OPENNESS: A TRAIT INFLUENCING PRESENCE IN VIRTUAL ENVIRONMENTS?

Vilde Heyerdahl Roland

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Supervisor: Ingvild Saksvik-Lehouillier

This bachelor thesis is included in the PLURAL research project at NTNU in Trondheim, led by supervisors Benjamin Schöne, Ingvild Saksvik-Lehouillier and Håvard R. Karlsen. All students who were part of the PLURAL project, including myself, participated in recruiting participants and conducting the experiments.

Two research assistants, who were also students at NTNU, made the virtual environments for the experiments with guidance from Benjamin Schöne.

Håvard R. Karlsen analyzed data from the questionnaires and transformed it to variables using the statistical program R.

The paper is a result of individual work, with some guidance from supervisor Ingvild Saksvik-Lehouiller. Thank you for guiding me through this semester.

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Abstract

Virtual reality (VR) has increased tremendously in usage in the psychological field in the last decades and has the potential of simulating life-like scenarios, facilitating experiments, and replicate previous studies. However, not all individuals benefit from VR education and training, potentially due to individual characteristics such as differences in personality. Research on how personality traits relate to presence in virtual environments is limited, and one of the least researched personality traits in this area is "openness".

This paper aimed to contribute to the scarce existing literature by investigating the relationship between openness and presence in VR among 47 Norwegian participants aged 18-30. This was done by exposing the participants to a neutral and negative virtual scenario in randomized order. Personality was assessed through the IPIP-NEO-120 before exposure, and presence was assessed after exposure using the Immersive Virtual Environment Questionnaire (IVEQ). The relation was investigated by performing a Pearson's correlation on ten variables: Presence, Openness, Imagination, Artistic Interests, Emotionality, Adventurousness, Intellect, Liberalism, Age and Gender.

This study found a significant relationship between gender and presence, $r(43) = -.35^*$, $p = .023$. No other significant correlations were found. A multiple regression was performed to see whether the predictors imagination, emotionality, and gender could predict presence, but no significant predictors were identified. These findings suggest that gender may have a stronger impact on presence in virtual environments compared to openness. Future research should explore this trait further with larger sample sizes, objective measures or look at other personality traits.

Key words: virtual reality (VR), presence, personality, openness, imagination, emotionality, gender

Virtual reality (VR) har økt betydelig i bruk i det psykologiske fagfeltet de siste årene, og har potensialet til å simulere virkelighetsnære scenarioer, fasilitere eksperimenter og replikere tidligere studier. Allikevel har det seg slik at ikke alle individer tjener på læring eller trening i VR, noe som potensielt kan forklares av individuelle karakteristikker, slik som forskjeller i personlighet, og «presence» (tilstedeværelse). Det er begrenset med forskning på hvordan personlighetstrekk relaterer til tilstedeværelse, og et av trekkene det er forsket minst på innen dette området er «åpenhet».

Denne artikkelen hadde som mål å bidra til den begrensede eksisterende litteraturen ved å undersøke forholdet mellom åpenhet og tilstedeværelse i VR blant 47 norske deltakere mellom 18 og 30 år. Dette ble gjort ved å eksponere deltakerne for et nøytralt og et negativt virtuelt scenario i randomisert rekkefølge. Personlighet ble målt gjennom spørreskjemaet IPIP-NEO-120 før eksponering til scenarioene, og tilstedeværelse ble målt etter eksponeringen ved bruk av «Immersive Virtual Environment Questionnaire» (IVEQ). Forholdet ble undersøkt ved å utføre en Pearson's korrelasjonsanalyse på ti variabler: Presence, Openness, Imagination, Artistic Interests, Emotionality, Adventurousness, Intellect, Liberalism, alder og kjønn.

Dette studiet fant et signifikant forhold mellom kjønn og tilstedeværelse, $r(43) = -.35^*$, $p = .023$. Ingen andre signifikante korrelasjoner ble oppdaget. En multippel regresjon ble utført for å se om prediktorene imaginasjon, emosjonalitet og kjønn kunne predikere tilstedeværelse, men ingen signifikante prediktorer ble identifisert. Disse funnene indikerer at kjønn kanskje har en sterkere påvirkning på tilstedeværelse i virtuelle miljøer sammenlignet med åpenhet. Fremtidige studier burde utforske dette trekket nærmere med et større utvalg, objektive mål, eller se på andre personlighetstrekk.

1. Introduction

In recent decades, the use of Virtual Reality (VR) has grown tremendously as technology is advancing, enabling the simulation of real-life situations and processes (Kisker et al., 2021). Improvements, such as 3D vision, 360-degree view, and head tracking facilitate the perception of virtual scenarios as "real-world" scenarios (Pan & Hamilton, 2018). Therefore, it can offer a much higher level of immersion in experiments compared to typical laboratory settings and enhance ecological validity in this type of design (Dibbets & Schulte-Ostermann, 2015). This makes it a valuable methodical tool for psychological research. VR scenarios also have the ability to be shared and carried out repeatedly once created, making it easier to test a larger number of participants across different laboratories. In addition to increasing the reliability of psychological research, this can contribute to facilitating replication of experimental studies, and thereby help solving one of the biggest challenges within this field.

While the increase of VR usage in the last decades has been immense, it is particularly evident in the field of psychology. As a result of technological advancements, different training methods that have previously been difficult to implement and situations that have been challenging or even unethical to research, can now be simulated in VR, allowing for supervised, controlled conditions (Pan & Hamilton, 2018). Emotional and cognitive responses to virtual environments have also shown, under the right circumstances, congruent results with reactions to real life scenarios (Felnhofer et al., 2015). Altogether, this contributes to VRs wide scope in the psychological field, now stretching from treatment of phobias (Peperkorn et al., 2014; Shiban et al., 2016), to training (Zhong et al., 2021), education (Lønne et al., 2023) and even memory assessment (Serino & Repetto, 2018).

There are several factors that can influence the participants experience of the virtual scenario as a real-world scenario. However, impact of individual differences on this experience have remained uninvestigated up until recent years, and questions on this domain are still unanswered. An area that remains scarce in existing literature is the role the user's personality plays in relationship to their sense of presence in the virtual environment. To contribute to filling this gap, this study will examine the relationship between the personality trait known as "openness" and the participants' perceived presence in virtual environments.

1.1 The roles of presence and immersion in virtual environments

VR is essentially a virtual simulation portraying potentially realistic scenarios, and therefore relies on sufficient selection of specific perceptual cues to evoke the same emotions and reactions as in similar real-world scenarios (Peperkorn et al., 2014; Shiban et al., 2016). This is closely related to *immersion* and *presence*. Presence can be described as the user's subjective sense of "being there" in the environment, even though they are physically present elsewhere (Slater & Wilbur, 1997, p. 3). This is now commonly seen as a necessary mediator for activation of real emotions in the virtual environment (Price et al., 2011, p. 768). Immersion, on the other hand, is concerned with the objective property of the system, describing to which extent the technology creates an "illusion" that the virtual sensory impression replaces the user's actual sensory stimuli (Tcha-Tokey et al., 2016, p. 34).

Immersive VR is typically experienced in a Head Mounted Display (HMD) that offers 3D vision all around, and a visual scene that updates with head movements (Pan & Hamilton, 2018). Therefore, the visual information available in the virtual environment matches the characteristics of available visual information in the real world. In this way, immersive environments differ from other types of VR technology, such as augmented reality that places

computer-generated items in the real world, and non-immersive computer-generated environments (Pan & Hamilton, 2018). This makes it a unique tool for replication of experiments and simulations of real-life scenarios.

Higher levels of presence have been found in more immersive VR systems compared to simpler setups in studies that assess different degrees of immersion. Already in 1999, Botella et al. reported stronger emotional responses to a neutral VR scene when using a high-quality HMD compared to an HMD with medium quality. Newer research has found that participants experience a stronger feeling of presence when exposed to immersive VR compared to PC conditions (Schöne et al., 2023) and 3D-movies (Dibbets & Schulte-Ostermann, 2015). In addition, audio feedback has been recognized as a critical factor in enhancing presence (Jelfs & Whitelock, 2000). Thereby, research indicates that the sense of presence can be increased by more advanced simulations offering higher immersion.

Furthermore, a high sense of presence in VR seemingly goes hand in hand with more intense emotions experienced in the scenarios. In a study from 2010, Alsina-Jurnet and Gutiérrez-Maldonado researched the influence of individual abilities on the sense of presence experienced in an anxiety triggering school test environment on a large sample (n = 210). Their results showed that the participants experienced a greater sense of presence in test anxiety environments than in a neutral environment. In addition, the students with higher scores on test anxiety generally felt more present than students with lower scores. Later on, Peperkorn et al. (2014) found similar results to the latter study when exposing a sample of participants with spider fear and a control group to VR spiders. Compared to the control group, there was a stronger feeling of presence among the fearful participants. As described, activation of emotions is one of the core mechanisms in virtual reality exposure therapy (VRET), that has been successfully used to reduce symptoms among patients with PTSD symptoms and different phobias (Goncalves et al., 2012; Peperkorn et al., 2014). Therefore,

research on the sense of presence in VR has gained great importance in the field of psychology.

1.2 Individual differences influence on presence

Studies have shown that participants experience different levels of presence, even when exposed to the same immersive VR-scenarios (Krijn et al., 2004). In a VRET-experiment from 2004, Krijn et al. had to exclude 10 out of 37 patients due to their lack of anxiety arousal. Interestingly, the participants experiencing no anxiety reported significantly lower presence than the patients who completed therapy. Since the external stimuli should be the same across all participants in immersive VR (Pan & Hamilton, 2018), one could assume that these variations in sense of presence is caused by influence of individual differences. Therefore, in order to facilitate a greater sense of presence, it could be a beneficial to improve the design of VR gear to align with these individual differences, as it may improve the effectiveness of VR education and therapy. Investigating which individual factors are influencing the sense of presence in virtual environments is essential to make this possible. It can also contribute to better methods for selecting participants who will profit most from training and treatment in VR.

Several studies have explored the connection between presence in virtual environments and a variety of individual factors, but the field is still not thoroughly researched. For instance, Alsina-Jurnet and Gutierrez-Maldonado (2010) discovered in their experiment on test-anxiety, as previously mentioned, that spatial intelligence influenced the sense of presence. However, this effect was only observed among students in the high test-anxiety group. Other individual characteristics that are known to potentially influence presence include visual ability, absorption, locus of control and personality (Ling et al., 2013).

1.3 Personality traits and their possible relationship with presence in virtual environments

In Costa and McCrae's Five-Factor model of personality, they describe what can be seen as five fundamental traits that make up our personality: neuroticism, extraversion, agreeableness, conscientiousness, and openness to new experiences, often described as the Big Five. These personality traits are and are relatively enduring tendencies that can be deduced from behavioral patterns (Costa & McCrae, 1992, s. 655). Therefore, they should be able to be similarly assessed by different observers and facilitate the identification of patterns in how individuals with similar traits tend to behave. Further, the model captures a broader understanding of personality beyond the five domains, as they all have their own narrow and more specific traits, also known as facets. These measure both common variance with other facets within the same domain, and unique variance (McCrae, 2010). Therefore, they have demonstrated incremental validity over the five factors in predicting behaviors and psychopathology.

Few studies have explored the effects of personality traits on presence in virtual environments, and these show contradictory results. While Laarni et al. (2004) observed that extraverts scored higher on presence scales, Alsina-Jurnet and Gutiérrez-Maldonado (2010) reported that a stronger sense of presence can be associated with higher scores on introversion. Seemingly, personality traits such as conscientiousness, agreeableness and openness to new experiences have received very little attention in this matter.

Openness is a trait in the Big Five Inventory characterized by creativity and intellectual curiosity (McCrae, 1994; Costa & McCrae, 1992). It also describes to which extent a person is imaginative and prefer variation over a strict routine. It comprises six

facets: fantasy, aesthetics, feelings, actions, ideas, and values. The “fantasy” facet describes the vividness of an individual’s imagination, while “aesthetics” assesses artistic interests and responsiveness to art forms like poetry and etc. The “feelings” domain represents awareness of one’s own and other’s emotions, as well as their perceived importance to the person. “Actions” describes the willingness to explore new activities and places, rather than sticking to a routine. “Ideas” measures open-mindedness and tendency to explore new intellectual interests, while the “values” facet indicates an openness to re-evaluate ones social, political, and religious values.

It appears to be a paucity in the existing literature of the relationship between openness and the sense of presence in virtual environments. However, research suggests that qualities on a facet level in the Five factory model (Costa & McCrae, 1992) may interact with presence. Imagination and emotionality could, for instance, potentially play an important role in this context, as they measure characteristics that have been included in research on the sense of presence (Kober & Neuper, 2013; Dibbets & Schulte-Ostermann, 2015; Alsina-Jurnet and Gutiérrez-Maldonado, 2010; Peperkorn et al., 2014).

The fantasy facet of the openness-trait in Big Five is closely related to imagination. This is probably why Johnson (2014) renamed it to “imagination” in the IPIP-NEO-120. There has been done some studies on the relevance of imagination when it comes to the experienced sense of presence in virtual scenarios. In 2003, Sas & O’Hare found that higher levels of presence were associated with higher scores on creative imagination among the participants. Additionally, Sas (2004) found that individuals who were more absorbed, more imaginative, and more empathic felt more present in VR scenarios. Nine years later, Kober and Neuper (2013) examined the relationship between personality variables and presence in VR by studying 30 female participants. They found that, across different presence measures, correlations were found between this variable and different aspects related to user’s

personality such as mental imagination and perspective taking. Being one of the core symptoms of PTSD, a psychological disorder that is currently being treated with VRET, researchers are arguing that deeper investigation on imagery abilities and their relationship with VR should be provided (Dibbets & Schulte-Ostermann, 2015). In fact, Dibbets and Schulte-Osterman (2015) found that higher imagery abilities coincided with more intrusions in VR-conditions among PTSD patients.

Emotionality, the facet representing an openness towards feelings, also seem relevant in the context of investigating individual differences' relation with presence in VR. As stated earlier, more intense emotions have, through several occasions, been linked to a higher sense of presence in virtual environments (Alsina-Jurnet and Gutiérrez-Maldonado, 2010; Peperkorn et al., 2014). Emotionality is also reflected in how participants understand others' feelings (Johnson, 2014). The research with the closest resemblance to investigating this, is regarding empathy. In Sas' (2004) study, empathy was associated with a greater sense of presence. Semana et al. (2009) found a positive association between presence and empathy, but only for the fantasy dimension of this characteristic. Later studies on the relationship between empathy and presence in virtual environment also shows that feelings of compassion and concern for others could affect the level of presence, when the virtual environments included other human characters (Ling et al., 2013). Therefore, literature might indicate that emotionality may be relevant in the matter of presence in VR.

Based on the preceding information, it appears to be a lack of research on personality within the VR field. Overall, researching the relationship between personality and presence in VR scenarios may have significant implications for personalized VR experiences in regard to education, training, and VR exposure therapy. Qualities linked to openness facets such as emotionality and imagination have been shown to enhance virtual experiences, indicating that this personality trait is under-researched in this area.

The aim of the current study is to contribute to more knowledge about the relationship between personality and participants' experience of VR. This will be achieved by investigating the possible connection between the personality trait "openness" from Costa and McCrae's Big Five Inventory (1992) and users' subjective experience of presence in virtual environments. This leads us to the research question:

How is the relationship between openness and presence in an immersive virtual environment?

With the following hypothesis:

H1: Higher scores on openness can be associated with a higher sense of presence in immersive virtual environments

H2: Higher scores on the "imagination" can be associated with a higher sense of presence in immersive virtual environments

H3: Higher scores on the "emotionality"-facet can be associated with a higher sense of presence in immersive virtual environments

2. Method

2.1 Participants

Potential participants were recruited using convenience sampling. Inclusion criteria for age of participants was set at 18 to 30 years old. Exclusion criteria for partaking in the experiment were that the participants (i) had neurological or psychical disorders, (ii) had been to, were recommended to or considered going to a psychologist the last five years, (iii) were generally unhealthy or influenced by alcohol, or that (iiii) participants took medication that influences the central nervous system. A flyer with information about these criteria was sent to potential

participants before their participation. Recruiting and testing of participants happened between 4th and 20th of March 2024.

The final sample consisted of 47 participants (63.8% women, 31.9% men, 4.3% did not answer) aged between 18 and 30 years (M = 22, SD = 2.17). Most participants were students at the Norwegian University of Science and Technology. Participants were aged 18 years or over and gave their informed written consent.

All participants were included in the analysis, examining data from the IPIP-NEO-120 and IVEQ questionnaires to evaluate how levels of openness, some of the inherent facets in this trait, and presence may impact each other.

2.2 Procedure

Sikt - "Norwegian Agency for Shared Services in Education and Research" has evaluated that personal data in this project are treated in accordance with the General Data Protection Regulation with following reference: 494059. All participants in the study gave their informed consent prior to the experiment. Data collection took place in March 2024 at the Norwegian University of Science and Technology in Trondheim. Participants did not receive any compensation for partaking in the study.

Prior to exposure to the virtual environment, each participant was guided to a room with a computer and asked to complete a self-report electronic questionnaire assessing their personality (IPIP-NEO 120), subjective experience of fear (RST-PQ) and their tendency to regulate emotions (ERQ). Experience with VR prior to the experiment was also reported on a scale from 1 to 10.

Participants was then guided to the VR-lab and got a thorough instruction of the experiment. Firstly, they were told to change from their shoes to the black slippers, before

they would be instructed to walk to the Start-field (Figure 1). Then, they were informed that sensors would be placed on both of their hands and feet. During instruction, participants were informed that they would be exploring a virtual environment, where their task was to find a sign saying “Level Complete” (Figure 2). Additionally, they were told to act like they would in the normal world (not walking through walls etc.), and to take off their VR-headset when or if they completed the task. They were also informed that the research personnel would not be able to talk to them or answer their questions during the exploration of the scenarios, except if they felt uncomfortable or wanted to stop the experiment, which they could do at any time. After information, sensors were attached to their arm wrists and legs (Figure 4), and the HMD was placed on their head and adjusted till they were comfortable.

Once participants remained still for a few seconds to allow the program to detect the sensors, they could start exploring the scenario. The participants were randomly assigned to either a neutral or a negative condition, and then subsequently exposed to the other condition. They could spend a maximal amount of 10 minutes in both scenarios in total. Data from participants spending more than 10 minutes in the scenarios was deleted or marked as invalid.

After completing both VR-conditions, the participants had to fill out a questionnaire measuring their experience of immersion and presence during the scenarios (Immersion and presence parts of IVEQ).

The total time for the entire experiment was approximately 30 minutes per participant. About 20 minutes were spent in total answering both questionnaires, and 5-10 minutes were spent in the two VR-environments altogether.

2.3 VR environment and setup

For both conditions, participants wore an HTC Vive Pro 2 HMD which allows for 3D/360° view, head tracking and stereophonic sound. It has a resolution of 4896 x 2448 pixels and contains steamVR tracking 2.0 technology, which sends signals to the headset and controllers to capture movements in space and reproduce them in virtual reality. HTC Vive Tracker 3 sensors were attached to the participants legs and arms for tracking and visualization of their movement, posture, and gait. A cable attached to the HMD connected it to the computer system. To ensure consistency in haptic sensation during exposure to the virtual environment, all participants wore identical black slippers with a thin rubber sole. The virtual environment was built in Unity, version 2021.3.33 and using the "Medieval Fantasy Ruins" asset from Unity's Asset Store (https://assetstore.unity.com/packages/3d/envir5onments/fantasy/hdrp-medieval-fantasy-ruins-dark-forest-environment-258405). For this asset we used High-Definition Render Pipeline (HDRP), which allows for creating high-fidelity graphics. For the neutral scenario, the "Mountain Environment" asset was used as well (https://assetstore.unity.com/packages/3d/vegetation/mountain-environment-dynamic-nature-191851).

Two quite similar scenarios resembling a forest with ruins were created for both conditions. The neutral environment (Figure 2) was set in daylight and featured abundant green trees and bushes. In contrast, the negative condition (Figure 3) was notably darker and contained other elements, such as a statue and torches illuminating the ruins.

Both scenarios had an area and outline equivalent to a T-maze (Figure 1), which is a simple forked passage resembling the letter T. It provides the subject with a straightforward choice and is often used in cognition experiments (mostly regarding animals) to assess spatial learning and memory (Brown et al., 2005; Weisberg & Newcombe, 2016). Therefore, to find the sign and complete the scenario, the participants needed to walk through an opening in the concrete walls in the scenario and walk behind them in the environment, creating a T-pattern. This means that the first direction the participants chose when entering the walls opening, would always be the wrong one. The layout was set up in the VR-lab with an area of 5 x 6 meters. To increase immersion, bird-sounds were added to the scene. The neutral scenario was accompanied by "normal" bird sounds, while more eerie crow sounds were in the background in the negative condition. These were audible through the HTC Vive Pro 2 headphones.

Figure 1

Illustration of the outline of the scenario, from start to finish. Participants had to reach one of the dashed boxes and walk in the other direction, before the "Level Complete"-sign would appear in the "Finish" area

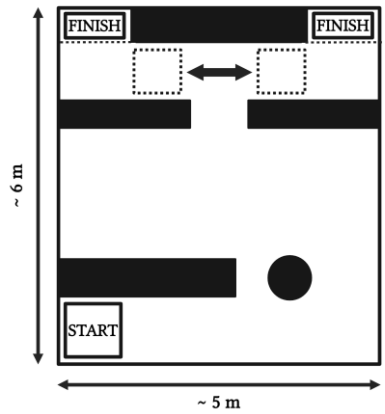

Figure 2

Inner Perspective of Neutral Condition

Figure 3

Inner Perspective of Negative Condition

Figure 4

Outer Perspective of the virtual environment and gear

Left panel: HMD and extremity sensors

Middle panel: Sensor on right arm

Right panel Sensor on left foot and shoes

2.5 Subjective measures

Questionnaire

To measure participant's user experience of the VR and their different scores on personality traits, a questionnaire based on existing questionnaires was developed. This consisted of IPIP-NEO-120, RST-PQ, ERQ and IVEQ. It also contained questions about gender (woman/man/other), age and prior experience with VR-technology.

IPIP-NEO-120 was used in this experiment to measure the facets and personality traits of Costa & McCrae's Five-Factor Model (Costa & McCrae, 1999; Johnson, 2014), and is a short form of the 300-item IPIP-NEO (Goldberg, 1999) created from the International Personality Item Pool, or IPIP. Goldberg's (1999) inventory was, again, made to measure constructs similar to the personality traits in the NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 1992). The IPIP-NEO-120 instrument is a self-report measure consisting of 120 items, and assesses the five traits of extraversion, neuroticism, agreeableness, conscientiousness, and openness to experience. Only the openness-items were included this study. The questionnaire differs from the NEO PI-R-instrument in terms of that the facet names related to the personality traits are changed, as you can see in Table 1, though they measure the same qualities. A Norwegian translation (Pran, 2021) based on the original English version (Johnson, 2014) was used.

Table 1

Openness Facets in IPIP-NEO-120 and their counterparts in NEO PI-R

Subscale	IPIP-NEO-120	NEO PI-R
O1	Imagination	Fantasy
O2	Artistic Interests	Aesthetics
O3	Emotionality	Feelings
O4	Adventurousness	Actions
O5	Intellect	Ideas
O6	Liberalism	Values

The "openness" trait is measured by in total 24 questions, where each of the six facets has four belonging questions. It was found to be highly reliable, 24 items, $\alpha = .83$, in Johnson's (2014) study, which is above the regular 0.7 to 0.8 acceptance value for counting variables as reliable (Kline, 1999). The imagination facet consisted of four items and had a quite high internal consistency, $\alpha = .76$, while the emotionality facet consisted of and was found to be less reliable, 4 items, $\alpha = .69$, in the IPIP-NEO-120 (Johnson, 2014). Cronbach's alpha (α) was also calculated to measure the reliability of the variables in the current study. Imagination consisted of four items and was found to be highly reliable, $\alpha = .81$, while emotionality scored a bit lower, $\alpha = .62$. The openness scale consisted of 24 items and was found to be reliable, $\alpha = .77$.

The questionnaire also incorporated the immersion and presence subscales from the Immersive Virtual Environment Questionnaire (IVEQ; Tcha-Tokey et al., 2016). This self-report instrument assesses various dimensions of user experience in immersive virtual environments through 87 items. The complete IVEQ questionnaire consists of 10 subscales to measure user experience, including presence, immersion, flow, usability, and other relevant factors.

The presence component was measured by a shortened version of the Presence Questionnaire (PQ) created by Witmer and Singer (1998). The original questionnaire

identifies individuals' level of presence and engagement in virtual environments and consists of 24 items divided in 5 subscales: involved, natural, auditory, resolution and interface quality.

In the IVEQ, the presence component is reduced to 12 items with answers on a 10-point Likert scale and is separated from the measure of engagement. It contains questions such as "my interactions with the virtual environment seemed natural", and "I felt proficient in moving and interacting with the virtual environment at the end of the experience" and showed a high internal consistency, ($\alpha = 0.88$) (Tcha-Tokey et al., 2016).

In our study, the presence variable had a high internal consistency, ($\alpha = .848$). A Norwegian translation used in earlier research (Lønne et al., 2023) was used.

2.6 Statistical analysis

All statistical analysis were performed in the software IBM SPSS Statistics version 29. The significance level for the analysis was set to $p = .05$.

A Pearson product-moment correlation was conducted to evaluate the relationship between presence (scores on the IVEQ presence component), all facets of the openness-trait from the IPIP questionnaire (Table 1) and relevant background variables.

A multiple regression was conducted to examine how the relevant facets "emotionality" and "imagination" could predict the participants' level of presence in the virtual environment.

Before performing the correlation between the variables, a priori power analysis was conducted in G*Power, a free-to-use software used to calculate statistical power. This showed that, to achieve a power of 80% in the correlation, a sample of 29 persons would be necessary to find large effects, but a sample of 84 persons would be required to find medium effects.

Our study, with a sample consisting of 47 participants, will therefore only be able to detect large effects with a high statistical strength. Effect sizes were interpreted, and power level was set according to Cohen's benchmarks (Cohen, 1998).

In addition, a priori power analysis was conducted in G*Power before performing the regression to see what sample size is required to test the overall regression model. This showed that to achieve a power of 80% in a regression with three predictors, 36 participants is required when expecting to find large effects, and 77 participants is required when expecting to find medium effects to achieve the same level of power.

Variables included in the correlation, look normally distributed in histograms and scatterplots. However, from boxplots, two outliers were detected in the "openness"-variable (id = 11, 13) and the "presence"-variable (id = 17, 34). Still, Both Shapiro-Wilk and Kolmogorov-Smornov tests were non-significant, which indicates that the assumption of normality was met.

Statistical assumptions underlying regression analysis were investigated. To examine the assumptions of homoscedasticity and normally distributed errors, histograms, and scatter plots of standardized residuals were investigated, and no clear systematic variations in residuals was discovered, indicating homoscedasticity. The assumption of independent errors was also investigated. The value of the Durbin-Watson test for the model was 1.57. According to Field (2009, p. 221), this indicates a low level of correlation between the residuals of the predictor and outcome variables included in the model. The correlation coefficients between the predictors — imagination, emotionality, and gender — ranged from -.07 to .23, indicating that there were no strong relationships between them. Therefore, the assumption of no multicollinearity was met. The standard residuals were slightly below -3, which contrasts the assumptions of the data being normal. However, since Durbin-Watson was between 1-3 and

Cook's distance was below 1, the statistical assumptions underlying regression analysis are considered sufficient for the current data.

The internal consistency of the "presence" variable from IVEQ was calculated. The presence variable consisted of 13 items, $\alpha = .848$. The item "Pre12" was removed from the variable after the reliability analysis showed that reliability would increase if this item was removed. Before CA After removing the item, it increased to $\alpha = .850$.

3. Results

The analysis did not include all participants, as some did not respond to all IPIP questions regarding openness. In the facet variables, measured by four items each, participants had to answer two items or more related to each facet to be part of the analysis. Thus, some variables only have 44 to 46 answers.

Table 2

Correlation between openness, facets of openness, presence, and relevant background variables (n = 44-47)

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Presence	7.59	1.31	-									
2. Openness	3.32	0.40	.03	-								
3. Imagination	13.00	3.40	.19	.56**	-							
4. Artistic interests	13.59	3.48	-.17	.67**	.12	-						
5. Emotionality	15.30	2.55	.03	.44**	-.07	.52**	-					
6. Adventurousness	12.30	2.42	.20	.65**	.18	.32*	.13	-				
7. Intellect	14.13	2.86	.13	.59**	.35*	.12	.10	.30*	-			
8. Liberalism	11.36	2.24	-.15	.42**	.15	.10	-.17	.34*	.11	-		
9. Age	22.00	2.17	.18	.14	.11	.19	.02	.08	.16	-.12	-	
10. Gender[a]	0.67	0.48	-.35*	.03	.08	.12	.23	-.10	-.32*	.26	-.33*	-

Note.

[a]0 = Male, 1 = Female

*$p < .05$, **$p < .01$

The results show that there was a significant correlation between gender and presence, $r(43) = -.35*$, $p = .023$. There were no significant correlations, $p > .05$, between the six openness-facets and presence. A multiple regression was run to predict presence from imagination, emotionality, and gender (Table 3). This resulted in a non-significant model, $F(3, 35) = 2.39$, $p > .05$.

Table 3

Regression Analysis Summary for Predicting Presence (n = 42)

Variable	*b*	*SE b*	β	R^2
Model				.16
Imagination	0.95	0.63	.23	
Emotionality	0.35	0.81	.07	
Gender	-8.61	4.24	-.32	

Note.

*$p < .05$

4. Discussion

The current study aimed to explore how personality traits might impact users' experiences in virtual environments by examining the relationship between relevant openness facets and presence within a virtual setting. Results showed that there were no associations between imagination, emotionality, and the sense of presence. These findings have implications for the use of VR in educational activities and virtual exposure therapy (VRET), as well as future research.

This study explores the research question: How is the relationship between openness and presence in an immersive virtual environment?

Some important findings were identified. Participants with high scores on openness did not feel significantly more present in the virtual environment, as opposed to what was expected in H1: that higher scores on openness can be associated with a higher sense of presence in immersive virtual environments. This might indicate that openness is a less important factor than assumed when researching individual differences' impact on presence, and that people with less open personalities may also benefit from training and treatment through VR. However, given the lack of prior research in this specific area, further studies on openness and presence should be conducted before drawing definite conclusions.

Furthermore, males seemed to feel significantly more present than females in the virtual scenarios. Since the environment in the current study was based on the T-maze layout, and therefore required spatial presence to be completed, an explanation for the gender differences in presence might be caused by differences in spatial abilities. This agrees with literature, as men have shown higher levels of spatial presence, involvement, and the sense of being in the virtual environment than female participants (Felnhofer et al., 2014). Earlier studies show that men have also demonstrated better performance than women in various of spatial tasks (Kryspin-Exner & Felnhofer, 2012). These tendencies may be a result of prior computer game experience, as men has been found to engage more frequently in playing computer games than women (Hartmann & Klimmt, 2006). Nevertheless, there was an uneven distribution of males and females in the current study, which indicates that research with more equal gender distributions is required to conclude that the findings are reliable.

The participants with higher scores on the imagination-facet did not feel significantly more present in the virtual environments. Thus, Hypothesis 2, that higher scores on the "imagination" can be associated with a higher sense of presence in immersive virtual environments, was not supported. This is contradictory with what Sas found in 2004, where the results showed that more imaginative participants experienced a greater level of presence. However, in virtual environments as advanced as those in this current study, the role of imagination may not have the same level of importance as in studies using less sophisticated equipment. Participants do not need to use as much imagination in highly immersive scenarios in order to experience the environment as convincing, as in scenarios that provide less sensorial stimuli. Being from 2004, Sas' study had more technological limitations than ours, and this might explain why their participants needed a higher score on imagination to feel present. Still, our results also contrast Kober and Neuper's (2013) findings across different presence measures, where a more vivid imagery was associated with increased sense

of presence. Regardless, their study was solely based on a female sample, and results may had been different if both genders were included in the experiment. Nevertheless, these disagreements in research indicate that more studies on the imagination facet is needed to expose its true relation with presence.

Emotionality in participants neither seemed to relate to a greater sense of presence, which contradicts the hypothesis that higher scores on the "emotionality"-facet could be associated with a higher sense of presence in immersive Virtual Environments (H3). However, this was not expected, as literature shows that a stronger feeling of emotions (Alsina-Jurnet & Gutiérrez-Maldonado, 2011; Peperkorn et al., 2014) and empathy (Semana et al., 2009; Ling et al., 2013) can be related to presence, potentially indicating that awareness of emotions would show the same tendencies. However, measuring emotionality on a facet level in a questionnaire assessing personality differs greatly from measuring to which extent emotions was induced from a virtual scenario. The first measure requires that the individual reflects around how they usually behave and respond to situations, while the latter often is a reported experience from a recent experiment. Therefore, these might not be as closely related as anticipated.

All in all, there was no associations between the openness trait and presence in this study, indicating that other personality traits may be of greater importance when investigating the relationship between personality and presence. As mentioned, personality traits can be used to predict psychopathology, but there are other personality traits that are more closely linked to this than openness. For instance, VRET is frequently used to treat specific phobias (Peperkorn et al., 2014), which in general has been strongly connected to higher scores on neuroticism and lower scores on conscientiousness (Kotov et al., 2010). Imagination may be a characteristic in post-traumatic stress disorder (PTSD), but this disorder shows a strong association with neuroticism and conscientiousness, which may indicate that these traits are

more relevant than imagination in this context. Therefore, neuroticism and conscientiousness may be more relevant in research on the relationship between personality and presence in VR aiming for improving the user experience in VRET.

However, this should also, when researching other personality traits, be examined on a facet level, as this best can predict both behaviors and psychopathology, which is one of the main arguments for researching personality (Costa & McCrae, 1992). In the context of VR and presence, this could be highly valuable for VRET technology, the discovery of other fields of VR usage within the psychological field, and when trying to enhance the user experience in VR.

Strengths and limitations

The VR scenario itself uses advanced gear which has been shown to allow for a high degree of both immersion and presence (Schöne et al., 2023; Dibbets & Schulte-Ostermann, 2015). In addition, the scenario was specifically built for our study. Including a neutral and a negative environment in the experiment with the same features and layout, in addition to making every participant complete both scenarios, is suited for measuring the personality differences in VR-settings. The randomized order of the environments also eliminates the chance of practice effects in the experiment, which happens when people repeatedly perform the same tasks and the response time decrease due to practice (Dutilh et al., 2009).

The exclusion criteria could be both a strength and a limitation to the study. By including all these, we end up with a quite homogenous sample, who might be a good representation of the group we want to research. The sample also consisted of mostly students. This makes it easier to generalize to this part of the population. On the other side,

the exclusion criteria are so strict that they may have contributed to a limited number of participants, which again is a limitation of the study.

Our sample size is somewhat small, especially considering that the regression analysis requires 77 participants to find medium effects with a high power. Due to delivery delays on the sensors, time for recruiting participants got limited. This could mean that there were not enough participants in the sample to be able to measure significant associations between the openness trait and the presence variable. To support this claim, a post hoc power analysis was performed in G*Power. A post hoc analysis also showed that the regression analysis of the present study had a power of 19%, which means that the Type II error rate is extremely high, 81%.

A weakness regarding studies of presence in general in VR is that they use different presence measures (Kober & Neuper, 2013). Since Kober and Neuper found that the relationship between personality and presence varies in research, and depends on the used presence measure, a standardized presence measure for VR scenarios should be developed. Still, in their study, mental imagination correlated with presence across different measures, indicating that this characteristic still may be a relevant trait contributing to a higher sense of presence.

IVEQ was used as a post-test questionnaire to measure the participant's sense of presence in the current study. The advantage of post-test rating scales is that they do not disrupt the media experience, and they are easy to administer. However, there are also drawbacks to these measures. For instance, the IVEQ does not measure participants' temporal variations in presence, which we would expect them to have when exploring the virtual environments.

In this study, presence is also measured after walking through both the negative and the neutral scenario. Hence, there could be differences in presence because of the scenic dissimilarities in the negative and neutral environment that the questionnaire does not capture. Given that openness is closely linked to both emotionality and imagination, the negative environment may have induced more feelings among participants with higher scores on these facets. The darker environment could have led to more presence by activating imagination among participants, because they easier can imagine what type of "scary" things that might be there. Therefore, in forthcoming studies, it may be beneficial to employ alternative methods for measuring presence rather than relying solely on a post-test questionnaire.

Furthermore, the measurement of presence used in this study relied on self-reporting, which is subject to demand characteristics that are widely recognized in research methodologies. It's important to consider social desirability, as participants might attempt to guess the researchers' focus and the desired outcomes. This can lead them to respond accordingly or contradictory to these expectations (Fischer, 1993). Therefore, only measuring self-reported presence needs to be considered carefully.

Slater & Wilbur (1997) presented that presence in virtual environments could be described both subjectively through their sense of "being there" and objectively through observable behaviour. According to them, a higher sense of presence should be shown through behavior in the virtual environment that is similar to the one in life-like situations. In our experiment, sensors were used to measure gait, posture, and movement, but these were not included in the current analysis. This may seem strange, as behavioral measures could provide an objective angle on the presence perspective. However, including physiological variables assumes that these responses are obvious, as in fearful or stressful situations. When it comes to characteristics such as vivid imagination or emotionality, one could assume that behavioral responses are vaguer, as these traits are more cognitive and therefore may be

easilier measured by brain activity patterns (Pearson, 2015) or subjective measures. In addition, presence is primarily a subjective feeling, thereby called the *sense* of being there (Slater & Wilbur, 1997, s. 4). Therefore, movement variables were excluded from this analysis after all.

Essentially, the participants were supposed to be able to move freely in the experiment area, but because of technical issues and limited time to fix them, there was a cable connecting the HMD to the computer in the experiment. The cable restricted the movement of the participants, and in some cases, hindered their immersion. This could potentially serve as a reminder that they were, in fact, in a university lab partaking in a VR experiment and not exploring forest ruins. This might have influenced the sense of presence in the study and should be considered when looking at the results.

Implications

The result of this study might be relevant for research in general including individuals being placed in a VR scenario, because it can contribute to an increase of more personalized VR gear, enhancing user experience in the future. The results implies that openness may not be as important for the sense of presence in virtual reality as assumed. This can indicate that researchers and people working within this field should not be afraid of testing virtual reality training programs or VRET on people with less open personalities in the future. However, result in the current study contradicts earlier research, and should be considered when researching these areas and testing VR interventions in the future. These findings also indicate that other personality traits might be more important than openness in relevance to the sense of presence in VR.

Future Research

This study reveals that personality traits in general should gain more attention when it comes to presence in virtual scenarios, because this can contribute to personalizing virtual experiences and enhance the effects of VR training and treatment. However, to get more reliable and more objective results in this field, it could be beneficial for future studies to include more objective, physiological measures. To access more reliable measures of the imagination and emotionality facets' influence on presence, neurological dimensions such as activation of different brain areas connected to vivid imagination, or different emotions, could be included in the experiment.

For future studies, it would also be beneficial to aim at gathering a larger sample size, increasing the statistical power and enhancing the chances of finding medium and small effects in the experiment. To increase this sample size in later studies, it might be necessary to revise the exclusion criteria, and for example remove "considered going to a psychologist the last 5 years" as this seemed to exclude many of our potential participants that received the flyer. For more reliable results on the gender effect on presence, future studies should also aim at including an equal number of males and females in the study.

It could also be of beneficial to use longer measure instruments for measuring personality, such as the NEO-PI-R (Costa & McCrae, 1992), for a more thoroughly measurement of facets. This could increase the reliability of these measurements, and offer as better predictors for behavior and psychopathology, enhancing the possibility of the study contributing to a better user experience in VR.

Conclusion

The present study illustrated that, among young adults, a more open personality was not associated with a higher sense of presence in immersive VR. Neither was imagination and emotionality. Additionally, females seemed to feel less present than males in the virtual scenarios in this study, but further research on this area is required to confirm these assumptions. In conclusion, there is a possibility that the openness trait and its characteristics are less relevant to enhance the feeling of presence in virtual environments than anticipated. However, research on this is still sparse, and there may be other personality traits that are more relevant to investigate in relevance to presence in virtual environments.

Virtual simulations in immersive VR offer incredible possibilities in education, training, and exposure therapy, as they can replicate real-life scenarios that may be impossible to recreate physically. Future research should work towards filling the information gap regarding personality's possible influence on presence in VR scenarios. Further exploration of the impact of the openness trait is needed, and including objective measurements such as brain activity might be necessary for reliable results. Additionally, more controlled, randomized studies with larger sample sizes than in the current study are crucial to thoroughly examine this effect. Nevertheless, the importance of acquiring insights into individual differences' influence on presence in VR should not be underestimated, as this can expand the reach of participants gaining benefit from virtual education, training and VRET.

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