User individual characteristics and perceived usability in immersive HMD VR: A mixed method explorative study

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Abstract. The association between personality and individual tendency for adopting and optimally interfacing with new technologies has often been proposed in the literature. However, only few published studies report experimental data. This study aims to provide evidence on the association between several individual variables and usability experience in modern immersive visual technologies. Our results are inconclusive regarding a relationship between participants' personality and experienced sense of presence with perceived usability. The severity of the simulator sickness symptoms during the virtual experience is showed to be negatively associated with reported system usability. However, due to the small sample size and the number of variables examined, our results have only an explorative value. Qualitative analyses show that, despite positive attitude towards the use of VR for training, the ergonomic limitations of the VR headset and the suboptimal realism of the simulated scene were reported by the participants.

Keywords: Usability · Virtual Reality · Personality · Presence · Simulator Sickness · HMD

1 Introduction

Usability has been defined as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [1]. Understanding and measuring usability is important for evaluating how well human cognition and technological systems are compatible [2]. Highly usable systems improve user performance and the overall user quality of experience [3,4]. Usability can be measured to determine how a certain product is designed to meet the needs of the users for whom the product is intended. Furthermore, measuring usability is important to ensure that new systems and interfaces are appropriate for the physical and cognitive limitations of the human users.
It is crucial that individual user characteristics that may be associated with perceived usability are well understood. Discovering these associations may have important consequences in both commercialization of the systems and scientific research. This aspect

is particularly important for the study of modern consumer-oriented virtual reality systems, which are nowadays being increasingly adopted by the public.

1.1 User individual factors possibly affecting usability

Users tend to rate the level of usability of the same system in very different ways: while someone may find a product easy to use and purposeful, others may find the exact same product difficult to handle. These differences regarding usability have sometimes been attributed to user individual differences. Individual differences are often described in the context of psychological research as traits and characteristics that make individuals distinguishable. User's personality rating has been proposed as one of the factors that may explain user perception differences in usability [2]. Personality has been shown to be a good predictor of a number of domains and is extensively used in the context of work environment [5]. Personality traits are shown to be predictive of learning style and academic success of pupils [6]. Personality has also been extensively studied as a predictor for an individual personal characteristic such as intelligence [7], political views [8], and wellbeing [9].
Researchers in the field of human-computer interaction argue that it is important to study the relationship between a variety of individual factors in the assessment of system interfaces [10]. Some lines of evidence show that user personality shapes the modality in which a technology is used [11] and the way in which a technology is accepted [12]. Earlier studies show the effect of personality on user rate of specific interface elements as menu characteristics [13] or have focused only on user satisfaction [14]. A personality trait in the context of psychology is defined as "a relatively stable, consistent, and enduring internal characteristic that is inferred from a pattern of behaviors, attitudes, feelings, and habits in the individual" [15]. Currently, only few empirical studies have assessed the impact of personality on subjective assessment of general systems usability [2]. A previous study has explored the effect of personality in shaping usability in several technological systems computers, tv remote controls, as well as computer softwares [2]. The reported results suggest that personality traits correlate with the rated usability of products and that openness to experience and agreeableness shows the strongest positive correlation with the rated usability. However, in their published work, the researchers did not assess how personality may affect usability perception of immersive visual technologies.
Usability of immersive VR systems has been studied in relationship with other factors affecting human experience while immersed in the virtual worlds. One of these is the experienced sense of presence [16]. Sense of presence has often been assessed with questionnaires, behavioral, and physiological measures (for a review see Grassini & Laumann, 2020) [17]. A positive association between sense of presence and perceived usability was reported in a recent study [18]. Several studies interpret the association of presence in usability as a direct effect of presence [19]. However, it has as well been claimed that usability could affect presence as an increased effectiveness, efficiency, and satisfaction experienced by the user while operating the system [20]. A further factor often mentioned in the context of quality of experience of modern immersive VR systems is simulator sickness (SS; also referred – with some differences - as cybersickness)[21]. SS is the feeling of discomfort that some users experience during a VR experience [22]. SS and presence have often shown a negative association [23,24,17]. SS

can be assessed through questionnaires (e.g. the SSQ [22]), and often reported symptoms range from nausea to headache and sweating. Scientific literature has previously reported a negative association between only some aspects of SS and perceived system usability [25,26]. Moreover, user feedback scores of a driver simulator are shown to be a good predictor of the degree of SS experienced by users [27]. Taking into consideration the good predictive value of personality scores in other domains, as well as encouraging published literature [2], it is likely that personality traits may be associated with the perceived level of usability of modern immersive visual technologies as well. Furthermore, sense of presence and SS experienced during the immersive virtual experience may be associated with the perceived usability of the system. In the context of a quick technological adoption of modern consumer-oriented virtual reality systems as the head-mounted-display (HMDs), it is important to understand which type of users may best fit and be willing to adopt the systems, especially when those systems are used for educational, training, and work purposes. Due to the small sample size employed in the present study, and the possible small effect sizes of the phenomena investigated, quantitative statistical analysis should be interpreted as explorative.

2. Method

2.1. Participants and equipment

Sixteen participants took part in the experiment (two males). The age of the participants ranged from 23 to 30 years (M = 25.81, SD = 2.34). The participants were recruited from among the student population at the Norwegian University of Science and Technology (campus Trondheim, Norway), and they participated voluntarily. The study was notified to the Norwegian Centre for Research Data (NSD) and was approved prior to the beginning of the experimental work.

The experiment was performed using a consumer-oriented HMD equipment. The equipment used was an HTC-Vive Pro, featuring a 2,880 × 1,600 pixels resolution, two wall-mounted sensors, and two controllers.

2.2 Experimental task

The participants were asked to interact with a virtual scene for a duration of ten minutes. The virtual scene featured a realistic workshop background and a table on which plastic-like building blocks were placed. Included in the virtual environment were instructions on how to build a toy airplane made of smaller blocks (both displaying an image of the item correctly assembled and displaying an instruction sheet). The participants were asked to train in a block-building task, using the HMD device and to learn the procedure of building the item as described in the displayed instructions.

2.3 Questionnaires

Participants were asked to answer paper-and-pencil questionnaires before and after the experiment. Before the start of the experiment, the participants completed the Neuroticism-Extraversion-Openness Five-Factor Inventory in its Norwegian validated translation (NEO-FFI; Martinsen, Nordvik, & Østbø, 2005) [28]. Permission from the copyright holder was obtained (Hogrefe Verlag GmbH & Co., Göttingen, Germany). The NEO-FFI (for the validation of the English version see McCrae & Costa Jr., 2004[29]) is a 60-items questionnaire used to assess personality traits. This inventory examines the big five personality traits, and each of the questionnaire items needs to be answer

on a 5-point scale. The SS Questionnaire (SSQ, Kennedy et al., 1993 [22]) was used to assess the SS level. It contains 16 items divided into three subscales based on the type of symptoms (nausea, oculomotor, and disorientation subscales). For each item, the participant rates the severity of the experienced symptoms via a 4-point scale (1 for none, 4 for severe). Th SSQ was administered before and after the experiment, as proposed and discussed in previous studies [22, 30, 31]. The total SSQ score was obtained by subtracting the total SSQ score as reported before the experiment from the total SSQ score as reported after the experiment. The total SSQ score was calculated according to guidelines [22]. The Presence Questionnaire (PQ, Witmer and Singer, 1998) [32], was used to investigate the sense of presence. The version of PQ questionnaire used in the present study consists of 24 items (Witmer & Singer, Vs. 3.0, Nov. 1994; Revised by the UQO Cyberpsychology Lab 2004) [33], on a Likert scale ranging from 1 (Not compelling) to 7 (Very compelling). The degree of perceived usability of the virtual-reality systems was measured with an adaptation of the System Usability Scale (SUS), which was developed by our lab specifically for this experiment. Similar to other version of the SUS, this scale uses a 5-point scale, with response rating ranging from Strongly Disagree to Strongly Agree. The items of the questionnaire were both positively and negatively worded to moderate responders' biases [34] and to limit the possibility for blind raters [35]. A final score was calculated with a singular numeric score for each participant, possibly ranging from 0 (worst usability) to 100 (best usability).
An open-ended questionnaire was also given to the participants after the experimental session. It included six questions about the participants' experience of the VR training, how they felt, what they liked or did not like, and their perceived advantages and disadvantages in comparison to the real-life task performance.

2.4 Analyses

Quantitative data was analyzed using IBM SPSS v.26. Two-tailed Pearson correlations were performed to understand the relationship between usability and the other variables of interests. Distinct correlation analyses instead of regression analyses were chosen as several of the explanatory variables (e.g., personality traits) correlate between each other (multicollinearity), and therefore it would be difficult to isolate their individual effects from the dependent variable (usability). The answers to the open-ended questions were analyzed using thematic analysis wherein text was coded into themes and subthemes using the guidance of Braun and Clarke, 2006 [36].

3. Results

3.1 Quantitative data

Descriptive statistics suggest that the system was perceived as well usable (min = 52.50, max = 90, mean = 72.13, SD = 10.80 – good usability level [37]. Table 1 reports the correlation scores of the usability score × personality scores, presence, and SS. Only the correlation between SS and usability was statistically significant (p = .036).

Table 1. Personality scores and usability correlation coefficients calculated using Pearson's correlations.

	P-N	P-E	P-O	P-A	P-C	Pre	SS
Usability	-.341	.062	-.411	-.217	.266	.212	-.527*

**p < 0.05.*
P: Personality, N: Neuroticism, E: Extraversion, O: Openness, A: Agreeableness.
Pre: Presence, SS: Simulator sickness.

3.2 Qualitative data

The analysis of the 15 open ended questionnaires revealed two major themes, positive outlook towards the use of VR for training and the ergonomic limitations and suboptimal realism. The majority of the participants were quite positive towards the use of VR for training, and they perceived it to be useful in preparing them for task performance in the real life. They felt excited, amused, and engaged during the VR training. This was mainly mentioned to be due to the novelty of this medium. It was evaluated to be an effective medium for training. It was mentioned to help remember the task for real-life execution. One could practice all the steps and could see the building pieces in a larger size and from various angles. Nevertheless, three participants indicate that they felt disoriented and needed time to get used to VR environment and the moving of hands and head before being able to focus on the task. One person reported feeling nauseous. However, another theme was the suboptimal ergonomic features that made the VR training less realistic. The sizes of the building pieces were not comparable to real life. The grip and control of the hands were not realistic, and they were slower than in real life. The images quality was reported to be not optimal and at times blurry. In general, VR training was perceived to be useful but not quite realistic, and it was only less stressful than the real-life task performance because the participants were not under time pressure to finish their task.

4. Discussion

The present article represents an explorative attempt to understand possible associations between several users' subjective factors and users reported system usability in the context of modern, costumer-oriented virtual reality devices (HDMs).

According to the results described in Kortum &Oswald [2], the usability score reported in our sample is in line (+- 3 average points) with the one reported for a digital video recorder (DVR), a navigation system, the Nintendo Wii (game console), an android telephone, a television remote control, and Turbotax (computer software). This confirm that, in general, the users perceive modern HMDs VR as well usable. However, the high level of usability reported for the system may be in part due to the specific sample of participants of our study: generally, young university students may have already been exposed to similar technologies in the past and, therefore, may have adapted to it. Therefore, our reported mean usability score is unlikely to be generalizable and to represent the general adult population. Quantitative data suggest that a negative association exists between the reported usability score and perceived sense of discomfort during the VR experience. The relationship between SS and usability is likely: A user that perceives a higher sense of discomfort during the use of a system may well experience more problems in utilizing such system. At the same time, an opposite direction for the relationship may also be true: A user that perceives a system as little usable may tend to experience more general sense of discomfort compared to a user that has a better command over the system. SS has been already discussed as a user factor that may possibly influence usability; nevertheless, the published experiential lines of evidence are somewhat scarce [26]. A recent study [25] found no direct effects of SS; however, the authors report that the total score of the SSQ was important when considered as co-variated in their predictive model. Previous studies have found that openness and agreeableness may be associated with perceived system usability [2]. In the present study, personality types, explored using the big five personality traits, were not associated with perceived system usability, but this may be due to the small sample size of our study. The qualitative analysis presented two major themes regarding perceived usability and experience of the VR training medium. The positive outlook towards the use of VR and its perceived usefulness for training for real task performance, improvement in retention and gaining the basic skills was in accordance with the literature on VR training [38-40]. The theme of ergonomic limitations and suboptimal realism was also quite aligned with the literature and current issues with perceived VR usability [40]. However, it must be mentioned that the pressure felt due to timing and expected performance influenced experience of VR task performance in comparison to real-life task performance, making it less stressful. If the timing pressure was equal, the results might have been different. Therefore, the effect of performance pressure in both environments needs to be further investigated in the future.

5. Conclusion

In the present study the experienced level of SS was negatively associated with the reported system usability. However, the reported results were inconclusive for user personality traits and experienced sense of presence. When asked, users evaluate positively the user of VR and perceived the VR environment as useful for training purposes but they also highlight technical limitations.

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