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May I Remain Seated: A Pilot Study on the Impact of Reducing Room-Scale Trainings to Seated Conditions for Long Procedural Virtual Reality Trainings

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***Abstract*—Although modern consumer level head-mounted-displays of today provide high-quality room scale tracking, and thus support a high level of immersion and presence, there are application contexts in which constraining oneself to seated set-ups is necessary. Classroom sized training groups are one highly relevant example. However, what is lost when constraining cybernauts to a stationary seated physical space? What is the impact on immersion, presence, cybersickness and what implications does this have on training success? Can a careful design for seated virtual reality (VR) amend some of these aspects? In this line of research, the study provides data on a comparison between standing and seated long (50-60 min) procedural VR training sessions of chemical operators in a realistic and lengthy chemical procedure (combination of digital and physical actions) inside a large 3-floor virtual chemical plant. Besides, a VR training framework based on Maslow's hierarchy of needs (MHN) is also proposed to systematically analyze the needs in VR environments. In the first of a series of studies, the physiological and safety needs of MHN are evaluated among seated and standing groups in the form of cybersickness, usability and user experience. The results (n=32, real personnel of a chemical plant) show no statistically significant differences among seated and standing groups. There were low levels of cybersickness along with good scores of usability and user experience for both conditions. From these results, it can be implied that the seated condition does not impose significant problems that might hinder its application in classroom training. A follow-up study with a larger sample will provide a more detailed analysis on differences in experienced presence and learning success.**

***Keywords*—virtual reality, chemical industry, operator training, cybersickness, seated VR, headset, procedural skills**

I. Introduction

Virtual reality (VR) trainings have been used in a broad range of areas like healthcare[1], military [2], physical skills [3], psychology [4] and industrial training [5]. There is no doubt that immersive VR has a potential to create an interactive simulation of reality that allows users to interact with virtual objects or 3D models in an almost natural way [6]. With the advances of VR technologies and the availability of VR devices in the consumer market, virtual trainings have become more and more feasible for a broader range of knowledge domains. Newer consumer head-mounted-displays not only allow for 3 degrees-of-freedom (DoF) tracking (orientation), but also for room-scale tracking of

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6 DoF (position and orientation) using in-build inside-out-tracking. This in principle renders such devices optimal for the training of scenarios within larger workspaces.

On the other hand, there is the problem of scalability with regards of participants when such trainings should be applied in educational settings, which not seldomly consist of groups of 10 or more trainees in one training unit. Applying virtual trainings with room scale tracking in parallel in such groups would require significantly larger training facilities, due to large tracking areas and the requirement of obstacle-free walking spaces [7]. Besides this, an increased count of teachers or teaching assistants would be required to supervise the trainees as to prevent accidents. The current systems are not yet prepared to prevent two people wearing the head-mounted-displays to bump into each other. The alternatives would then be to train in turns, thus increasing session lengths. Or to form groups with only one trainee performing the training and the others overlooking or couching the performer. This problem becomes even more of an issue with increasing durations of training sessions. Thus room-scale tracking currently limits the adoption of VR trainings in educational domains, such as in the training of chemical operators, which is the domain addressed in the paper at hand. As an alternative to standing VR with room-scale tracking, stationary tracking can be combined with a seated VR experience. In our case, the participant is then seated on a stationary yet rotatable chair which allows free orientation changes but prevents the participant to change his/her location significantly. Recent work has addressed the issue of using mixed reality in seated conditions and tried to optimize usability [8]. This is in line with our own research in which we investigate ways to realize seated VR training simulations to allow for large group events.

The research reported here was conducted in the context of the EU Horizon 2020 CHARMING project which is looking to answer, as one of its research questions, how immersive technologies can support the chemical process industry to train employees [9].

Various studies have also explored procedural skills training using headset-based VR [10], [11]. These studies not only evaluated learning outcomes and knowledge retention but also presence, usability, cybersickness and acceptability of the VR technology among trainees [12], [13]. Thus a lot of research is focusing on evaluating different kinds of human factors but the systematic exploration of requirements is still missing in immersive virtual environments [14]. In this paper, a VR framework is also proposed based on Maslow's hierarchy of needs (MHN) [15]. It is used to systematically evaluate the VR training experience from basic needs. The first two levels (physiological and safety needs) are the initial focus of this pilot study, while the other levels will be explored in future studies.

Within a research project targeting the design and implementation of large-scale VR training applications, a prototype implementing both standing and seated VR has been created. The main characteristics of the experimented prototype are as follow:

- A full procedural training for making butyllithium that requires a huge virtual chemical plant (ideal to analyze our research). The content and standard operating procedure (SOP) is provided by the industrial partner Merck KGaA. The procedure consists of physical actions and also digital actions on a virtual computer control screen inside the VR simulation. The set and sequence of steps are the same as for the real chemical procedure.
- The VR training includes two realistic emergency scenarios related to trainee error or system failure. The user can freely decide to experience the emergency scenarios even if he/she has completed all actions correctly.
- The VR training includes all steps of a lengthy chemical procedure. The average duration of the experience is 68 min; therefore, users are allowed to take breaks (only if needed) between the steps and then resume.
- The training is designed to enable trainees to perform actions while standing or being seated. This is to analyze the difference between both conditions in pursuit of future VR training designs.

In this paper, a pilot study of seated and standing conditions of the VR training are studied and presented. The research is not investigating which condition is the best, but it is exploring, if both conditions have the potential to enable actions in VR while maintaining the MHN's physiological needs (good usability, comfort for the users) and safety needs (the practicality to deal with large space VR in small physical training areas). Therefore, the research questions we intend to answer here are:

- R1: Is there any significant difference in system usability between the two experimental conditions?
- R2: Are there differences in VR sickness across the seated and standing conditions?
- R3: Are there significant differences in user experience between the two experimental conditions?
- R4: Is there any performance difference during the training based on completion time and number of wrong attempts between seated and standing participants?
- R5: Are there qualitative insights that could inform improvements of the training for the larger study on differences in learning outcome?

The paper is divided into the following sections: Materials and Methods in which the MHN based framework, VR setup, training scenario and the implementation of VR prototype is described along with the experiment design for conducting the study. Next, the results from the pilot study are presented, followed by a discussion of the limitation, conclusion, and our future work.

II. Related Work

A recent study compared room-scale VR with seated VR in a virtual environment in which the room-scale version covered the full virtual environment and thus no teleportation was required [16]. The results are in favor of the standing room-scale VR setup. We are now addressing scenarios where the simulated environment is larger than the tracking space (e.g. virtual chemical plant) and thus a combination of teleportation for navigation and room-scale tracking for maneuvering is required, even in the standing VR condition. The locomotion thus is rather similar between the two scenarios and primarily the condition at the interaction spots is different. In another study addressing only 360° video content, it was found that the seated condition provided advantages regarding simulator sickness (to no surprise, as there was no locomotion involved) and slightly faster performance in a quality assessment task [17].

A. *Interaction Techniques for Seated VR*

The current state-of-the-art technique for locomotion in larger-than-tracking-space scenarios (lttss) is teleportation or steering-based control using thumb sticks or joysticks [7], [18]. These techniques, however, come with side-effects, such as reduced spatial cognition and an increased likelihood for cybersickness. Several alternative user interfaces for locomotion in seated conditions have been proposed in the past [7], [19]–[21]. The most recent approaches try to compensate some of the deficiencies and improve spatial cognition, as well as angle and distance estimation, which has been shown to be deprived in non-walking VR set-ups [22], [23]. In addition to the described problems regarding locomotion in VR, seated VR also comes with limitations regarding the reaching space and the ease of inspecting every part of the environment (e.g., due to restricted torso movements and a smaller overall interaction space). This has also been emphasized in prior work [16].

B. *Maslow's Hierarchy of Needs (MHN)*

Maslow's hierarchy of needs consists of a five-level model starting from bottom (physiological needs) to top level (self-actualization). It is a motivational theory that provides a layout of human needs in organized form [15]. Recently, MHN has been used to guide the design of VR environments for long immersive sessions, such as Mixed Reality (MR) office environments, to ensure that the first three levels of MHN are considered to satisfy human deficient needs [14]. Similarly, another MR system has been developed guided by all levels of the MHN model in order to perform chemical experiments [24]. Regarding performance and motivation, a recent review showed that MHN has made significant contributions in management and organization of employees [25].

III. Materials and Methods

A. *Hierarchy of Needs for VR Training*

Inspired from MHN, a framework for VR training is proposed to systematically identify the needs of humans training in a VR environment: In the proposed framework, we approached MHN from two different perspectives in order to fulfill the human needs in VR. On the one hand there are the general requirements regarding a VR system (which have to be met by hardware, operating system and VR software frameworks) and on the other hand the requirements specific to VR training are presented (see Fig. 1).

Our seated vs standing approach focuses on improving safety needs in MHN. To explore the potential of seated vs. standing experience, the basic/physiological needs should be evaluated first to ensure a general familiarity with the VR environment. In the real-world food, water, drink, warmth etc. are the physiological needs for survival. Similarly, usability (to survive a virtual world) and comfort (no simulator sickness) are the grounds to build up familiarity within VR environments. For safety needs, the very first thing is to avoid collisions with physical obstacles. For this, a large empty space is needed as we discussed in the introduction. That is why a seated condition is introduced to limit the playing area, to avoid the risk of injuries, to prevent sicknesses in long sessions and to scale down larger VR trainings in smaller physical spaces or allow for a scaling up in terms of parallel user sessions within a confined space at a time. But the question is whether the seated condition also meets the physiological needs and, if so, are there any differences to a standing VR experience? That is why, the first two levels are the main focus in this pilot study to explore the seated experience among safety, comfort and usability needs as compared to a standing approach. The other three levels will be organized and evaluated accordingly in the future, once any issues or side effects of a seated VR have been clarified, as any problems of seated VR should not interfere with higher level requirements.

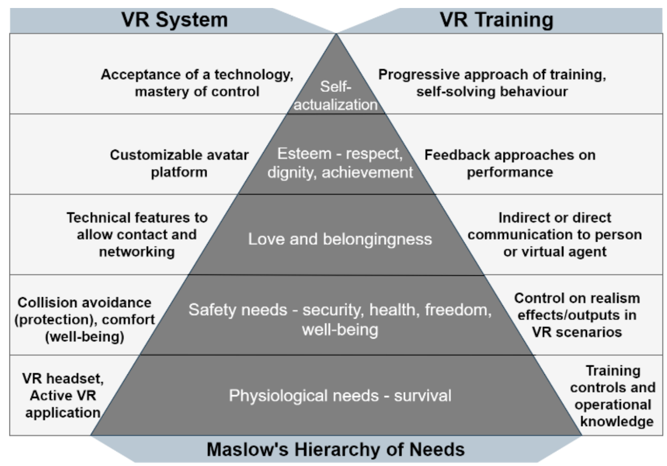

Fig. 1. Conceptual framework of requirements for VR trainings based on the MHN pyramid.

B. *"Operate Your Own Reactor" – VR Setup*

A VR prototype named 'Operate your own reactor' has been developed for the training of chemical operators. As the name indicates the prototype is designed around the operation of a chemical reactor inside a VR environment. The prototype consists of 3 floors in which a 3D reactor setup is placed as shown in Fig. 2. Every floor has certain kinds of equipment to do respective tasks. The content requirements are taken from industrial partners to ensure authenticity.

1) Training scenario: The prototype begins with an introduction scene as shown in Fig. 3. On the left of the scene, there is a short description of the required VR interactions to interact with the environment. In the middle of the scene, there is a main menu to navigate the user to the main training environment. It gives the user the option to start a new simulation or resume the simulation from where the user left. The simulation is divided into four phases starting from Preparation, Setup, Reaction to Extraction (see Fig. 5). Each phase is accessible after the completion of the previous phase.

The training objective is to carry out the procedure for making butyllithium (BuLi). The procedure is a real method of making BuLi. There is no deduction or modification in order to shorten the scenario. Thus, the prototype consists of four main tasks and 24 sub-tasks in total. Completing the standard procedure takes around 50-60 min and the duration of the two emergency scenarios is approximately 2 min in total. The emergency scenarios come in between the sub-tasks and users have the option to handle or skip these situations. The emergency procedures show the consequence of incorrect procedural decisions by the user and a system failure.

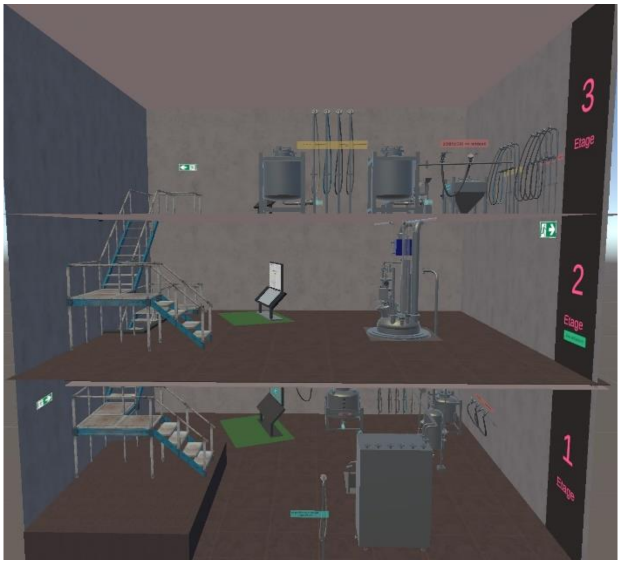

Fig. 2. VR environment of the training prototype for the production of butyllithium (scaled side view) in a 3-level chemical plant. Participants experience the environment in natural scales using an HMD.

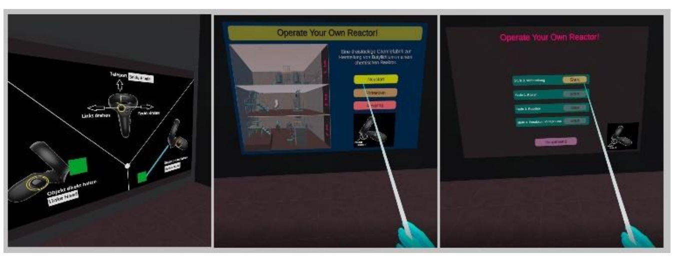

Fig. 3. Introduction scene of the main menu in VR prototype.

Fig. 4. Computer control screens inside VR environment, larger than live due to readability issues with current consumer HMDs.

There are two types of interactions in the prototype. The first is the simulated physical interaction with the instruments and the VR environment. The second is the digital control of the reactor via a computer screen inside the VR chemical plant. There are two digital computer screens (Fig. 4): one is the main screen which triggers tasks, and the second screen is a procedure board which shows procedural steps. These steps include both physical and digital tasks according to the procedure. This design is in line with what is found in the chemical plants of the industrial partner. There is also guidance on the left side of the procedure board to support trainees with the use of the VR controllers and task execution.

Thus, the prototype is a VR experience of procedural skills training to operate a chemical reactor. Not only to perform physical actions but also to learn digital aspects connected to the chemical procedure along with emergency scenarios. The layout of a prototype with the procedural tasks and emergency scenarios is described in Fig. 5.

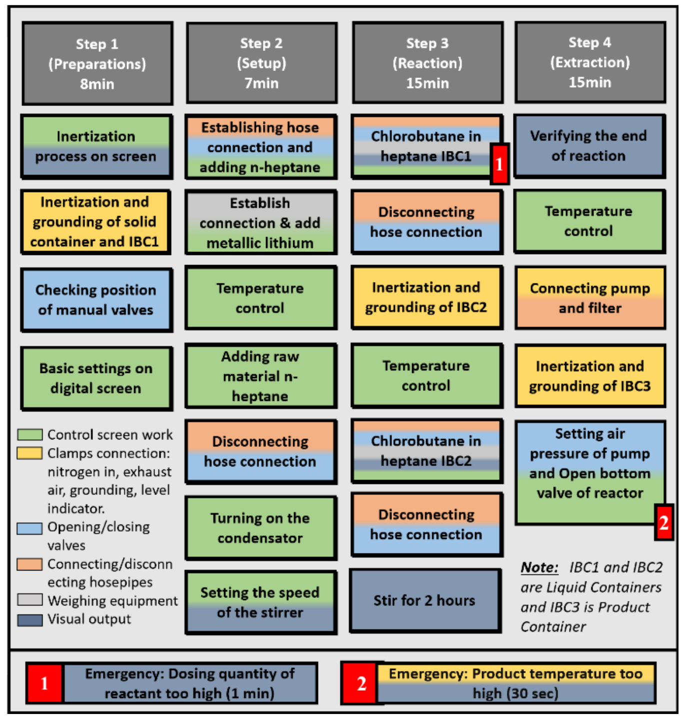

Fig. 5. Procedural layout of the VR prototype.

Fig. 6. Emergency scenario in the VR prototype.

There are two emergency scenarios to enable users to see the consequences of their wrong choices: 1) Product temperature too high: The product container is filled at a temperature higher than 40°C. The container loses its integrity, and the situation slowly moves towards spillage and fire. The user gets a chance to fix this situation. 2) Dosing quantity reactant BuCl too high: Increases in pressure and temperature cause a boiling of liquids inside the pipes and reactor. This eventually causes fire and an explosion as shown in Fig. 6. There is no way of avoiding this explosion and the user will see the result in VR.

2) Implementation of VR prototype: The current prototype is implemented in Unity3D along with XR interaction toolkit for enabling VR interactions. The XR-Rig from the XR interaction toolkit is used for adjusting the camera offset regarding seated and standing views. The 3D models of the chemical equipment were obtained from the industrial partner. They are modified and enhanced through Cinema 4D and Blender. The prototype is usable with any consumer VR headset. In this pilot study, the Oculus Quest 2 is used for a wireless VR experience. The language of the prototype is in both German and English. The German version was used in this study matching the native language of participants.

C. Seated vs Standing Conditions

The study consisted of two conditions (seated or standing) within the wide play-area of 12x12 ft (still 3 times smaller than one floor of the virtual chemical plant implemented in the VR prototype). Thus, both conditions make use of teleportation for locomotion. The free style of teleportation is used in both conditions. Besides, both have the options of direct grab and distance grab (grabbing the object from distance through ray-casting using the right-hand controller). Participants in the standing condition completed the VR training in standing posture while those in the seating condition completed the experience while seated on the rotatable office chair (Fig. 7).

Fig. 7. Seated (left) vs Standing (right) VR experience.

D. Experimental design

1) Participants: The study included 32 participants from the chemical company Merck KGaA, 9.4% of the participants were female. The age of the participants was in the range of 20-60 years old (M=45 years, SD=10.8 years). 90% of the participants reported that they were familiar with the concept of virtual reality, and approx. 60% reported that they have used virtual reality at least one time prior to the study. The participants were divided into two groups of 16 participants each: “seated” and “standing”. When selecting the participants for the study, a diverse group in terms of knowledge and experience was acquired to help minimizing the risk of bias in the feedback provided on the prototype. Six participants were part of the apprenticeship program (trainers and managers), nine were from the plants that the VR models are based on (including plant managers, plant assistant, and chemical operators), four were representatives of the Health and Safety department, two were from the fire protection team (trainers), five were from the team of process development and plant engineering, and six from the digital engineering team and engineering services. Besides, no money incentive was offered to the participants. Regarding ethical aspects, all participants received detailed information on the research aims and the expectations of the study and signed a consensus form before their participation. They were informed of the freedom of leaving the research experience at any moment. All the information was provided in German. The instruments used, and the virtual reality testing itself received ethical approval, data privacy and legal compliance approval from Merck KGaA, Darmstadt, Germany. The related university also agreed to ethical approval as long as it is authorized by the company where the evaluation has taken place.

2) Data Collection: The following data is recorded inside the headset during the VR training in the form of system logs: 1) Date/Time when VR session starts and ends. From here, duration of the training is estimated. 2) Number of wrong attempts by the participant while performing the procedure. Based upon which the performance is calculated. 3) Number of breaks a participant took while doing the VR experience. After finishing each phase (total four phases), the system lets users opt to take a pause or to continue.

3) Evaluation methods: After the participants finished the VR procedure, they were asked to complete four questionnaires. Questionnaire #1: “System Usability Scale” (SUS). The SUS is composed of 10 questions which were developed based on the usability criteria defined by the ISO 9241-11 (e.g., effectiveness, efficiency, learnability, and satisfaction) with five response options ranging from strongly disagree to strongly agree [26]. Questionnaire #2: “User Experience Questionnaire” (UEQ). It measures six usability aspects: attractiveness, perspicuity, efficiency, dependability, stimulation, novelty. Each aspect consists of 4 to 6 items. Thus, there are a total of 26 items that a user needed to answer. Each item is presented in the form of a pair of words with opposite meanings. It is rated on a 7-point Likert scale. Answers to each item range from -3 (agree with negative word) to +3 (agree with positive word) [27], [28]. Questionnaire #3: “Virtual Reality Sickness Questionnaire” (VRSQ). It is a subcategory of the simulator sickness questionnaire (SSQ) especially designed for headset-based VR environments. It measures motion sickness of the VR system based on two components: oculomotor and disorientation. The nine items or symptoms of VR sickness (divided into oculomotor and disorientation) are presented, and each item can be scored between 0 to 3 (0=none, 1=slight, 2=moderate, 3=severe). Based upon the scores, sickness is calculated by the VRSQ formula. [29]. Questionnaire #4: “Feedback”. This questionnaire elicited feedback from the participants about the accuracy of the procedure and their experience using the VR headset and controllers. It consisted of a 5 point-Likert scale with statements concerning the accuracy of content as well as VR usability. It also included an open question where users could provide more specific feedback. The researchers also took notes about experience and observations in this stage. The participants were given the option of answering the questionnaires online or on paper. In addition, participants were encouraged to talk-aloud during the experience to collect qualitative feedback, note any issues, suggestions, or mistakes (feedback points). All this feedback was collected by the researchers.

E. Environment Setup

For each participant 90 minutes were allocated in the schedule. This time included the VR experience and the completion of questionnaires. Participants were also able to complete the questionnaires on their own time, which was provided as an option due to the potentially demanding nature of the lengthy experience.

As the study was conducted during the months of April and May 2021, Covid19-VR research protocol was followed [30], keeping participants and researchers safe. An email with the schedule of the day and recommendations to follow was send in advance. There was no overlap of participant sessions. The researchers were tested for Covid19 every morning and the participants also had the option to be tested. A minimum distance of 1.5m was ensured between participant and researchers. The participants that opted to answer the questionnaires online were emailed the link for doing so, while those who opted to complete the questionnaires on paper moved to a separate room.

IV. Results and Discussion

In this section, the results are presented along with the discussion in order to seek the answers for the research questions of this study.

A. System Usability Scale (SUS)

In this study, a quantitative analysis of the usability of VR training while sitting and standing was carried out using a SUS scale. The SUS score typically ranges from 0 to 100. According to Lewis and Sauro [31], a SUS score above 68 is considered average while SUS score above 80 is considered above average. An open source SUS toolkit [32] is used here to analyze and present our findings. As observed in Fig. 8, the average SUS scores for seated and standing participants were 80 and 76.41, respectively. This shows a general acceptance and usefulness of both conditions as majority of the individual SUS scores were in the region of good and excellent.

To examine the significant differences between two interested groups, independent two sample t-test (parametric) and Mann-Whitney U test (non-parametric) can be used [33]. Upon checking the normality of the data in SPSS using the Shapiro-Wilk tests, it was revealed that the p-value for seated subpopulation is less than <0.05 (TABLE I). Hence it is not normally distributed, thus, the non-parametric Mann-Whitney U test was used through SPSS (from IBM SPSS statistics) software.

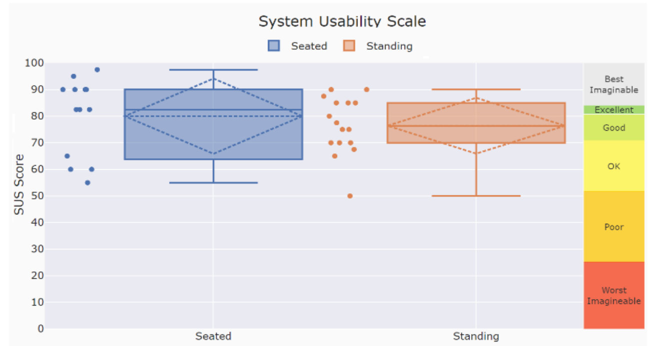

Fig. 8. System Usability Scale results, seated and standing version.

TABLE I. Normality Test Based on SUS Scores

	Shapiro-Wilk			
SUS Score	***Groups***	***Statistic***	***df***	***p-value***
	Standing	0.927	16	0.222
	Seated	0.855	13	0.033

TABLE II. Comparison between Groups Based on SUS Scores

Ranks				Test Statistics		
Groups	***N***	***Mean Rank***	***Sum of Ranks***	***Mann Whitney U***	***Z***	***P***
Standing	16	13.59	217.50	81.50	-0.99	0.33
Seated	13	16.73	217.50			
Total	29					

As shown in TABLE II, there are no statistically significant differences (p-value ≥ 0.05) between the groups according to Mann-Whitney U test. It is still important to take into account these conditions as there are definite group differences in terms of the degree of importance of each SUS item/construct among each subpopulation (Fig. 9). For instance, the average SUS scores for the construct’s “inconsistency” (Q7), “awkward to use” (Q8), and “need to learn a lot before use” (Q10) were lower for the seated participants as compared to standing participants. This means that it is important for the next prototype to carefully check these factors (detailed discussion in later section) in order to get higher SUS scores if the future prototype is intended to include seated use.

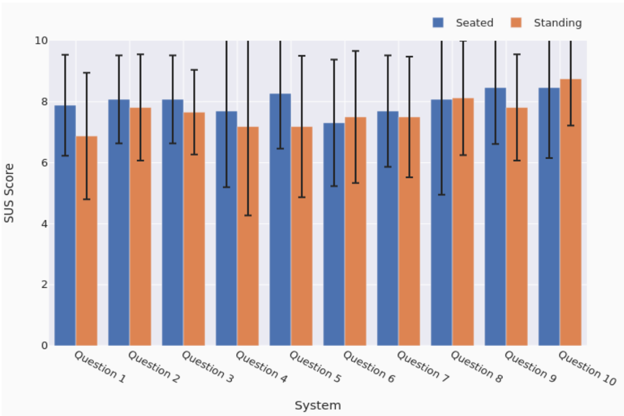

Fig. 1. Average SUS score per item of seated and standing version (Q1: use frequently, Q2: complex, Q3: easy, Q4: need support, Q5: well-integrated, Q6: inconsistency, Q7: learn quickly, Q8: cumbersome, Q9: confident to use, Q10: need to learn a lot to use).

B. *Virtual Reality Sickness (VRSQ)*

The sickness questionnaire is filled out after the testing to report any kind of discomfort that might have occurred during the simulation as suggested by VRSQ [29] and followed by others [34]. 25 out of 32 participants have handed over the VRSQ questionnaires. This is because some participants opted to answer the questionnaires via email link and did not reply. There was no sickness verbally reported by the participants and all participants successfully completed the procedure. The mean sickness scores were 10.69 and 9.68 out of 100 for standing and seated group, respectively, as shown in TABLE III.

TABLE III. SICKNESS SCORES FOR SEATED VS STANDING

VRSQ Scores		**Mean**	**Std Dev**	**Min – Max**
Oculomotor	Standing	15.28	10.67	0.0 – 33.33
	Seated	14.74	12.72	0.0 – 33.33
Disorientation	Standing	6.11	5.06	0.0 – 13.33
	Seated	4.61	4.81	0.0 – 13.33
Total	Standing	10.69	7,59	0.0 – 23.33
	Seated	9.68	8.49	0.0 – 23.33

TABLE IV. TWO SAMPLES- T-TEST

t-test for Equality of Means for VRSQ Scores					
Equal Variances	***Sig. 2-tailed***	***Mean Diff***	***Std. Error Diff***	***95% Confidence Interval Difference***	
				Lower	***Upper***
assumed	.766	1.015	3.368	-5.953	7.983
not assumed	.765	1.014	3.353	-5.922	7.952

Upon checking the normality of the data in SPSS using the Shapiro-Wilk tests, p values (Sig.) for both standing (n=13, Sig = 0.27) and seated (n=12, Sig = 0.09) conditions are greater than 0.05. Hence the distribution of the data are normally distributed and the 2-sample independent t-test must be used. From Levene's test for equality of variances, p-value(Sig = 0.505) is greater than 0.05. So the variances are equal. From t-test as shown in TABLE IV, the p-value (Sig = 0.766) is greater than 0.05, it can be assumed that there is no significant difference between the groups of standing and seated participants for sickness scores.

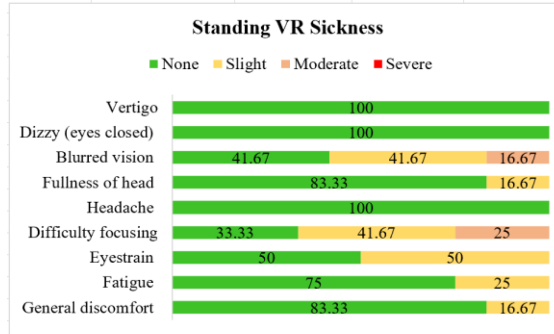

Fig. 10. Percentage distribution of the symptoms of VRSQ – standing version.

In Fig. 10 and Fig. 11, the symptoms of VR sickness are also presented individually to see where the prototype needs improvement. These symptoms are the 9 items of the VRSQ questionnaire that participants scored from 0-3 (none-severe). The most reported symptom for both seated and standing is "difficult focusing". For the standing version, the other symptom was blurred vision and for seated condition, fatigue was highlighted. Although the percentages of these symptoms as compared to number of participants are not high, it gives us the idea to some extent for future improvements.

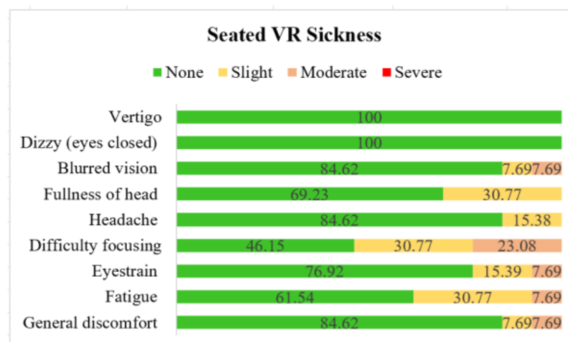

Fig. 11. Percentage distribution of the symptoms of VRSQ – seated version.

C. *User Experience (UEQ)*

In Fig. 12, the six usability aspects are presented. For both groups and in all the aspects, the opinion of the participants resulted in a positive (values > 0.8) evaluation of the training environments.

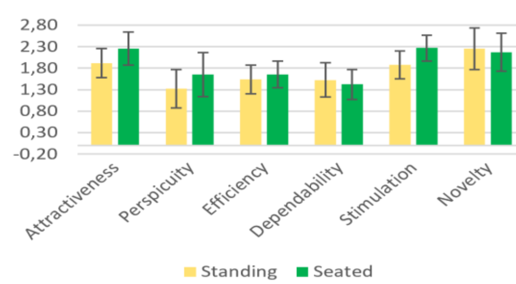

Fig. 12. Comparison of scale means for the User Experience Questionnaire (UEQ) for group Standing (n=14) and group Seated (n=13)

By checking the normality of the data in SPSS using the Shapiro-Wilk tests, p-value (Sig.) for both conditions are greater than 0.05 for the first five constructs of UEQ. So the data for the first five constructs were normally distributed. Thus, 2-sample independent t-test must be used. On the other hand, the p-values for the construct "novelty" for both groups were less than 0.05. Thus, the Mann-Whitney U test mut be used for "novelty" data.

From Levene's test, it was found out that the p-values were 0.829, 0.726, 0.680, 0.525, and 0.999 for the constructs attractiveness, perspicuity, efficiency, dependability, and stimulation, respectively. Since the p-values for the Levene's test for these constructs were greater than 0.05, it can be concluded that the variances are equal. Thus using 2-sample independent t-test, it was found out that the p-values between seated and standing participants in terms of the attractiveness, perspicuity, efficiency, dependability, and stimulation were 0.207, 0.345, 0.619, 0.714, and 0.094, respectively. Since these p-values for the t-test were greater than 0.05, it can be concluded that there are no statistically significant differences between the groups in terms of these five constructs. This means that the impression of the users in terms of attractiveness (i.e., overall impression of the product), perspicuity (i.e., easiness to get familiar with the product), efficiency (i.e., solving problem without unnecessary effort), dependability (i.e., feeling of in control of the interaction), and stimulation (i.e., excitement and degree of motivation to use the product) were the same regardless of the group (standing or seated) as that the mean values for the abovementioned constructs were close to each other (shown in Fig. 12).

On the other hand, upon checking the p-value using the Mann-Whitney U test as shown in TABLE V, it was found out that the p-value in terms of the construct novelty was 0.720 between seated and standing participants. Since the calculated p-value was greater than 0.05, it can be concluded that there are no statistically significant differences between the seated and standing groups. This means that the impression of the users in terms of novelty (i.e., creativeness of the design of the product), were the same regardless of the group since the mean values for the construct novelty for both standing and seated groups were close to each other (shown in Fig. 12).

TABLE V. MANN-WHITNEY U TEST FOR NOVELTY IN UEQ

Ranks				**Test Statistics**			
Groups	***N***	***Mean Rank***	***Sum of Ranks***	***Mann Whitney U***	***Z***	***W***	***Sig.***
Stand	14	14.6	204	83.0	-0.39	174	0.72
Seat	13	13.4	174				
Total	27						

D. *Quantitative Performance*

The VR prototype recorded the number of wrong attempts and time duration of each participant in its system log. Given that the completion/engaged time (i.e., the time spent by the trainees to complete the entire VR training) and the number of wrong attempts (i.e., the number of mistake(s) committed by the trainees during the VR training) were commonly used metrics for assessment in digital-based simulations/games, the abovementioned metrics were used as the main metrics for recognizing the performance and behavior of the trainees for this study [35].

Besides, the willingness of seeing emergency scenarios is also considered. From 32 participants, everyone has opted for at least one emergency scenario. Only five participants (4 standing and 1 seated) have opted for one scenario. While others have chosen both scenarios. The total time is thus not significantly affected, as both scenarios are of 1-2 minutes altogether. Interestingly, everyone has shown interest to experience the emergency scenarios even in the long VR simulation. Upon checking the normality of the completion time data using the Shapiro-Wilk tests in SPSS, it was found out that the p-values for standing and seated subgroups were 0.999 and 0.768. As they were greater than 0.05, thus, 2-sample independent t-test must be used. On the other hand, the p-values for standing and seated based on the number of wrong attempts were 0.023 and 0.611 which is less than 0.05, thus, Mann-Whitney U test must be used.

After checking the p-value using the 2-sample independent t-test assuming equal variance, it was found that the p-value between seated and standing participants based on the completion time was 0.890. Moreover, it was found from the Mann-Whitney U test that the p-value between seated and standing participants based on the number of mistakes was 0.911. Since the p-values for both tests were greater than 0.05, it can be concluded that there are no statistically significant differences between the groups. As the average completion time as well as number of mistakes across the two groups were relatively the same (68 minutes and 6 mistakes for standing group and 69 minutes and 7 mistakes for seated group), it can be generalized that the performance of the trainees does not affect whether the participant is seated or standing. This means that regardless of the posture/orientation (e.g., standing or sitting), their completion time as well as the number of mistakes will not change as long as they are comfortable and able to focus on their current tasks.

E. *Qualitative Feedback*

Written feedback was collected using "Questionnaire #4: Feedback", and verbal feedback was collected by the experimenters who took notes of comments made by participants during their use of the prototype.

The responses obtained from the feedback correlated with the comments collected during the VR testing and experience. Regarding the virtual reality usage, it was reported several times (Fig. 13), that the participants have issues learning to use the VR controllers and grabbing objects (Statement C – VR). Another issue reported several times during the test was the difficulty to read the control screen (Fig. 4), this is reflected as well in the statement A-VR "easy to read on computer screens", where 28% of the participants disagree with it. For the rest of the statements, positive response was reported, with high proportions of Agree and Strongly disagree statements. Finally, statement F – VR: "I think a tutorial on how to use VR controllers should be included" somehow shows equivalent proportions for agree and disagree.

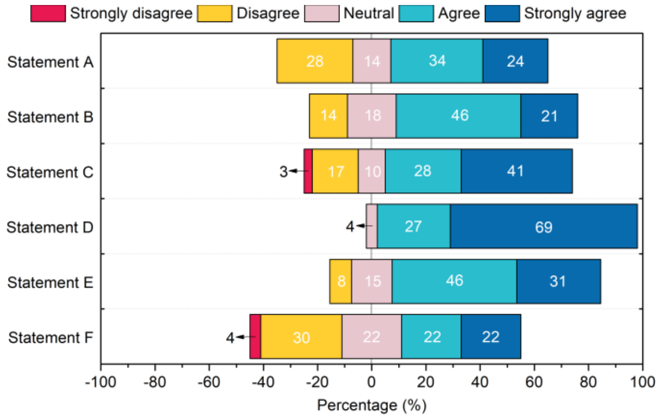

Fig. 13. Feedback participants (n=29) regarding virtual reality usage. Statement A - VR: The text was easy to read on computer screens; Statement B - VR: It was easy to interact on computer screens; Statement C - VR: It was easy to grab objects; Statement D - VR4: It was easy to teleport anywhere; Statement E - VR5: I easily understood the buttons for grab, click and teleport in VR; Statement F - VR6: I think a tutorial on how to use VR controllers should be included.

The other thing noticed by the experimenter is that for the seated version, users moved their chairs or stretched a lot to grab or touch something inside the VR. They subconsciously moved chairs instead of using teleportation when they perceived objects nearer (but not in reaching distance). Although it still produced good results regarding usability and cybersickness, an explicit design (position of objects and teleportation guidance) for seated posture could help to create a more comfortable experience and avoid chair movements.

V. Limitations

In this pilot study, we did not focus on evaluating learning outcomes or knowledge gain and therefore provided support throughout the training. Users could ask freely anything during the procedure and receive verbal support in response. The reason this additional support was offered relates to the need for all users to successfully perform all tasks inside the VR so that they could provide feedback on the system usability and sickness (MHN needs for VR). The other thing is for the seated version, the same interface and interaction training design was used as in the standing version. This sometimes caused users to move their chairs or stretch a lot to grab or touch something inside the VR instead of using teleportation.

VI. Conclusion

In this paper, the seated and standing VR experiences are studied in the form of long procedural training i.e., for the operation of chemical reactor inside a virtual chemical plant. The presented findings are in contrast to prior work [16], which will be detailed in the following. One particular finding is, that in the presented study users found both conditions to be useful and valid for the training, with no visible advantage for the condition with room-scale tracking, as opposed to the findings in [16].

The results of system usability for seated and standing participants were 80 and 76.41 out of 100, respectively. However, there was no statistically significant difference in the group comparison. The study also shows low levels of symptoms from VR sickness. The results were 9.68 and 10.69 out of 100 for seated and standing conditions with no significant difference between the groups. Few common symptoms of sickness were difficult focusing and blurred vision. This could lead us to the reported feedback about difficulty in reading small text on the computer control screen inside the VR. Regarding aspects of user experience, both groups (seated and standing) are positive (values > 0.8) and there is also no significant difference between the conditions. From system logs, the average completion time as well as number of mistakes across the two groups were captured (68 minutes and 6 mistakes for standing group and 69 minutes and 7 mistakes for seated group). The results from current setup shows that regardless of the posture/orientation (e.g., standing or sitting), the completion time as well as the number of mistake(s) will not change as long as trainees are comfortable and able to focus on their current task(s).

Coming back to the comparison with prior work [16], the study has revealed no difference in usability or simulator sickness between the two conditions. However, the individual participants in the presented study had no direct comparison, due to the between-subjects design, while the within-subjects design of the prior work enabled participants to directly compare the two different setups. So, it might well be that there are detectable differences and preferences of users, which, however, might not have an impact on the overall usefulness and applicability of the training and thus might not contradict the use of seated VR in classroom settings. This is an important finding as it could pave the way for large scale implementations of VR trainings in educational settings.

Thus, from the results of this pilot study, it can be assumed that the seated condition has the potential to enable procedural actions in VR while preserving the MHN's physiological needs (good usability, comfort for the users) and safety needs (the practicality to deal with large space VR in small physical training areas). Besides, the qualitative feedback would help us further in enhancing both of these levels of MHN's model (based upon which our framework is proposed). For example, the design guidelines that should be followed when transforming room-scale VR trainings (or similarly real-world room-scale activities) into seated VR trainings. Some users in the seated condition moved their chairs instead of using teleportation when trying to reach nearby objects. A proper seated condition should thus be designed more carefully, so that all actions can be conducted without the relocation of the chair or requiring the user to stand up. This would be interesting to examine in the future. First ideas include guided teleportation styles that could be explored in the form of foot marks or snapped teleporting to allow seated users to find their perfect position around the objects while seated (especially in procedural trainings where physical tasks are present).

What remains to be tested is whether seated VR has an effect on the important aspects of presence and learning outcome. For this, a study with a larger sample size (n>100) is underway. Besides, the other levels of our proposed framework (based on MHN) will be explored to systematically approach the human needs for VR trainings.

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