

The Relationship Between Personality, Recalled Cybersickness Severity, and Recalled Cybersickness Recovery Time

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Characteristics of a virtual reality user are known to affect cybersickness, but the specific role of individual differences, such as personality, is largely unknown. This study addressed this gap through examination of subjective recall survey data relating to experiences in virtual reality, including severity of cybersickness symptoms, cybersickness recovery time, and personality. Mediation structural equation modeling on data from 203 participants who used virtual reality at least once per month indicated that extraversion, agreeableness, and conscientiousness were associated with cybersickness severity and that severity was associated with cybersickness recovery time. Further, cybersickness severity fully mediated the relationship between personality and recovery time. These findings highlight the potential relationship between individual differences in personality and suggest further investigation into cybersickness with experimental data and validated measures.

INTRODUCTION

Motion sickness has been studied for decades due to its widespread prevalence in a variety of environments where motion is common, including travel by car, boat, plane, and train. Beyond daily commuters, it has also afflicted those training as pilots and astronauts, creating barriers for individuals in these professions. Virtual reality (VR) is a cost effective, alternative training environment that can be utilized to train these individuals. However, VR can also lead to its own form of sickness, known as cybersickness (Stanney et al., 2020), which is impacted by four types of characteristics: hardware and software, virtual environment design, tasks, and the user (Wiederhold & Bouchard, 2014). However, the role of individual characteristics, such as personality, in cybersickness remain unclear. To better understand how to create accessible virtual environments that account for individual differences in cybersickness susceptibility and recovery, we can look to extant research on the relationship between motion sickness and individual differences in personality.

Cybersickness

Cybersickness is motion sickness specifically attributed to VR, augmented reality (AR), and other virtual experiences in the absence of physical motion (Stanney et al., 2020). Cybersickness has been studied for many years under various names including simulator sickness (Kennedy et al., 1993) and visually induced motion sickness (VIMS) (Kennedy et al., 2010). While the root of cybersickness is yet to be determined, three main theories attempt to explain the phenomenon. First, the ecological theory states that cybersickness originates from postural instability (Kemeny et al., 2020; Riccio & Stoffregen, 1991). Second, the rest frame theory (Prothero, 1998; Kemeny et al., 2020) states that a stationary object must be in an individual's field of view to reduce feelings of motion sickness. If this reference frame is not available in VR, the prevalence of cybersickness is much higher (Kemeny et al., 2020). Third is the sensory conflict theory, which suggests that cybersickness is due to a mismatch of different sensory inputs

(i.e., vestibular and visual) involved in motion perception (Kemeny et al., 2020; Reason & Brand, 1975). If one of these systems is given different information than the other, such as standing still but moving visually through a virtual space, this can lead to cybersickness (Turner et al., 2000).

While such theories are valuable in theorizing about the origin of symptoms, research on individual differences in cybersickness can be used to better pinpoint characteristics that make certain individuals more sensitive to the effects of VR and slower to recover.

Individual Differences in Cybersickness

It is critical to consider individual user needs to avoid undesirable side effects of cybersickness. Some individuals may be up to 10,000 times more susceptible to motion sickness symptoms (Lackner, 2014). Experience of cybersickness and motion sickness symptoms are significantly related (Gavgani et al., 2018), suggesting that some individuals may also be highly susceptible to cybersickness symptoms, making virtual environments potentially inaccessible for certain populations. For instance, women (Jasper et al., 2020; Munafò et al., 2017), and older individuals (Arns & Cerney, 2005) have been found to be more susceptible to cybersickness, whereas those who play video games more often are less susceptible (Jasper et al., 2020). Additionally, there is some evidence for individual differences in cybersickness recovery such that women experienced a greater reduction in cybersickness symptoms in 10 minutes after discontinuation (Jasper et al., 2020). Beyond demographic differences in susceptibility, understanding the role of personality in cybersickness may provide important insights due to links between personality and health (Takahashi et al., 2013).

There is limited research on the relationship between personality traits and cybersickness, an extended reality (XR) health indicator. A recent study found no correlations between Big-Five personality traits (i.e., neuroticism/emotional stability, extraversion, openness, agreeableness, and conscientiousness) and cybersickness (Golding et al., 2021),

but other findings link greater anxiety, a facet of neuroticism, to more severe cybersickness symptoms (Stelling et al., 2021). Further, anxiety has been found to mediate the relationship between VR setting and nausea and disorientation (Pot-Kolder et al., 2018).

Despite the limited investigation with VR, personality has been linked to self-reported health (Takahashi et al., 2013), which further suggests a possible relationship to cybersickness. For instance, neuroticism is connected to lower reported health, whereas extraversion, openness, and conscientiousness are related to more positive reports of health (Letzring et al., 2014; Magee et al., 2013), perhaps due to a stronger inclination to report symptoms. Those who are more agreeable tend to report themselves with fewer symptoms (Mroczek & Spiro 3rd, 2007), potentially because they are less inclined to “create a fuss.” Because there is limited information about the relationship between personality and cybersickness, motion sickness research may help draw additional connections about the role of individual differences in personality and cybersickness.

Individual Differences in Motion Sickness

Research on individual differences and motion sickness suggest that personality may play a role in symptoms (Gordon et al., 1994), but findings are mixed. Motion sickness susceptibility has been correlated with neuroticism (Reason & Brand, 1975; Shupak & Gordon, 2006), introversion (Shupak & Gordon, 2006), and anxiety (Owen et al., 1998). Additionally, personality-related factors including trait-anxiety, locus of control, and repression-sensitization can have a significant impact on the susceptibility of motion sickness (Keinan et al., 1981; Stelling et al., 2021). However, other research has shown that there are no significant correlations between the Big-Five personality inventory and motion sickness susceptibility (Golding, 2006; Nieto & Golding, 2006).

Although there are conflicting findings in personality and motion sickness research, it is clear that there are individual differences that may show disparities in motion sickness susceptibility. Lackner (2014) and Gilbert et al. (2021) have theorized about possible susceptibility, adaptability, and recovery of motion sickness, claiming that multiple states and traits can affect susceptibility (Gilbert et al., 2021; Lackner, 2014).

Motivation and Purpose

Research on the relationship between personality and cybersickness, as well as personality and recovery from motion sickness or cybersickness, is limited. It is crucial to understand the role of personality and cybersickness as a health indicator in order to develop more accessible virtual environments. Health personality research demonstrates that personality is significantly connected to health outcomes (Martin et al., 2020) and health trajectory (Kern & Friedman, 2011). As such, further investigation into the impact of personality on cybersickness as a type of health outcome is warranted.

While there exists some evidence for the relationship between certain personality domains and motion sickness, it remains unclear whether these relationships, or others, also impact cybersickness susceptibility and recovery. The purpose of this study is to understand how personality is directly and indirectly related to subjective, recalled cybersickness severity and cybersickness recovery time in order to better understand individual differences that contribute to the experience of cybersickness (Figure 1). A further understanding of personality’s impact on sickness may give insights into the true nature of cybersickness and promote development of more accessible virtual environments.

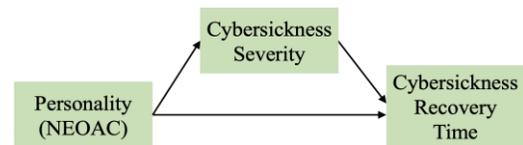


Figure 1. The hypothesized relationship between personality (NEOAC: neuroticism, extraversion, openness to experience, agreeableness, conscientiousness), cybersickness severity, and cybersickness recovery.

METHODS

Participants

The sample originally included 683 participants (206 female, 358 male, 4 missing responses). We excluded individuals who did not use VR at least once per month or did not respond to this question ($n = 457$ excluded), those who had missing responses for all dependent variables ($n = 22$ excluded), and those who were younger than 18 ($n = 1$). The final sample consisted of 203 participants (38 female, 159 male, 2 non-binary, 2 transgender, 2 prefer not to answer) ranging in age from 18 to 64 (mean = 28.8). Participants were recruited from a large US university, LinkedIn, and VR-related Reddit pages. All participants reported using VR at least once per month: Once per month ($n = 15$); 2-3 times per month ($n = 30$); Once per week ($n = 29$); 2-3 times per week ($n = 80$); Every day ($n = 49$).

Survey Design

The purpose of this survey was to understand individuals’ experiences within virtual environments, including their predisposition to motion sickness, details of their VR usage, and experiences with cybersickness symptoms as it relates to individual characteristics, such as demographics and personality.

Variables

Personality. The Big Five Inventory-10 (Rammstedt & John, 2007) was used to assess the five personality domains of neuroticism (e.g., “I see myself as someone who gets nervous easily”), extraversion (e.g., “I see myself as someone who is outgoing, sociable”), openness to experience (e.g., “I see myself as someone who has an active imagination”), agreeableness (e.g., “I see myself as someone who is generally trusting”), and conscientiousness (e.g., “I see myself as someone who does a thorough job”). Response options ranged

on a Likert scale for “Disagree strongly” (1) to “Agree strongly” (5). Select items were reverse coded, and scales were summed (two items per subscale) for scores that ranged from 2 to 10.

Sickness severity. The survey asked three separate questions regarding the severity of their nausea symptoms, oculomotor discomfort symptoms, and general disorientation symptoms from exposure to VR environments. These three questions were inspired by the Simulator Sickness Questionnaire (SSQ), which contains three subscales pertaining to experiences of nausea, oculomotor strain, and general disorientation (Kennedy et al., 1993). Responses to our items were rated on a scale with options “No symptoms” (1), “Mild” (2), “Moderate” (3), and “Severe” (4). The responses from these three questions were summed for a total Sickness Severity variable that ranged in possible scores from 3 to 12.

Recovery time. To understand individual cybersickness recovery time, participants were asked, “How long after exiting a virtual environment does it typically take for symptoms to subside?” Responses ranged from “No symptoms” (1) ($n = 45$), “Less than 10 minutes” (2) ($n = 75$), “10 to 30 minutes” (3) ($n = 45$), “30 to 60 minutes” (4) ($n = 20$), and “More than 60 minutes” (5) ($n = 11$).

Data Analyses

Data analyses were completed in SPSS 26 (for descriptive statistics) and Mplus version 8.1 (for modeling). A structural equation model (SEM) was completed to examine the direct effects between personality (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness), cybersickness severity, and cybersickness recovery time (Tabri & Elliott, 2012). This SEM was run as a mediation model using bootstrapping to examine the indirect effects of cybersickness severity on the relationship between personality and cybersickness recovery time.

RESULTS

The hypothesized mediation model fit was optimal, indicating the data fit the model well ($\chi^2 (df = 11) = 114.99$, $p < .01$, RMSEA = .00, CFI = 1.00) (Figure 2). No modification indices were available to improve the fit. The exogenous personality variables were all significantly correlated with one another.

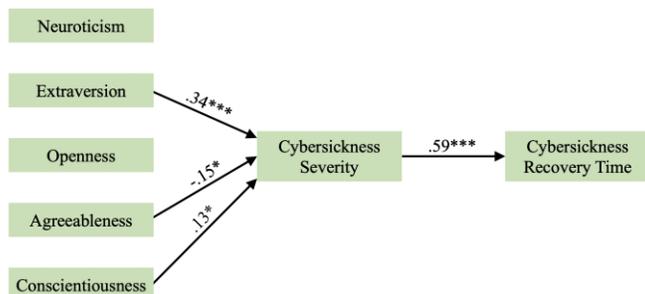


Figure 2. The significant mediation model between personality, cybersickness severity, and cybersickness recovery time. Only significant pathways are shown. * $p < .05$, ** $p < .01$, *** $p < .001$.

Predicting Cybersickness Severity

Personality was significantly associated with cybersickness severity. Specifically, a higher level of sickness severity was predicted by greater extraversion ($\beta = .34$, $p < .001$), lower agreeableness ($\beta = -.15$, $p < .05$), and greater conscientiousness ($\beta = .13$, $p < .05$) (Table 1).

Table 1. Direct effects between personality domains, cybersickness severity, and cybersickness recovery

	β	SE
Cybersickness Severity		
Neuroticism	-.10	.10
Extraversion	.34***	.07
Openness	-.02	.07
Agreeableness	-.15*	.07
Conscientiousness	.13*	.07
Cybersickness Recovery		
Cybersickness Severity	.59***	.05
Neuroticism	.02	.07
Extraversion	.04	.08
Openness	.08	.05
Agreeableness	.07	.07
Conscientiousness	.09	.06

Betas represent standardized path estimates. * $p < .05$, ** $p < .01$, *** $p < .001$.

Predicting Cybersickness Recovery Time

While personality significantly predicted cybersickness severity, there were no significant relationships between personality and cybersickness recovery time. However, cybersickness severity was significantly associated with cybersickness recovery time, such that greater severity predicted longer recovery time ($\beta = .56$, $p < .001$).

Cybersickness Severity as a Mediator Between Personality Recovery Time

Cybersickness severity significantly mediated the relationship between extraversion and recovery time ($\beta_E\beta_S = .20$, $p = .00$, 95% CI = .12, .28), agreeableness and recovery time ($\beta_A\beta_S = -.09$, $p = .04$, 95% CI = -.18, -.01), and conscientiousness and recovery time ($\beta_C\beta_S = .08$, $p = .05$, 95% CI = .00, .16). Due to complete mediation, these findings indicate that severity of an individual’s cybersickness symptoms accounts for the relationship and variance between their personality and cybersickness recovery time.

DISCUSSION

We examined the predictive relationship between personality (i.e., neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness), cybersickness severity, and cybersickness recovery time from subjective recall through survey data. Additionally, we investigated the mediating role of cybersickness severity on the relationship between personality and recovery time to better understand the complexity of individual differences in the experiences of cybersickness. Personality was found to be related to cybersickness, but not in an entirely expected way.

Inconsistent with previous research, neither cybersickness severity nor recovery time were significantly related to neuroticism, which encompasses trait anxiety (Flett et al.,

1989). Anxiety has been linked to motion sickness (Owen et al., 1998), so it is not inconceivable that anxiety is related to virtual experiences that cause sickness symptoms. It is possible that because the data involve subjectively recalled experiences, participants downplayed or misremembered the distressful experiences they had, largely in line with memory recall research (Urban et al., 2019). Further, a closer examination of the neuroticism items from the Big-Five Inventory-10 reveal that the two neuroticism items asked are not specific to anxiety; rather they pertain to handling stress well and getting nervous easily. Using a longer version of the Big-Five scale, which includes a wider variety of neuroticism items, may bolster this statistical relationship.

Greater extraversion was associated with more severe cybersickness symptoms. While it is somewhat unclear why extraversion, characterized by being outgoing, sociable, and gregarious, is related to severity of symptoms, it is possible that individuals higher in this personality trait are more comfortable disclosing and recalling their previous experiences, or even more willing to participate in the survey, than a less extraverted individual. While this may somewhat overlap with openness to experiences, extraverted individuals may also be more motivated to seek out socially engaging virtual experiences, such as co-op game play with friends, especially during the COVID-19 pandemic, well known for social gathering and travel restrictions (Gostin & Wiley, 2020). The more virtual experiences an individual partakes in, regardless of intrinsic motivation (e.g., social time), makes them more likely to engage with environments that induce symptoms. The potential symptom reporting bias between individuals with high and low extraversion could be better accounted for by using objective measures of cybersickness.

Likewise, it may initially seem surprising that openness to experience was not associated with cybersickness if people higher in this trait are seeking to engage in virtual experiences more often or try new types of virtual experiences. However, research has suggested that there are individual differences in motion sickness adaptability, such that repeated exposure to virtual environments may result in greater adaptation and fewer symptoms, which could be applied to cybersickness inducing environments (Lackner, 2014). Given the idea of cybersickness adaptability, it is also plausible that greater openness could be negatively associated with cybersickness severity, depending on the context of exposure (e.g., type of environment, length of exposure, etc.). Building off this idea, the sample consisted of VR users, some of whom use VR every day. Because of this, it is possible that participants were more adapted to VR due to more frequent use, thus reducing the relationship between openness and cybersickness severity.

Agreeableness, characterized by a tendency to agree with others and to value harmonious interactions, was associated with less severe cybersickness. The reporting of less severe symptoms in those with higher agreeableness may reflect these individuals' drive to "not rock the boat" by saying their experiences were not challenging or uncomfortable. These findings align with previous research that found agreeable individuals to perceive themselves as healthier (Mroczek & Spiro 3rd, 2007). This may once again reflect subjective reporting bias, similar to those with higher extraversion.

Greater conscientiousness was positively related to more severe symptoms. This finding reflects literature on conscientious individuals and health personality, such that they are more likely to be highly aware of their physiological experiences and thus report more accurately (Martin et al., 2020). However, this is in contrast to personality and health research that tends to report a positive relationship between conscientiousness and health (Magee et al., 2013).

Cybersickness severity fully mediated the relationship between recovery and extraversion, agreeableness, and conscientiousness. Full mediation indicates a causal relationship (Zhao et al., 2010) such that the mediator (cybersickness severity) causes the relationship between personality and cybersickness recovery. This conclusion, although supported by the current analyses, should be re-evaluated with data collected immediately after exposure and with more extensive measures of cybersickness, such as the Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993), the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ) (Keshavarz et al., 2019), and objective sickness data. However, the current findings support the idea of interdependent relationships between personality, cybersickness severity, and cybersickness recovery and warrant future research integrating personality variability.

CONCLUSION

Motion sickness has been studied for many years due to its impact on a variety of fields and now cybersickness has become a prominent subject of interest. VR has been proposed as a cost-effective tool for training, however the prevalence of cybersickness has created barriers to entry. Research on individual differences of users, one of the four characteristics affecting cybersickness, may be able to give deeper insights into the nature of cybersickness. These preliminary findings indicate that there may be a relationship between personality, cybersickness severity, and cybersickness recovery, supporting the need for deeper investigations.

Future Directions

The current research provides valuable groundwork for future research on cybersickness and personality using extended assessments of personality, such as the Big Five Inventory (John & Srivastava, 1999) or NEO-PI-R (Costa & McCrae, 1992). First, studies should compare personality with standardized, commonly used experimental measures of cybersickness, such as the SSQ (Kennedy et al., 1993) or the VIMSSQ (Keshavarz et al., 2019), to make stronger claims about these relationships. Similarly, the second area for future work is the comparison between personality and potential objective proxy measures of cybersickness, such as postural sway. This would not only help with inaccurate reports of cybersickness symptoms and validating subjective measures (e.g., SSQ), but also help reduce possible response bias based on personality traits (e.g., high agreeableness leading to lower reports of symptoms). Finally, given this research excluded VR novices, studies should compare adaptation between novices and experts to better understand differences in adaptation to VR. Taken together, this study provides a

valuable glimpse into the impact of personality on cybersickness and can be used to guide research on individual differences in cybersickness susceptibility and recovery.

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