Did it Feel Real to You?- Personal characteristics influencing Presence and Interaction in VR

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Abstract

The importance of VR technology is increasing in many fields, yet current literature regarding personal characteristics and their ability to influence VR experiences is very limited and ambiguous. In order to have a better understanding of these dynamics, this study analyses the relationship between Sense of Presence and interaction with VR environments in relation to certain personal characteristics such as personality type and mental rotation ability. For this purpose, 22 participants are recruited to experience the presented virtual environment. They are able to interact with certain objects within it, for example by lifting them up and throwing them around. Each interaction is counted and their answers on the Ten Item Personality Inventory (TIPI), Igroup Presence Questionnaire (IPQ) and a Mental Rotation task are measured. A correlational design is used and scores are analysed by means of multiple linear regression models.

Results show no significant effects for any of the factors after correcting for multiple testing, however Neuroticism shows a positive pattern for Spatial Presence (p<.05) and Mental Rotation demonstrates a possible positive relation with Realism (p<.05). In conclusion, it is postulated that personal characteristics might play a role in feelings of presence in virtual spaces, however due to limited power and other methodological factors, significance was not reached. In alignment with our aim, this study aids in enriching the scarce literature that is currently available by presenting its own results and by further offering interesting clues for future research into the relationship (neuro)-psychological factors might have with our experiences of VR.

Layman's abstract

Virtual reality has become very popular around the world and with better technology and graphics the experience is becoming more immersive. However, immersion itself is not the only factor that is important when it comes to creating a feeling of ‘’being’’ in the virtual world (Sense of Presence). This study aims to find out whether personal characteristics such as the ability to mentally rotate objects and personality contribute to Sense of Presence and the way people interact with virtual objects.

To test this, participants experience a virtual room in which they are able to move around and interact with certain items, after which they answer personality and presence questionnaires and are asked to perform a figure rotation test.

Results do not show any conclusive effects of personal characteristics, however they do provide some promising finds. For example, it seems to be possible that with an increasing inclination towards negative emotions (Neuroticism), users experience a heightened feeling of actually being within the virtual room (Spatial Presence). Furthermore, with better ability to mentally rotate objects, it may be that participants feel like the environment is more like the real world (experienced realism). These findings enrich the current knowledge we have about personal factors and VR and help in creating better experiences for users in the future, both privately and in clinical settings.

Did it Feel Real to You?- Personal characteristics influencing Presence and Interaction in VR

Virtual reality is a topic that is becoming increasingly popular around the world. From the gaming-industry to the medical field, VR has embedded itself in different domains. Over the years, costs for VR systems have dropped, which makes their use in these areas more compelling. Funding towards VR and Augmented reality technology is staggering with an estimated market value of 14.84 Billion USD in 2020, which is only predicted to increase in the future (Valuates Reports, 2022). It is therefore surprising that the users themselves do not seem to be a greater point of focus in the research towards improving VR experiences. Especially, when considering that the core concepts of VR rely both on the technology and on the person operating the system.

The most prominent concepts mentioned are Immersion and Presence. Immersion describes the objective technological measures taken to include the user's senses into the experience, for example by displaying a realistic looking beach while playing soft wave sounds in the background. Presence on the other hand, describes the psychological and subjective phenomenon of feeling like one is existing and acting within the presented environment (Berkam & Akan, 2018). Theoretically, Presence is influenced by both the objective level of Immersion and subjective user-related factors. For instance, one can be placed in a very realistic looking environment (Immersion), but because they are anxious for an upcoming exam (subjective factor) they may be less likely to focus on the presented environment resulting in a decreased feeling of realism (Presence). To date, it is not quite clear how important these personal characteristics are in contributing to the user's experience. One of the first factors one might think about is the personality type of the user, indeed extensive research has shown that individuals do behave and experience things differently in their everyday life, depending on their personality type (Ching et al., 2014). In this study we want to focus on one of the most used, researched and known models, the Big Five. Furthermore, the importance of cognitive functions such as spatial ability is unequivocal to our sense of orientation and ability to move within a space in the real world. Therefore, this study also looks at how the importance of our spatial ability translates to its importance in VR using Mental Rotation ability as an indicator.

The Big Five Personality Traits

The Big Five are the result of contributions from many scientists over the years starting in 1936 with a long list of personal characteristics by Gordon Allport and Henry Odbert. Especially the work by Goldberg (1990) and McCrae & Costa (1999) is what shaped the Five Factor model we use today consisting of Openness to Experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism. According to the Big Five, people’s personality does not consist of binary traits, but rather of gradients between

the extremes. Therefore, each trait has two oppositional states. Openness to Experience consists of “prefers routine, practical vs. imaginative, spontaneous”, Extraversion is bound to “reserved, thoughtful vs. sociable, fun-loving”, Conscientiousness holds “impulsive, disorganised vs. disciplined, careful”, Neuroticism depends on “calm, confident vs. anxious, pessimistic’’ and lastly, Agreeableness contains “suspicious, uncooperative vs. trusting, helpful’’ (Lim, 2020).

Looking at the research regarding the role of personality traits, one can see that it is quite inconclusive. One stream of literature suggests that there is no relationship between personality traits and Sense of Presence, such as demonstrated by the study by Grassini et al. (2021). They conclude that personality traits are not a measure that can differentiate well between individuals' presence in virtual environments, however they do also mention that different outcomes might be ascribable to the different types of personality frameworks that are used. Additionally, the type of questionnaire used to assess presence might also significantly impact results.

On the other hand, a number of studies report that relationships do exist, for example a positive relationship between Extraversion and Sense of Presence. Theory suggests that extraverted people might be able to feel more present in a VR environment as they tend to focus their attention on external stimuli rather than internal ones (Lim, 2020). This outcome has indeed been detected by a multitude of studies using different operationalizations of Sense of presence. For example, the study by Laarni et al. (2004), which used the MEC Spatial Presence Questionnaire (MEC-SPQ) and the Independent Television Commission Sense of Presence Inventory (ITC-SOPI). They explain their findings with the theory that Extraverts are possibly able to process more information within a given time than Introverts. This would result in their increased feelings of presence in the Virtual Environment. Furthermore, a quantitative study by Budhram (2021), using the same measure of Sense of Presence as our study (IPQ), also confirms this relationship. However, negative relationships between Extraversion and presence are demonstrated as well, such as by the study by Jurnet and Maldando (2010). Their participants were presented with different Test Anxiety Virtual Environments (TAVE). The use of anxiety inducing VR experiences however, prerequisites a focus on internal processes to feel connected to the environment, thus cancelling out the effect of Extraversion as per theory. The finding that Extraversion is negatively correlated to presence in fear-inducing conditions does therefore not dismiss the findings that it is positively correlated to more neutral environments.

Regarding Openness to Experience, different outcomes are reported as well. Openness is characterised by the tendency to be adventurous and to seek new experiences (Lim, 2020), therefore it is plausible that people higher in this trait would feel more present as they have a motivation to indulge in the experience. Indeed, the study by Budhram (2021)

confirms the theoretical framework by finding a positive correlation between Openness and Sense of Presence. However, the opposite has also been presented in the literature, for example by the study by Stavropoulos et al. (2016). That study specifically targeted adolescence in a classroom setting, in which openness to the real-world environment (the classroom) was tested against their feeling of presence while they were online. It therefore does not represent how Openness influences Sense of Presence in immersive environments and cannot contextually counter the results of Budhram (2021).

Literature on the relationship between personality and interaction with VR environments is often targeted towards user performance on specific tasks (Katifori et al., 2022; Rosenthal et al., 2012) rather than on random, uninstructed and more ‘’natural’’ ways of interacting. Theoretically, it would make sense that certain personality traits would correlate to the behaviour of the participants in the virtual environment as they do in real life (Ching et al., 2014), however studies that do analyse more ‘’casual’’ or ‘’life-like’’ behaviour in VR do not show the ability to replicate these dynamics. For instance, as demonstrated by the study by Schnack et al. (2021) analysing shopping behaviour. It showed no significant results, which contradicts real-world findings. Overall, it becomes apparent that evidence is either lacking or quite ambiguous, however it seems to be the case that Extraversion and Openness might overall contribute to an increased Sense of Presence.

Mental Rotation Ability

Just like personality, spatial ability such as Mental Rotation (MR) impacts our behaviour in everyday life. One of the first scientists to research MR were Shepard and Metzler (1971). They described the ability of humans to recognize a number of 2-dimensional objects in different orientations as one 3-dimensional object. This understanding of objects in different perspectives is what helps us to navigate around and interact with them in the real world (Michelin, 2014). Therefore, it is assumed that these mechanisms are translatable to virtual spaces, however no conclusive evidence has been produced yet.

A number of studies suggest that there is no relationship between MR and Sense of presence such as the ones by Grassini et al. (2021) and Coxon et al (2016). However, due to the great importance of spatial ability in real life, they attributed these findings to differences in measures of spatial ability rather than dismissing its importance. In line with expected outcomes based on the knowledge we have about spatial ability in real environments, the study by Jurnet and Maldonado (2010) reported a positive relation between Spatial Intelligence and Presence. Spatial Intelligence was constructed using the Solid Figures rotation test (Yela, 1968) reflecting the measure of Mental Rotation. They explained their findings by stating that participants with better spatial abilities are able to interact with the virtual environment in a more stimulating way, making the experience feel

more realistic. Notably however, most studies used less immersive environments such as 360-degree videos and desktop interfaces. Looking at MR and interaction, it has been demonstrated by Bogomolova et al. (2020) that participants lower in MR ability experienced greater learning from stereoscopic interaction (in AR) as opposed to viewing the materials monoscopically or in 2D. This shows that MR ability and interaction type can influence cognitive processes, which might be applicable to the relationship between MR, interaction and presence. However, it is not yet clear if a difference between high MR ability and low MR ability exists in ‘’how’’ one interacts with objects in VR.

Broadening our understanding of different factors that could influence how VR is being experienced by people, would enable us to take these differences into account when creating new environments and to further develop existing tools. It would also bring us closer to understanding which populations might and might not be very susceptible to VR experiences, as research clearly suggests that personal factors do play a role (Jasper et al., 2021; Park et al., 2006; Keshavarz et al., 2018). This would make it possible to not only enrich the information that is available to the private sector, but it would also have important implications for patient populations using VR for assessment and treatment. Therefore, the aim of this study is to explore if individual differences in Mental Rotation ability and personality traits are related to how real the presented VR environment feels to people and how much they interact with it. Using an exploratory approach, this study also focuses on adding onto the empirical data to aid and inspire future research in this field.

It is hypothesised that Openness to Experience will be positively correlated with Sense of Presence and Interaction. This is explained by the theory concerning the trait (Lim, 2020) and results shown by the study of Budhram (2021). In practice, it is expected that participants higher in Openness will score higher on the Sense of Presence questionnaire and will interact with more items in the VR environment than people that are less open to experiences. Furthermore, it is expected that Extraversion will be positively correlated with Sense of Presence and Interaction. The reason for this being the nature of Extraversion (Lim, 2020) and the outcomes of studies done by Laarni et al. (2004) and Budhram (2021). Therefore, participants higher on trait Extraversion will report that the virtual environment felt more realistic to them and they will interact with more items than people lower in that trait. Lastly, it is hypothesised that Mental Rotation ability will be positively correlated to Sense of Presence and Interaction. This is mostly derived from research showing a positive relation (Jurnet & Maldonado, 2010) and the importance of Mental Rotation when navigating space in the real world (Michelin, 2014). This means that it is expected that participants who are able to answer more spatial tasks correctly within the limited time frame, will feel more present in the VR environment and interact with more objects than people who solved less tasks.

Methods

Design

For this study a quantitative-research design was used. The independent variables were Mental Rotation ability and the Big Five personality traits. The dependent variables were Sense of Presence and Interaction.

Participants

The requirements for participation were to be at least 18 years old and to have a good understanding of English. Furthermore, no participation was possible in case of any physical ailments that limit movement, or disorders such as epilepsy and any proneness to seizures that could be triggered by the VR experience. Participants were not explicitly tested or asked for any use of medications, drugs or alcohol, however assessment of sobriety and the ability to participate was done by the researcher on sight.

Measures

Ten-Item Personality Inventory (TIPI)

The Big Five were measured using the TIPI consisting of 10 items measuring the personality dimensions Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness to Experience. Gosling et al. (2003) created and published the TIPI as a shorter version of more lengthy Big Five personality tests.

The following are examples of items for each of the personality traits: ‘’I see myself as open to new experiences, complex’’ (Openness to experience); ‘’I see myself as dependable, self-disciplined’’ (Conscientiousness); ‘’I see myself as extraverted, enthusiastic’’ (Extraversion); ‘’I see myself as critical quarrelsome’’ (Agreeableness) and ’’I see myself as anxious, easily upset’’ (Emotional stability/ Neuroticism). Each dimension has two items which are rated on a seven-point Likert scale going from 1 (disagree strongly) to 7 (agree strongly). An increasing score on each subscale indicates higher levels of a trait.

For scoring, the reverse-scored items (2, 4, 6, 8, 10) have to be recoded (7 with 1, 6 with 2, 5 with 3, 4 stays 4, etc.). For each trait, scores on both items are added and divided by two to get an average score. Items 1 and 6 belong to Extraversion, items 2 and 7 to Agreeableness, 3 and 8 to Conscientiousness, 4 and 9 to Emotional stability and lastly items 5 and 10 to Openness to Experience.

The Cronbach's alpha for the test is reported to be rather low, One analysis by Nunes et al. (2018), for example showed a low-to-moderate alpha level (α = 0.40 - 0.68). However, this is not considered to be problematic for the validity of the TIPI as a lower Cronbach's alpha is a usual finding for scales with a low number of items. The analysis by Gosling et al. (2003) showed high significance for the validity of each personality trait.

Mental Rotation Test

The ability of participants to mentally rotate objects was measured using a Mental Rotation Test (MRT) by Shepard and Metzler (1971) consisting of 24 items.
Each item contains one target image of a 3-dimensional object and four answer options, which depict two images of the same (target) object in a different orientation and two images of similar objects. For each subset of tasks one point was granted when both correct images were selected. Performance was assessed by the number of correct responses within 3 minutes. In general, the Cronbach's alpha of the MRT and similar tests is rather high. An analysis by Caissie et al. (2009) reported a Cronbach's alpha of 0.91. Furthermore, the test was validated by Vandenberg and Kuse (1978).

Interaction

Interaction with the VR environment was operationalized by counting the amount of items one had successfully grabbed (not all items in the environment were interactive). In case the same item was grabbed twice, it was only counted as two interactions if the participant did something else in between (e.g. going over to the mirror) or if another item was grabbed before the same item was picked up for a second time. This decision was made to minimise the number of errors while manually counting the interactions and to rule out scenarios in which the person picked up an item again after involuntarily letting go of the button making the item fall. A higher level of Interaction is reflected in an increasing raw score of items grabbed.

Sense of Presence

Sense of Presence was assessed using the Igroup Presence Questionnaire (IPQ) of Schubert and colleagues, which started the development of the IPQ in 1997. Now it consists of 14 items on a seven-point Likert scale ranging from -3 (fully disagree/ not at all) to +3 (fully agree/ very much). The items are divided into three subscales, namely Spatial Presence (feeling that one is within the virtual space), Involvement (how attentive the participant is to the virtual environment) and Experienced Realism (how real the virtual environment feels to the participant). In addition there is one stand-alone item that is related to all subscales (‘’In the computer generated world I had a sense of ‘being there’’).

The following are examples of items on each subscale: ‘’Somehow I felt that the virtual world surrounded me.’’ (Spatial Presence); ‘’I was not aware of my real environment.’’ (Involvement) and ‘’How real did the virtual world feel to you?’’ (Experienced Realism). Items 2, 3, 4, 5 and 6 belong to the subscale Spatial Presence, items 7, 8, 9 and 10 belong to Involvement, items 11, 12 ,13 and 14 belong to Experienced Realism and item 1 is the stand-alone item.

To score the IPQ, the reverse-coded items 3, 9 and 11 were recoded, after which a mean score for each subscale could be calculated. A total score could also be derived from

the mean of all subscores (plus stand-alone item). Higher scores on each subscale indicate an increased feeling in the specific subcategory. Higher scores on the total score, indicate a higher sense of presence.

The reported Cronbach's alpha by Schubert et al. (2001) in an analysis using data from 296 participants is 0.87 for all items. The IPQ shows sufficient reliability and validity.

Procedure

For this study, the Oculus Meta Quest 2 device was used (headset and handheld devices). The Virtual Environment was made in the Unity Game Engine and showcased an atelier with interactive art supplies on a table and a mirror in which the participants could see a wooden manikin figure representing themselves. The software was run using the Oculus app version 41.0.0.113.353.

The study was conducted in the context of the Cinedans festival as part of their VRLab event. Attendees and interested people were able to come by and participate. They were presented with an information letter and the informed consent, after which the experimenter on sight chose one of the two figures (male/ female) that most represented the participants' physical appearance. Each participant received a brief explanation of how to move and interact with the environment. It was mentioned to them that some items were interactive, but no specifics were given. The only task was to explore the virtual space to one's liking. The experience started right at the moment the headset was put on and the handheld devices were given. Once in the environment, each participant got three minutes to explore. Afterwards, each participant was asked to continue with the questionnaire, which upon completion displayed a debriefing.

Ethical approval was granted for this study by the Committee Ethics Psychology (CEP) (approval number: 4050, title: VR and dance: Sense of presence, embodiment and interoception) on 20.07.2022.

Statistical Analysis

For the main analyses, two multiple linear regressions were run for each dependent variable (Interaction and Sense of Presence). Sense of Presence was assessed by computing a total score on the IPQ.

The first analysis contained Mental rotation ability, Openness, Conscientiousness, Extraversion, Agreeableness and Emotional stability as the independent variables and Interaction as the dependent variable. The second analysis had Mental rotation ability, Openness, Conscientiousness, Extraversion, Agreeableness and Emotional stability as the independent variables and Sense of Presence as the dependent variable.

The significance of each model was assessed by the *F*-statistic, while specific interactions between the dependent and independent variables were assessed with regressions.

As secondary exploratory analyses using multiple regression, Mental rotation ability, Openness, Conscientiousness, Extraversion, Agreeableness and Emotional stability were run as independent variables against each of the subscales of the IPQ (Spatial Presence, Involvement and Experienced Realism).

The assumptions of homoscedasticity, normality, linearity and multicollinearity were tested. Furthermore, a Bonferroni correction was used for multiple testing. All analyses were run using the software IBM SPSS (Statistical Package for the Social Sciences) version 26. Sample size and power calculations were run using the software G*Power 3.1.9.4.

Results

Descriptive statistics

The total sample comprised (*N*) 22 participants of which 54.5% were female *(N* = 12). The variable Interaction could only be scored for 21 participants as one video file was lost. The age span from 21 to 53 years old (*M* = 32.55, *SD* = 9.96). When asked about the participants' experience with the VR device used in this study, 18 participants noted that they have used the same set-up before and only 2 people (9.10%) had never experienced VR at all. All average scores for each of the variables (dependent and independent) and their standard deviations (*SD*) are listed in the table below (Table 1).

Table 1

Descriptive statistics

	Mean	*SD*
Openness (1.00 - 7.00)	6.1136	.98720
Conscientiousness (1.00 - 7.00)	5.3636	1.30185
Extraversion (1.00 - 7.00)	4.3636	1.69159
Neuroticism (1.00 - 7.00)	3.7955	1.36852
Mental Rotation (.00 - 24.00)	5.5000	3.44688
IPQ total (1.00 - 7.00)	4.3875	.65766
Interaction (.00 - 17.00)	8.00	4.52769

Assumptions

To check for homoscedasticity in the sample, scatterplots of the standardised residuals against the standardised predicted values were analysed. None of the values fell outside of the range of -3 to 3, meaning that the assumption of homoscedasticity was met. To test for normality, the distribution of scores on the dependent variables were inspected using the Shapiro-Wilk test. None of the response variables showed a significant result, thus confirming normality. Linearity could also be confirmed, as visual inspection of the Normal P-P plots showed no great deviance from a linear distribution. Multicollinearity between the predictors was tested by looking at their Pearson Correlation. None of the independent variables showed a correlation greater than 0.7, which made it possible to deduce that none of the explanatory variables are correlated. Therefore, no multicollinearity was observed in this sample.

Inferential statistics

For the first hypothesis an analysis was conducted to test if personality (Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism) and Mental Rotation ability were positively correlated to sense of presence. Results showed no significance for the model ($R2$ =.33, F(3.005) = 1.24, p = .34). Additionally, none of the predictors showed any significance (see Table 2).

Table 2

Summary of multiple regression analysis

Variables	B	SEB	β	t	Sig.	VIF
Openness	-.026	.204	-.038	-.125	.902	2.099
Conscientiousness	-.046	.126	-.092	-.368	.718	1.390
Extraversion	.028	.104	.071	.265	.795	1.611
Agreeableness	-.218	.237	-.226	-.920	.372	1.354
Neuroticism	.134	.154	.279	.870	.398	2.313
Mental Rotation	.070	.047	.367	1.486	.158	1.369

Dependant variable: IPQ total score

Note. B = unstandardized regression coefficient; SEB = standard error; β = standardised regression coefficient; t = t-statistic; Sig. = significance; VIF = collinearity statistic

*p < .0083

Another regression analysis was used for the second hypothesis, which states that the Big 5 and MR might be able to predict how many items one interacts with in the VR environment. No significance was found for this model ($R2$ =.19, F(76,056) = 0.531, p = .78) and no predictors had any significance (Table 3).

Table 3

Summary of multiple regression analysis

Variables	B	SEB	β	t	Sig.	VIF
Openness	-.1.231	1.570	-.274	-.784	.446	2.100
Conscientiousness	-1.073	.966	-.314	-1.111	.285	1.376
Extraversion	.447	.800	.169	.559	.585	1.576
Agreeableness	-.812	1.821	-.125	-.446	.663	1.354
Neuroticism	-.098	1.211	-.030	-.081	.937	2.309
Mental Rotation	-.102	.364	-.079	-.279	.784	1.383

Dependant variable: Interaction

Note. B = unstandardized regression coefficient; SEB = standard error; β = standardised regression coefficient; t = t-statistic; Sig. = significance; VIF = collinearity statistic

*p < .0083

Lastly, as an exploratory analysis, the Big 5 and MR scores were checked against each subscale of the IPQ to have a clearer picture of the relationships with the subscales. The following results were noted, the analysis looking at the IPQ SP subscale was not significant ($R2$ =.40, F(3.302) = 1.679, p = .19), the model containing the IPQ INV subscale also showed no significance ($R2$ =.30, F(6.801) = 1.077, p = .42), as did the model with the IPQ REALISM subscale ($R2$ =.45, F(9.790) = 2.060, p = .12). Analysis for each of the predictors showed Mental Rotation ability in relation to the Realism subscale and Neuroticism in relation to the Spatial Presence subscale, to have a significance level below

.05 (see Table 4 and 5). Furthermore, both predictors show an effect size (*f2*) of 0.34. Due to multiple testing however, Bonferroni correction was used to minimise the chance of inflating alpha levels, which resulted in a lower value for statistical significance ($p < .0083$).

Due to the small number of participants, the required sample size was calculated, at which sufficient power would be reached for the presented effect sizes. Alpha error probability was set to .0083 (6 predictors) and power level was set to .8. Results showed a required sample size of (*N*) 67 participants.

Table 4

Summary of exploratory regression analysis (IPQ Spatial Presence)

Variables	B	SEB	β	t	Sig.
Openness	.155	.183	.244	.844	.412
Conscientiousness	.018	.113	.038	.160	.875
Extraversion	.165	.094	.446	1.761	.099
Agreeableness	-.128	.213	-.139	-.599	.558
Neuroticism	.314	.139	.687	2.261	.039
Mental Rotation	-.029	.042	-.160	-.684	.504

Dependant variable: IPQ Spatial Presence subscore

Note. B = unstandardized regression coefficient; SEB = standard error; β = standardised regression coefficient; t = t-statistic; Sig. = significance; *$p < .0083$

Table 5

Summary of exploratory regression analysis (IPQ REALISM)

Variables	B	SEB	β	t	Sig.
Openness	-.532	.285	-.517	-1.865	.082
Conscientiousness	-.088	.176	-.113	-.500	.624

Extraversion	-.210	.146	-.350	-1.441	.170
Agreeableness	-.359	.332	-.241	-1.098	.380
Neuroticism	-.224	.216	-.301	-1.036	.316
Mental Rotation	.150	.066	.509	2.274	.038

Dependant variable: IPQ Realism subscore

Note. B = unstandardized regression coefficient; SEB = standard error; β = standardised regression coefficient; t = t-statistic; Sig. = significance; *$p < .008$

Discussion

This study aimed to contribute to the scientific literature on VR experiences, by finding out whether personal characteristics such as personality and MR, influence how people experience and interact with virtual environments. It was hypothesised that people that are more extraverted and open, would experience the environment to be more realistic and show increased interaction, than people lower in those traits. Furthermore, it was also assumed that individuals with a better ability to mentally rotate objects would feel more immersed in the virtual environment, leading to heightened feelings of realism and increased interaction in comparison to individuals with lesser MR capabilities. None of the analyses showed significance, though through means of an explorative approach positive patterns could be identified for MR and Neuroticism. Possible theoretical explanations are discussed for each of the predictors, after which methodological considerations, strengths and weaknesses are presented.

Personality Traits

Openness to Experience

Previous research on Openness to Experience is rather ambiguous. While some studies report on effects (Budhram, 2021; Stavropoulos et al., 2016; Weibel et al., 2010), others do not (Grassini et al., 2021; Sacau et al., 2005). In our study Openness to Experience does not show a relation to Sense of Presence, nor is it related to interaction. A possible explanation for these ambiguous findings is that different studies use different tests to assess sense of presence. Indeed a study by Kober & Neuper (2012) shows that the use of different presence measures brought up heterogeneous findings in relation to the Big Five. Furthermore and opposed to our study, many of the studies mentioned used a gaming VR experience, which might increase the effect of Openness as it has been demonstrated to be associated with immersion in games (Graham & Gosling, 2013). Thus, Openness cannot

be confidently dismissed nor confirmed in its correlation to presence. Regarding interaction, some studies report that openness does influence how participants act within virtual environments. As shown by the study by Katifori et al. (2022), individuals higher in Openness were able to start and perform their task faster than people lower in the trait, underlying increased spontaneity and creativity. However, these studies mainly measure object manipulation as task performance that is instructed, while our study aimed to look at interaction in a more ‘’natural’’ way. A problem with that is that the virtual objects did not physically behave realistic enough. Sounds could have been added when objects are thrown and paint tubes could have been made squeezable so that paint would come out and be usable for drawing. In fact, many participants reported that they tried to interact with the objects in such ‘’life-like’’ ways but were unable to. Adjusting the objects to react to the user more realistically might be a way to increase engagement enough to see differences between individuals.

Extraversion

The literature on Extraversion is even less conclusive as relationships between the trait and feelings of presence in different studies are either positive, negative or non-existent (Budhram, 2021; Jurnet & Maldonado; Grassini et al., 2021). This study did not find a significant effect for Extraversion on any measure of presence or interaction. Many reasons as to why this might be the case connect to possible reasons why effects for Openness were not found (sample size, different tests, inadequate operationalisation of interaction). However, it might also be the case that our environment in specific did not evoke Extraversion. Extraversion itself is associated with a heightened need and want for social interaction, our environment however was not socially stimulating. In fact, looking at the studies in which Extraversion showed effects, they are mostly engaging the users with commands and somewhat ‘’social’’ content (Fishing game in study by Budhram (2021), Classroom and Metro conditions in study by Jurnet & Maldonado (2010)), while studies that did not find effects, have the user take a more passive role (Sacau et al., 2005; Grassini et al., 2021). Extraverts are known to express their personality through means of online-gaming by interacting with other players and characters (De Hesselle et al., 2021). It is therefore not unlikely to assume that they would respond more strongly to social stimuli within virtual environments.

Neuroticism

Using an exploratory approach, Neuroticism showed notable patterns in the sample in regards to how much individuals felt like they were existing within the presented environment (Spatial Presence). A positive relationship between Neuroticism and Spatial presence might exist, considering that even the large effect size of this finding requires a sample size of at least triple the amount that was recruited. Generally, Neuroticism itself is

not linked to feelings of presence (Grassini et al., 2021; Budhram, 2021; Laarni et al., 2005). The trait is described as the propensity to experience increased negative emotions, therefore the nature of the trait might explain why an effect is likely to be observed. In fact, it has been demonstrated that experiencing negative emotions is associated with an increased employment of and reliance on sensory processes (Kensinger, 2009), meaning that the individual is more focused on their surroundings through the means of their senses. Coupled with the highly immersive environment we used, it comes to no surprise that Spatial Presence in particular seems to be affected. This is further strengthened by the finding that Neuroticism is positively correlated to one of the key components of presence: absorption, which describes the tendency to become occupied with (media)-objects (Laarni et al., 2005). Though our virtual environment was not designed to elicit negative emotions, it might be that participants higher in Neuroticism felt more stressed or nervous and therefore had a more vivid experience of the environment.

Mental rotation

Mental Rotation ability showed a positive pattern in relation to experienced realism. A possible relationship between these factors is suggested, as insignificance is likely due to a lack of power, demonstrated by the sample size calculation based on the effect size of the finding. While previous literature finding a positive relationship between Sense of Presence and MR notes that individuals with an increased Mental Rotation ability might experience the environment in a more stimulating way (Grassini et al., 2021), there might be an actual link to motor processes. A study by Wexler et al. (1998) for example supports the theoretical connection between pathways used for motor processes and mental rotation of non-body objects. The Movements of participants were directly linked to their performance on a mental rotation task. Though it needs to be noted that they were moving while performing the task, we stipulate that it might be that individuals' ability to move within virtual environments is guided by their level of mental rotation ability. Being able to mentally conceptualise how objects within the environment look from different angles and moving towards those in corresponding ways, such as is done in the real world, could explain the relationship with experienced realism. One would assume that interaction would also be positively correlated to MR, as it is an extension of the concept of presence, however this study could not find an effect. While this specific dynamic has not been studied before, research about presence and Spatial Cognition performance does state a relationship between the two, in which Sense of presence predicts how well individuals are able to solve spatial tasks in VR (Maneuvrier et al., 2020). We raise the possibility that spatial cognition modulates the way VR is perceived and interacted with.

Strengths and Weaknesses

It is suspected that this study was mainly unable to find significant effects due to its small sample size. Even larger effect sizes as demonstrated by Neuroticism and MR in respect to certain IPQ subscales, would have needed a sample three times as big as the one used. In addition, multiple testing necessitated the use of rigid Bonferroni correction, which further suppressed significance levels. Another possible flaw might have been the operationalization of interaction. It might be the case that differences in interaction were more random due to the lack of instructions given. Many participants spent a considerable amount of time navigating through the environment and grabbing non-interactive objects. Due to limited time (3 minutes), it is quite plausible that there was not enough standardisation between subjects to detect effects of personal characteristics. Despite the limitations of this study, interesting patterns could still be identified, resulting in important contributions to the field. Additionally, the used VR environment is highly immersive as opposed to environments used by other studies. This results in a better ecological validity when trying to compare results to real world findings. This point also ties to the way we looked at behaviour. No game elements were included, the environment was designed to mimic a ‘’natural’’ room and thus capture behaviour that is more realistic. Though some alterations need to be made to the objects to behave more life-like as explained, we think that it is important to keep looking at uninstructed modes of behaviour in VR. Furthermore, while correcting for multiple testing negated some findings, it is stressed that correction was used to ensure proper scientific practice by not inflating the significance level. Many studies mentioned did not note running any corrections for their analyses which is another point that can be raised when trying to explain the ambiguous literature.

Taking the findings and limitations of this study into consideration, it is suggested to use a large enough sample size (min. 67 participants) to have sufficient power for the analyses. Furthermore, it is encouraged to minimise the amount of testing done in the same sample by focusing on variables that are especially of interest. Since the exploratory approach showed some promising results regarding Neuroticism and Mental Rotation ability, we encourage further research to look deeper into those relationships. Furthermore, it might be helpful to make the interaction with the environment more clear, by pointing out specifically which items one can use. It is also recommended to add measures of time (time spent interacting / time of first interaction) instead of only counting the number of items that were picked up. Alternatively, pathways to guide participants through the virtual room could be included to tackle the problem of a lack of standardisation. In connection to these augmentations, it is also recommended to increase the amount of time that participants are exposed to the virtual experience.

To conclude, this study adds to the research concerning personal characteristics that influence presence in VR. We were able to establish meaningful practical and theoretical connections to the findings and hope to inspire future research to further look into these relationships. Furthermore, we provided some foundational work for certain constructs such as uninstructed interactions in VR and MR in connection to interaction with 3D objects, that have not been tested before. We offered suggestions for improvement of these constructs so that they can be taken into consideration in the future. It became apparent that personal characteristics cannot be disregarded and come in addition to immersion to create a certain level of presence. While some promising results are demonstrated by this study, it is also clear that a lot more research needs to be directed at this topic. Having a conclusive body of evidence regarding factors that influence feelings of presence in virtual environments is of utmost importance for the further development of VR media that can be consumed privately or used for therapeutic purposes. It also adds meaning and importance to the human aspect of the collaboration between technology and the individual.

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