of presence which simulations can convey. On the one hand, users who generally feel more present in VR simulations than other users might focus more on the environment than the actual task. On the other hand, simulations that generally convey a higher sense of presence could lead to more imprinting experiences and therefore positively affect knowledge improvement.

5.1 Limitations

There are some flaws in the study design. On the one hand, the VR simulation aims to teach nursing skills. The participants, however, were physiotherapy students as there were no larger nursing student groups available to the authors for testing. Additionally, previous experience in suction is likely to influence performance. On the other hand, the large amount of effects looked upon with a relatively small amount of study participants could lead to statistical errors. Another problem is that no split of groups was done. Participants all ran the same simulation which lead to making assumptions based on general effect size classes and correlation of constructs rather than comparing effect sizes.

5.2 Conclusion

Our pilot study analysed various aspects of VR learning in the health care education sector. In the study, performance expectancy and effort expectancy had a significant effect on behavioural intention in the target group while self-efficacy and anxiety did not. This reflects the results from the creators of UTAUT [VMD03]. We could not confirm the effects of social influence and facilitating conditions due to unreliability of our constructs. Moreover, our results suggest that the sense of presence could have a positive effect with large size on behavioural intention of health care VR learning simulations. In further research, the UTAUT based items must be improved in order to more reliably gain insight,

especially about the anxiety construct, which according to our observations seemed to play a role. Moreover, our detected effect of presence must be confirmed through further studies.
Finally, we found that there was a significant negative correlation between spatial presence and knowledge improvement. We explained a possible reason for the discrepancy of the measured effects of presence on learning outcomes in different studies. There is still no consensus about the effect of presence on learning and further research needs to investigate the reasons for this.

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