Individual Differences and Contextual Influences on Group Behavior in Virtual Reality: An Exploratory Person-Environment Interactionist Perspective

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Abstract

In virtual reality (VR), people can transform both who and where they are with the touch of a button. While many studies have examined each of these factors individually, few have examined how they interact. Person-environment (P-E) effects are critical to investigate because they can help scholars understand meaningful social and behavioral dynamics like group cohesion (e.g., entitativity), non-verbal social behaviors (e.g., social attention), and simulator sickness. We analyzed participant data from a large university course conducted in VR to understand how the interaction of individual level variables (e.g., personality) and environment level variables (e.g., the setting, spaciousness of the virtual environment) associated with such dynamics. A limited number of P-E effects emerged, including the idea that people high on extraversion in a panoramic environment reported the greatest entitativity. Implications of this interactionist perspective for exploratory social VR research, plus practical implications for collaboration in VR, are discussed.

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Virtual reality (VR) provides people with experiences that seem genuine but can be physically impossible in the real world. These unique experiences are facilitated by a range of VR affordances, which permit the perceptual immersion of its users and provide real-time reactions to their body movements. Over two decades of scholarship, for example, suggest that VR experiences can lead to prosocial behavior (Aitamurto et al., 2021; Herrera et al., 2018), bias mitigation (Peck et al., 2013), and recovery from self-harm (Kruzan et al., 2020). Such technology can be effective and engaging in educational settings (Moreno & Mayer, 2002; Parong & Mayer, 2018). People can learn about complex scientific topics like climate change and pro-environmental behaviors (Ahn et al., 2015; Markowitz et al., 2018), doctors can be trained on challenging medical procedures (Ruthenbeck & Reynolds, 2015), and construction site supervisors can receive vocational training (Francis & Paton-Cole, 2021), to list just a few examples. Together, a wealth of evidence suggests people learn in immersive VR and the technology creates psychologically impactful experiences (Bailenson, 2018a; Blascovich et al., 2002). However, researchers know surprisingly little about how individual differences and one's virtual environment interact to shape how people think, feel, and interact with others. To what extent do people vary in how they interact individually and in groups in VR, and what psychological mechanisms explain this variation? We address these questions by taking a person-environment (P-E) perspective to understand how participants experience small group social interactions in a VR classroom during an 8-week university course.

The idea of evaluating P-E effects in VR is timely and important for several reasons. First, most VR research considers mean differences across experimental groups to identify how

VR experiences change perceptions or behaviors. For example, consider studies that aim to understand how embodying different avatars affects behaviors (Van Der Heide et al., 2013; Yee & Bailenson, 2007). We understand these findings by averaging the results of people in VR studies out of convenience to create group means, though *individuals* embody such avatars, and it is unclear how characteristics of the participants and the environments they are placed in, jointly impact VR experiences. We address a key need in immersive VR research to focus on the interaction of the individual and their environment in shaping entitativity and non-verbal social behavior (e.g., how much people attend to others in an immersive VR experience).

Second, immersive VR effects are often constrained by studies that occur in a laboratory setting. Participants may be placed in scenarios that are fantastical or difficult to replicate outside of the lab (Rosenberg et al., 2013), requiring additional research to assess the effectiveness of VR experiences outside of such laboratory environments. The current research examined participants who learned about VR while taking an academic course on VR, measuring how they interacted with others longitudinally and in a naturalistic setting. We therefore could examine individual differences and P-E effects outside of the lab, relieving ecological constraints of most immersive VR studies to date.

Finally, most VR studies are intrapersonal (e.g., a participant has an experience that is unimpacted by others). As reviewed in other work (Han et al., 2022), few immersive VR studies are social in nature, in that users are rarely connected to each other and interacting dynamically in the same virtual environment. Against this backdrop, we provide one of the first immersive social VR studies to examine P-E effects, offering new insights into how the individual and their environment can impact interactions in social VR.

We ground our work theoretically in Transformed Social Interaction (TSI) research.

Originally published in 2004, the framework helps scholars to understand how virtual systems can transform people and places during interpersonal communication, filtering and modifying cues in real time (Bailenson et al., 2004). The two parameters of the theory that are most relevant to the current work are transforming self-representation (e.g., the behavior and appearances of one's avatars) and contextual situations (e.g., the characteristics of the perceived virtual location). Over the past twenty years, many studies have examined factors such as personality and spatial location individually (for a review, see P. Wang et al., 2024), but there is a lack of research integrating the parameters of TSI to study interaction effects. In the current work, we extend TSI by also measuring how contextual situation variables like setting (e.g., indoor or outdoor virtual environments) and spaciousness (e.g., limited or expansive field of view) interact with individual level variables (e.g., personality, demographics) in social VR. Altogether, TSI is a helpful framework to guide the selection of variables and methodologies to explicate the impact of contextual situations on downstream behaviors in VR (Bolouki, 2024; Han et al., 2023; M. Lee et al., 2022), which is why we apply and extend it in the present work.

An Introduction to Virtual Reality: Affordances and Individual Differences

Immersive VR is a communication medium that typically uses head and hand tracking to allow people to interact naturally within a virtual environment. This is typically made possible through head-mounted displays that offer stereoscopic, high-resolution images in a wide field of view and spatialized sound. Three affordances of immersive VR are central to the medium: presence, immersion, and embodiment. Presence is the psychological feeling of "being there" in a virtual environment (Green & McAllister, 2020; Heeter, 1992; K. M. Lee, 2004; Slater & Wilbur, 1997; Steuer, 1992), or the feeling of non-mediation. People who report high levels of presence (e.g., social presence, self presence, physical presence) tend to feel more engaged during their virtual experience than people who report low levels of presence. This concept is often measured via self-report scales, though not without critiques (Slater, 2004), and is positively linked to how well the technology approximates human movements (Cummings & Bailenson, 2016).

Technological immersion describes media quality, with those that can approximate head and hand movements more efficiently and accurately, considered to be more immersive (Slater & Wilbur, 1997). More immersive media (e.g., immersive VR versus desktop VR) can typically facilitate presence and a more seamless virtual experience than less immersive media. Finally, embodiment is the adoption of an avatar that can approximate one's physical self (Ahn et al., 2016; Peck & Good, 2023). Embodiment can create the illusion of *body transfer*, where people take on the characteristics of their avatar (Biocca, 1997; Botvinick & Cohen, 1998; Slater et al., 2010). Together, while these affordances of immersive VR are presented as separate concepts, they occur simultaneously for users (e.g., the feeling of "being there" in an avatar's body can occur with high-fidelity technology) and define experiences in the medium. Furthermore, advancements in conceptual (e.g., Bente et al., 2008; Slater, 2009; Slater & Steed, 2000) and technical (e.g., Newman et al., 2022; Slater et al., 2009) aspects of immersive VR have further enhanced immersion and the understanding of it, to offer an even more nuanced, multi-faceted understanding of users' experiences.

In VR, the study of individual differences — personal traits or enduring characteristics that distinguish one person from other — has largely focused on four domains: (1) demographics, (2) personality traits, (3) cognitive and psychological factors, and (4) VR-specific characteristics (e.g., one's proclivity to experience simulator sickness). For example, a recent paper studied VR driving simulations and observed that, consistent with evidence from offline settings, male participants drove faster than female participants and older participants drove slower than younger participants (Maxwell et al., 2021). Other work has observed that affective perception and pleasantness of virtual touch was moderated by participant gender (Harjunen et al., 2017). One recent experiment has also observed that female participants performed differently than male participants in spatial updating when teleporting virtually (Cherep et al., 2023). Across various VR scenarios and settings, gender has been shown to moderate VR effects and play a critical role in understanding how people behave in the virtual environment (Adamo-Villani et al., 2008). However, the relevance of other demographics (e.g., ethnicity, age) are not as well understood (Katz et al., 2024; Schwebel et al., 2024), despite there being good reason to expect such factors shape VR and other mediated experiences (e.g., how avatars influence perceptions and behaviors) (Basu et al., 2016; Bowman et al., 2002; Moore et al., 2023; Oh et al., 2016; Ratan et al., 2020).

Prior research also suggests that personality traits can predict individual effects and behaviors in VR (Kang et al., 2025; Y.-M. Wang et al., 2022; Widyanti & Hafizhah, 2022). For example, openness to experience has been shown to be an antecedent to feelings of presence (Weibel et al., 2010; Wirth et al., 2007). Similarly, another study showed that people who believed they had greater control over the outcome of their lives (i.e., a greater external locus of control) also tended to have a greater sense of body ownership in VR compared to those with lower control (Dewez et al., 2019). A recent experiment had actual burglars and university students as participants, measuring individual differences like personality and placing them into a VR task to "scout" a target for burglary (van Sintemaartensdijk et al., 2022). Participants role-playing burglars, who were also high on an honesty-humility personality trait (Ashton et al., 2014; K. Lee & Ashton, 2018), were less likely to spend time scouting a virtual environment for something to steal and traveled less than burglars low on honesty-humility. Moreover, a recent study on the role of personality traits in avatar customization found that participants who scored high on Machiavellianism were more open to creating avatars that modified core aspects of their identity compared to those with high self-monitoring tendencies (Kang et al., 2025).

Another thread of research has explored how cognitive and psychological individual differences can shape performance and perceptions of VR experiences (Han et al., 2024; A. Lawson, 2025). In the context of using VR for education, executive function (i.e., the ability to focus on new information without distraction) and working memory capacity (i.e., how much information one can keep in their mind at a time) exhibited higher posttest learning performance (A. P. Lawson & and Mayer, 2025; A. P. Lawson & Mayer, 2024). Other scholars have explored the role of neurodiversity in sensory perception of VR (Boyd et al., 2018). Hence, one's ability to process sensory information and learn within the perceptually demanding medium of VR can be affected by differences in cognitive factors. Performance can also be susceptible to psychological factors, such as computer anxiety. A recent experiment found that compared to those with low computer anxiety, participants with high computer anxiety had more difficulty completing tasks in VR and reported having a more negative view of their VR experience (Han et al., 2024).

Finally, another important individual difference pertains to VR-specific characteristics such as simulator sickness (Kourtesis et al., 2024). Simulator sickness refers to one's experienced discomfort while in virtual environments, and is characterized by nausea, dizziness, eye-strain, and headaches. Women and females, on average, are more likely to report effects of simulator sickness than men and males in VR (Howard & Van Zandt, 2021; Weech et al., 2019), which may be explained by interpupillary distance differences between sexes and/or genders (Dodgson, 2004; Murray et al., 2017). A recent paper replicated this general trend using 80, 360°-video stimuli across the topics of people, animals, nature, and underwater scenes (Jun et al., 2022), though the magnitude of the gender effects were small and only occurred in a small number of videos. Similarly, an analysis by Peck et al. (2020) suggested that when considering the small percentage of women in the experiments themselves, as well as possible response biases in admitting one is sick, these gender differences may be inflated. Simulator sickness is typically assessed using self-report measures (Kennedy et al., 1993) and often attenuates as one becomes more familiar with virtuality (Bailenson & Yee, 2006).

Altogether, research about individual differences in VR research has typically considered demographics, personality traits, cognitive and psychological factors, and certain VR-specific characteristics, such as one's proclivity toward simulator sickness. Therein lies an opportunity to build on this empirical foundation and test how individual differences link to a variety of consequential outcomes, like group cohesion (e.g., entitativity), behavioral dynamics in social VR (e.g., social attention), and critically, how person-level factors and environment-level factors, systematically interact to produce P-E effects (e.g., Bailenson et al., 2004).

Person-Environment Effects

Person-environment (P-E) perspectives provide a means of understanding and assessing the factors that explain a behavior of interest (Endler & Magnusson, 1976; Walsh et al., 2014). Research on P-E interactions seeks to answer the following questions: To what extent do (1) characteristics of the individual person and/or (2) their surrounding environment independently shape behavior? Critically, P-E interaction research is *most* interested in: (3) How do the person and environment characteristics interact with one another to shape behavior?

The majority of research relevant to P-E relations has focused on the environment in terms of the natural and built environment (e.g., the home, public places, workplaces, being in nature) or psychological situations in which behaviors occur (e.g., situations perceived to be social) (Meagher, 2020; Oishi & Graham, 2010; Rauthmann et al., 2015). In general, such research demonstrates the effects of personality (e.g., extraverts tend to engage in more social behavior in general) and environments on behavior (e.g., people engage in more social behavior in certain situations) (Funder, 2009; Matz & Harari, 2021; Wrzus et al., 2016). Moreover, the interactive effects of persons and environments suggest that people with certain traits are more (or less) likely to engage in a behavior when in certain environments (e.g., increases in social behavior when in social situations is greater for extraverts) (Breil et al., 2019). Such insights are valuable for determining whether, and to what extent, person and environmental factors shape behavior. However, we are unaware of studies that have adopted a P-E perspective to explain behavior in immersive VR, except for some recent work (Han et al., 2023). Understanding how individuals differentially behave based on location is especially important in VR, where both are malleable and can easily be transformed (Bailenson et al., 2004).

Here, we use the lens of P-E interactions to explain the factors driving entitativity and a key behavior in VR which has been shown to have psychological importance on VR perceptions: non-verbal social behavior (see Bailenson, 2018a, Chapter 7 for a review). For our exploratory interests, we focus on demographic characteristics (gender, ethnicity) and personality traits (the Big Five) as person-level factors that may explain these perceptions and behaviors. The environment-level factors focused on the manipulation of the virtual environment because in VR, one's environment can be modified in ways that the physical environment cannot. Specifically, the virtual environment refers to the virtual surroundings experienced within VR by the person using the headset, which can be characterized by various features (e.g., the setting or spaciousness of the virtual surroundings when a user interacts in VR). How the virtual environment is presented to a user may be associated with different perceptions and social behaviors. For example, prior work suggests non-verbal synchrony increased between social VR users as the virtual space expanded (e.g., in constrained versus panoramic virtual views) (Han et al., 2023). Our work builds on this foundation by examining the moderating role of the setting and spaciousness of the virtual environment in predicting key VR outcomes.

The Current Paper

We took a layered approach to understand how factors related to an individual within a given environment predict entitativity, non-verbal social behavior, and simulator sickness when people interact together via avatars in groups. The dearth of P-E research, particularly in social VR, has been due to pragmatic issues surrounding the complications of managing hardware and software remotely. Until recently, it has been difficult to include multiple users in the same immersive VR environment and simultaneously track individual and group-level experiences. Social VR, such as applications like ENGAGE, make social and group-level VR possible while maintaining the integrity of foundational VR affordances (e.g., presence, immersion, and embodiment). So here, we use social VR to understand how P-E effects associate with entitativity, presenting some of the first work of its kind to evaluate how individual differences, environmental factors, and the interaction of the two relate to entitativity. We then evaluated how individual differences predict the degree to which participants move in relation to one another, attend to others' gaze, and experience negative downstream effects of being in VR like simulator sickness.

Our interests are exploratory, and we therefore do not formalize hypotheses about our key variables of interest, given the scarcity of work that has connected these concepts. The exploratory nature of this work does not undermine its theoretical importance, however.

Exploratory work, defined as “research guided by curiosity and seeking to document a finding or set of findings rather engaging in hypothetico-deductive hypothesis testing or focusing on explanation,” is just as important as confirmatory research in theory development because exploratory work can be useful when it is unclear how concepts will be related (Levine & Markowitz, 2024, p. 157). We seek to examine P-E effects in social VR in the spirit of using such evidence in future, more systematic theory building and developing a greater conceptualization of how the person and their environment jointly impact various group dynamics in social VR.

Method

Participants and Procedure

The present data is a subset of the Stanford Longitudinal VR Classroom Dataset, which includes data from approximately 700 student participants across four years, each of whom took one of four separate IRB-approved studies during courses taught via Meta Quest 2 VR headsets (Han & Bailenson, 2024). While all students who were part of the course took part in all the VR activities, only those who consented to participate in the study contributed data for analysis. Safeguards implemented to ensure privacy and consent included review both by the IRB and a second university ethics organization, and third-party oversight of the consent process and data collection. Participants were reminded of the recording through a visual notification at the beginning of a session or upon joining a session.

The current paper used a dataset on a maximum of 137 consenting participants from one of the courses from that dataset. The full procedure and demographics are described in Han et al. (2023). Participants met in one of 32 groups, ranging from two to 14 members, for eight weekly sessions which lasted about 30 minutes per session. During each session, participants took part in an instructor-led discussion with either the whole group or smaller groups to talk over the material covered in the course. Across all sessions, participants' verbal, non-verbal, and performance data were tracked. Each student provided self-report data about their experience after each session. Multiple aspects of individuals' behaviors and attitudes were measured at the start of the study (pre-test), and during and after each of the eight weekly sessions. To reduce fatigue, repetitiveness, and burden, item sets for each construct were purposely designed to be brief.

To set up the virtual classrooms, each virtual environment was extensively planned, underwent approval to ensure that they met specific requirements, developed by a teaching team, and set up prior to the class. Furthermore, multiple teaching staff were present across media: in person, on video-conferencing calls, and in VR, to ensure students received adequate help throughout their experience both in and out of the virtual environment. Lastly, training sessions and guides were set up to onboard students from various technological backgrounds to ensure the smoothness of the first sessions. Each participant contained 76 megabytes of data, on average, across 8 weeks, after tracking their movements (17 gigabytes in total across participants).

Out of space considerations, please see the online appendix for additional methodological information. Note, underlying data for this study cannot be shared or made public due to conflicts with our IRB protocol, which focused on protecting participant nonverbal and tracking data (Bailenson, 2018b; Miller et al., 2020).

Hardware and VR Equipment

Participants were provided with Meta Quest 2 headsets (standalone head-mounted display with 1832 x 1920 resolution per eye, 104.00° horizontal FOV, 98.00° FOV, 90Hz re- fresh rate, and six-degree-of-freedom inside-out head and hand tracking, 503 g) and two hand controllers

(126 g) for use in their personal environment. Of all the participants, 2 owned personal headsets (Valve Index) and participated using those devices.

Virtual Environment: ENGAGE

All sessions were held in ENGAGE, a collaborative social VR platform designed for education. Every week, the virtual environment consisted of a private (password restricted) area that allowed participants to walk and/or teleport freely, create 3D drawings, write on personal whiteboards and/or stickies, add immersive effects and/or 3D objects, and display media content.

Dependent Variables

Entitativity

Entitativity, which approximated the concept of group cohesion, was measured by eight items adapted from prior work using a 7-point Likert scale (1 = Strongly disagree, 7 = Strongly agree) (Rydell & McConnell, 2005). Sample items include “My discussion group is important to its members” and “Members of my discussion group are affected by the behaviors of other members.” Weekly entitativity scores were calculated as the mean of the seven items (Cronbach’s $\alpha = 0.86$); higher scores indicated greater entitativity than lower scores.

Non-Verbal Social Behaviors

Social Attention. Social attention, defined as the amount of spatial attention allocated to another person in a session, was calculated as the percentage of time an individual had at least one group member’s head within 15° of the center of their HMD’s view. We chose this value based on our prior experience that suggests this degree produces scores that are often normally distributed within a sample; see thresholding technique proposed in prior work (Miller et al., 2021), and because the angle between one’s gaze and head direction is typically less than 15° (Foulsham et al., 2011). Each individual had a social attention outcome per session. Greater social attention indicates an individual spent more time looking at other people in the session.

Simulator Sickness

Simulator sickness was measured by four items adapted from the Simulator Sickness Questionnaire from Kennedy and colleagues (1993) using a 5-point Likert scale (1 = Not at all, 5 = Extremely). Sample items include "I feel my eyes are strained" and "I feel aware of my stomach." Weekly simulator sickness scores were calculated as the mean of the four items (Cronbach's $\alpha = 0.89$), with higher scores indicating greater simulator sickness (Kennedy et al., 1993).

Person-Level Independent Variables

Person-level measures of individual differences used as independent variables were obtained during the pre-test.

Demographic traits

Two demographic variables were evaluated in this study: (1) gender (men $n = 78$, women $n = 59$), and (2) ethnicity (Asian $n = 47$, Black $n = 12$, Hispanic $n = 8$, Indigenous $n = 2$, Middle Eastern $n = 1$, mixed race/ethnicity $n = 19$, Native Hawaiian $n = 5$, and White $n = 40$). We created a level of the ethnicity variable called "other" after combining those with less than or equal to 5 participants. This process helped to ensure statistical model simplicity and stability.[1] We also collected age information on each participant ($M = 20.89$ years, $SD = 2.79$ years), though variation in age for this university sample was expectedly low.

Big 5 Personality Traits

Individuals' ratings for the Big 5 personality traits (Openness, Conscientiousness,

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[1] We excluded participants who listed their gender as "other" or did not answer because of their low prevalence in our sample. We also excluded those who did not answer the ethnicity question.

Extroversion, Agreeableness, and Neuroticism) were measured at the start of the study using the Ten-Item Personality Inventory (TIPI) (Gosling et al., 2003). The TIPI scale consists of two items to measure each of the five dominant personality dimensions. Internal consistencies (calculated using Spearman–Brown formula, as recommended for two-item measures) (Eisinga et al., 2013), across all participants were 0.449 for Openness, 0.689 for Conscientiousness, 0.779 for Extroversion, 0.283 for Agreeableness, and 0.641 for Neuroticism. Low reliability instruments with a small number of items, such as the TIPI scale, are expected, as they were designed to measure broad domains (Gosling et al., 2003). We used this shortened personality scale because of the anticipated effort burden for participants that we wanted to keep reasonable within the context of our study and the course at large.

Environment-Level Independent Variables

The virtual environments varied by two factors: *setting* and *spaciousness*. In the setting condition, environments were either indoors or outdoors. In the spaciousness condition, environments were either constrained (i.e., environments which provided a limited view of the virtual space) or panoramic/panoptic (i.e., environments in which people could see wide and far). Individuals were in one of four types of environments (2 spaciousness x 2 setting): (a) panoramic outdoors, (b) panoramic indoors, (c) constrained outdoors, or (d) constrained indoors. See Figure 1 for visual depictions of these conditions, plus many different virtual environment orientations experienced throughout the course given the stimulus sampling approach to vary the surface details of context while maintaining the theoretical variables constant. Each environment was built by research personnel using 3D objects. In total, there were 192 uniquely built environments that differed in size of moving area and height. These 192 environments contained diverse thematic features, as opposed to relying on a single stimuli manipulation, as recommended by prior work (Reeves et al., 2016).

The moving area of the environments was measured by adding markers to the corners and ceilings of the environments inside ENGAGE and then calculating the areas using the positional data of the markers (see Han et al. 2023 for a detailed account of these scenes). Descriptive information about the different environments is in the online supplement out of space concerns.

[FIGURE 1 HERE]

Analytic Plan

We used linear mixed models with a random intercept for participant to account for within-person dependencies (Bates et al., 2015; Kuznetsova et al., 2020). Therefore, participants had multiple observations for the same measure for each of our dependent variables across weeks, and scores on each measure reflected participants' average rating for the week. We did not add week to our models because we were not theoretically interested in week-by-week effects nor time effects in the current paper. However, post-hoc analyses revealed that adding week as a fixed effect in the interaction models did not substantively change the significant results nor their interpretation.

Given that our primary interests were in P-E interactions, we computed mixed effects interaction models. All models included a person-level factor (e.g., age, gender, ethnicity, each personality variable) interacting with an environment-level factor (e.g., setting, spaciousness). Due to the exploratory nature of this investigation, which operates from a different set of assumptions and conditions than confirmatory investigations, contrasts are not corrected for multiple comparisons unless noted.

Results

Figures 2 and 3 provide histograms of key variables and we organize the results by each dependent variable of interest.

[FIGURE 2 HERE]

[FIGURE 3 HERE]

Entitativity

The results in Table 1 reveal those high on extraversion and in the panoramic condition reported more entitativity than those in the constrained condition (see Figure 4 for a visual depiction of these data).

Social Attention

A significant person × environment interaction effect emerged between ethnicity and spaciousness for social attention (Table 1), where the most systematic differences emerged among Black and White participants across conditions (see top panel of Figure 5 and the online supplement for contrasts out of space considerations).

The bottom panel of Figure 5 suggests a significant agreeableness × spaciousness interaction emerged predicting social attention. Spaciousness, particularly the panoramic condition, interacted with agreeableness the most to impact social attention, suggesting that those high on agreeableness and in the panoramic condition attended to others more often than those low on agreeableness and in the constrained condition.

[FIGURE 4 HERE]

Table 1

Person × Environment Interaction Effect Results

Entitativity	DF*n*	DF*d*	*F*	*p*
Age × Setting	1	809.76	0.41	.521
Gender × Setting	1	811.03	0.71	.400
Ethnicity × Setting	5	806.01	0.96	.439
Openness × Setting	1	812.30	0.66	.417
Conscientiousness × Setting	1	810.45	1.06	.304
Extraversion × Setting	1	811.16	3.71	.055
Agreeableness × Setting	1	812.07	1.26	.262
Neuroticism × Setting	1	811.95	0.21	.650

Entitativity	DF*n*	DF*d*	*F*	*p*
Age × Spaciousness	1	807.11	1.43	.233
Gender × Spaciousness	1	810.02	1.66	.198
Ethnicity × Spaciousness	5	805.80	1.81	.108
Openness × Spaciousness	1	810.52	1.17	.279
Conscientiousness × Spaciousness	1	809.44	1.94	.164
Extraversion × Spaciousness	**1**	**810.26**	**6.25**	**.013**
Agreeableness × Spaciousness	1	809.13	0.29	.591
Neuroticism × Spaciousness	1	811.08	0.09	.767

Social attention	DF*n*	DF*d*	*F*	*p*
Age × Setting	1	826.64	3.12	.078
Gender × Setting	1	839.33	0.10	.748
Ethnicity × Setting	5	831.69	0.69	.627
Openness × Setting	1	843.68	1.17	.280
Conscientiousness × Setting	1	849.48	0.66	.418
Extraversion × Setting	1	835.15	0.05	.820
Agreeableness × Setting	1	842.98	0.47	.494
Neuroticism × Setting	1	845.95	2.36	.125

Social attention	DF*n*	DF*d*	*F*	*p*
Age × Spaciousness	1	826.89	1.78	.183
Gender × Spaciousness	1	839.82	0.01	.913
Ethnicity × Spaciousness	**5**	**836.72**	**2.23**	**.050**
Openness × Spaciousness	1	843.00	0.76	.384
Conscientiousness × Spaciousness	1	839.22	0.40	.528
Extraversion × Spaciousness	1	841.32	1.32	.251
Agreeableness × Spaciousness	**1**	**838.43**	**5.35**	**.021**
Neuroticism × Spaciousness	1	842.21	3.36	.067

Simulator sickness	DF*n*	DF*d*	*F*	*p*
Age × Setting	1	811.10	0.20	.651
Gender × Setting	1	813.77	0.29	.591
Ethnicity × Setting	5	808.76	0.55	.738
Openness × Setting	1	815.29	0.01	.912
Conscientiousness × Setting	1	813.51	0.01	.915
Extraversion × Setting	1	813.66	0.84	.359
Agreeableness × Setting	1	815.48	1.35	.245
Neuroticism × Setting	1	814.98	0.65	.422

Simulator sickness	DF*n*	DF*d*	*F*	*p*
Age × Spaciousness	1	806.71	0.02	.897
Gender × Spaciousness	1	811.45	3.55	.060
Ethnicity × Spaciousness	**5**	**806.59**	**2.68**	**.021**
Openness × Spaciousness	1	812.12	0.38	.536
Conscientiousness × Spaciousness	1	810.89	0.00	.996
Extraversion × Spaciousness	1	812.24	0.05	.827
Agreeableness × Spaciousness	**1**	**810.04**	**4.37**	**.037**
Neuroticism × Spaciousness	1	813.32	0.41	.524

Note. All interactions included lower-order main effects, but they are not reported here out of space considerations. DF*n* = numerator degrees of freedom. DF*d* = denominator degrees of freedom. Bolded statistics are significant at $p < .05$. We reran our mixed models controlling for section size and all significant effects reported in the main text were maintained. We also reran the models controlling for the number of people that individuals interacted with, and all effects were maintained, minus the interactions that predicted simulator sickness, *p*s > .281. Therefore, after accounting for how many people individuals saw in their visual space, person-situation interaction effects appear to be less systematic to predict simulator sickness.

Simulator Sickness

The interaction of ethnicity and spaciousness was statistically significant. The most robust effect concerned White participants in the constrained condition having less simulator sickness than Asian participants in the panoramic and constrained conditions. The interaction of agreeableness and spaciousness was also statistically significant, where those high on agreeableness and in the panoramic condition tended to have more simulator sickness than those high in agreeableness in the constrained condition. While men reported less simulator sickness than women (B = -0.31, SE = 0.13, t = -2.89, p = .018), the interaction of gender and spaciousness was not statistically significant at the 5% level (p = .06), as reported in Table 1.

[FIGURE 5 HERE]

Discussion

A core component of social science research is the focus on the individual and their environment (Lewin, 1935). One's disposition and their environment can have an independent impact on perceptions and behavior. Critically, P-E interactions are just as crucial to investigate as the components themselves (Bowers, 1973; Endler & Parker, 1992), especially when environments need not be fixed, such as with technology like immersive VR. We investigated the interactive role of person effects (e.g., demographics, personality) and environment effects (e.g., the setting, spaciousness) to predict entitativity, nonverbal behaviors, and simulator sickness. While many interaction effects were not statistically significant, a few important P-E interactions still emerged. For example, those high on extraversion and in the panoramic condition felt more entitativity than those low on extraversion and in the constrained condition.

Therefore, in this piece, we present evidence that is some of the first to systematically document how and when certain individual traits and environmental factors jointly impact group dynamics in an immersive, educational, and social VR setting.

There are several contributions of this work that are worth highlighting. First, scholars have been studying human behavior in VR for decades (Blascovich et al., 2002; Steuer, 1992; Zheng et al., 1998). A substantial number of published studies have documented how VR compares to other media, and its feasibility and efficacy in domains such as medicine, education, and social interaction (Bailenson, 2018a). However, despite this important work on the "how" (e.g., how VR can approximate physical world experiences and how to create immersive VR worlds), there is a dearth of research examining the "who" and "where" (e.g., who behaves in particular ways in VR and in what environments). Clearly, as the results in the current study and other research suggest, individual differences matter, and given the complexity of VR as a medium, understanding person-level effects in tandem with environmental effects is a worthwhile research pursuit in both the academic and applied domains.

It is also important to position this research within a broader P-E interactionist perspective and highlight the novelty of certain patterns. First, we observed a significant interaction between extraversion and spaciousness, where people who are high on extraversion and in a panoramic environment felt more entitativity. Why did this effect emerge? Prior work suggests that corporate teams with higher-than-average levels of extraversion tend to work better and receive better reviews from their supervisors than teams with lower-than-average levels of extraversion; crucially, "extraversion [was] associated with team viability through social cohesion" (Barrick et al., 1998, p. 377). Other work also suggests when people have more physical space to move (e.g., a more spacious environment), they self-disclose to others more

(Okken et al., 2013). It is therefore possible that extraverts in a panoramic and spacious environment felt more entitativity because they could talk to more people in their view. The more that a virtual environment is open, the more that extraverts may feel like they can open up and disclose to others verbally. This contention is worth exploring in future work that examines the relationship between personality, virtual environments, entitativity, and language use.

A second relationship worth interrogating is the interaction between ethnicity and spaciousness predicting simulator sickness. Asian participants reported more simulator sickness than White participants, an effect that is likely related to interpupillary distance (Dodgson, 2004; Murray et al., 2017). Immersive VR headsets are often not customized for people of different genders or ethnicities. Our evidence and others suggest a universal headset may be an ineffective way to create a seamless, immersive, and fluid user experience. One relatively simple way to facilitate inclusivity in VR may be to start with hardware and have VR headsets that are more customizable than what are currently offered. It is also possible that for each immersive VR session, headsets should be calibrated to the user. Some headsets provide instructions on how to accomplish this task (VIVE, 2023), but this process can be unintuitive for first-time users. Having hardware and software work for the user and not the user work for the hardware or software is an important development goal for immersive VR in the future. Simulator sickness can have negative downstream consequences for how people think, feel, and behave in VR (Kolasinski, 1995), and the ability to customize headsets can be one way to alleviate this issue.

A novel and actionable finding from the P-E analyses is the interaction between spaciousness and extraversion. Of all the personality metrics, extraversion is likely the easiest one to measure automatically in real-time, either from the amount of utterances by a certain avatar or the percentage of time spent speaking in a group conversation (for examples of studying language in VR, see DeVeaux et al., 2023, 2024). Currently, in most social VR platforms, virtual worlds often "shard." That is, when the worlds are visited by a certain number of avatars, they split into another instance, and subsequent avatars who join a particular world arrive automatically at the second instance. For example, in Meta's *Horizon Worlds*, a typical scene shards after a few dozen avatars join, and at any given moment there are many instances of that particular scene. Sharding is done to ensure the system does not get overloaded by rendering too many avatars within a scene. However, one can imagine creating a sharding algorithm to maximize group cohesion based on the current P-E findings, such that worlds can shard based on extraversion, where groups high in extraverts can experience a panoramic version of a given world while groups low in extraverts experience one that is more constrained. By simply sharding worlds based on a few minutes of speech data, as opposed to an arbitrary binning based on arrival time, platforms such as VRChat, Horizon Worlds, and RecRoom can take a small step to increase the quality of group cohesion in social VR. Given the amount of griefing and negative group interactions that are prevalent on these platforms (Freeman et al., 2022), any positive step will likely have a positive impact.

In addition to these empirical and applied contributions, we — along with other studies (Han et al., 2023; Han & and Bailenson, 2024) — continue to offer a proof-of-concept for how to leverage physical university classrooms for studies in social VR. Given the requirement of this study, as articulated in the method section, we recommend that such studies might be more accessible to other research teams if pipelines of preprocessing tools were built. We call upon a range of academic research teams and industry partners to develop this pipeline collaboratively to make such large-scale, social VR research accessible to all.

Finally, our significant P-E interactions have the potential to be theoretically impactful because they suggest that evaluating the person or the environment in isolation fails to account for other simultaneous effects that occur within the same social VR experience. These results hopefully motivate a new line of theory building, alongside the TSI (Bailenson et al., 2004), encouraging others to take certain P-E interactions seriously, and to explicate why such effects emerge. Examining various mechanisms for P-E effects is an important next step for immersive VR researchers.

Limitations and Future Directions

Our study included participants with a relatively constrained age range. Therefore, expanding our framework to include participants who are non-students and have greater age variability will be important next steps. We also largely limited our person and environmental variables of interest to those with established relevance in the immersive VR research space (e.g., demographics, personality, setting, spaciousness). There are other individual differences and environmental variables worth exploring, however. For example, are Dark Triad personality traits predictive of entitativity and non-verbal social behaviors? To what extent do person-level traits like political ideology relate to who people interact with and choose to embody in immersive VR? These open questions, among many others, are worth examining. Our exploratory tests now provide future directions for additional research, which can also undergo more strict multiple comparisons testing in top-down, confirmatory research that examines specific hypotheses about individual differences, environments, and their interactions.

Another limitation of our research is the scalability of the research paradigm. Despite the profound interest in immersive VR and the metaverse in academic communities, VR is still relatively new and less adopted by mainstream technology consumers. Therefore, it will be crucial to repeat similar studies with people from the general public as immersive VR becomes more mainstream.

Finally, the present study featured students in a university setting who chose to be a part of a class on immersive VR. There might be some meaningful social or psychological difference between students who select this class (e.g., technologically curious individuals, early adopters of media) and those who did not self-select for this class. Future research should examine selection bias more directly when considering who is involved in a VR research study, especially in a VR classroom setting.

References

Adamo-Villani, N., Wilbur, R., & Wasburn, M. (2008). Gender Differences in Usability and Enjoyment of VR Educational Games: A Study of SMILE™. *2008 International Conference Visualisation*, 114–119. https://doi.org/10.1109/VIS.2008.10

Ahn, S. J., Bostick, J., Ogle, E., Nowak, K. L., McGillicuddy, K. T., & Bailenson, J. N. (2016). Experiencing nature: Embodying animals in immersive virtual environments increases inclusion of nature in self and involvement with nature. *Journal of Computer-Mediated Communication*, *21*(6), 399–419. https://doi.org/10.1111/jcc4.12173

Ahn, S. J., Fox, J., Dale, K. R., & Avant, J. A. (2015). Framing virtual experiences: Effects on environmental efficacy and behavior over time. *Communication Research*, *42*(6), 839–863. https://doi.org/10.1177/0093650214534973

Aitamurto, T., Stevenson Won, A., & Zhou, S. (2021). Examining virtual reality for pro-social attitude change. *New Media & Society*, *23*(8), 2139–2143. https://doi.org/10.1177/1461444821993129

Ashton, M. C., Lee, K., & de Vries, R. E. (2014). The HEXACO Honesty-Humility, Agreeableness, and Emotionality Factors: A review of research and theory. *Personality and Social Psychology Review*, *18*(2), 139–152. https://doi.org/10.1177/1088868314523838

Bailenson, J. N. (2018a). *Experience on demand: What virtual reality is, how it works, and what it can do*. W. W. Norton & Company.

Bailenson, J. N. (2018b). Protecting nonverbal data tracked in virtual reality. *JAMA Pediatrics*, *172*(10), 905–906. https://doi.org/10.1001/jamapediatrics.2018.1909

Bailenson, J. N., Beall, A. C., Loomis, J., Blascovich, J., & Turk, M. (2004). Transformed social interaction: Decoupling representation from Behavior and form in collaborative virtual environments. *Presence: Teleoperators and Virtual Environments*, *13*(4), 428–441. https://doi.org/10.1162/1054746041944803

Bailenson, J. N., & Yee, N. (2006). A longitudinal study of task performance, head movements, subjective report, simulator sickness, and transformed social interaction in collaborative virtual environments. *Presence: Teleoperators and Virtual Environments*, *15*(6), 699–716. https://doi.org/10.1162/pres.15.6.699

Barrick, M. R., Stewart, G. L., Neubert, M. J., & Mount, M. K. (1998). Relating member ability and personality to work-team processes and team effectiveness. *Journal of Applied Psychology*, *83*(3), 377–391. https://doi.org/10.1037/0021-9010.83.3.377

Basu, A., Ball, C., Manning, B., & Johnsen, K. (2016). Effects of user physical fitness on performance in virtual reality. *2016 IEEE Symposium on 3D User Interfaces (3DUI)*, 233–234. https://doi.org/10.1109/3DUI.2016.7460057

Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Bente, G., Rüggenberg, S., Krämer, N. C., & Eschenburg, F. (2008). Avatar-mediated networking: Increasing social presence and interpersonal trust in net-based collaborations. *Human Communication Research*, *34*(2), 287–318. https://doi.org/10.1111/j.1468-2958.2008.00322.x

Biocca, F. (1997). The cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of Computer-Mediated Communication*, *3*(2), JCMC324. https://doi.org/10.1111/j.1083-6101.1997.tb00070.x

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*(2), 103–124. https://doi.org/10.1207/S15327965PLI1302_01

Bolouki, A. (2024). The impact of virtual reality natural and built environments on affective responses: A systematic review and meta-analysis. *International Journal of Environmental Health Research*, *34*(1), 73–89. https://doi.org/10.1080/09603123.2022.2130881

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature*, *391*, 756–756. https://doi.org/10.1038/35784

Bowers, K. S. (1973). Situationism in psychology: An analysis and a critique. *Psychological Review*, *80*, 307–336. https://doi.org/10.1037/h0035592

Bowman, D. A., Gabbard, J. L., & Hix, D. (2002). A survey of usability evaluation in virtual environments: Classification and comparison of methods. *Presence: Teleoperators and Virtual Environments*, *11*(4), 404–424. https://doi.org/10.1162/105474602760204309

Boyd, L., Day, K., Stewart, N., Abdo, K., Lamkin, K., & Linstead, E. (2018). Leveling the Playing Field: Supporting Neurodiversity via Virtual Realities. *Mathematics, Physics, and Computer Science Faculty Articles and Research*. https://doi.org/10.21300/20.1-2.2018.105

Breil, S. M., Geukes, K., Wilson, R. E., Nestler, S., Vazire, S., & Back, M. D. (2019). Zooming into real-life extraversion—How personality and situation shape sociability in social interactions. *Collabra: Psychology*, *5*(1). https://doi.org/10.1525/collabra.170

Cherep, L. A., Kelly, J. W., Miller, A., Lim, A. F., & Gilbert, S. B. (2023). Individual differences in teleporting through virtual environments. *Journal of Experimental Psychology: Applied*, *29*(1), 111–123. https://doi.org/10.1037/xap0000396

Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*, *19*(2), 272–309. https://doi.org/10.1080/15213269.2015.1015740

DeVeaux, C., Markowitz, D. M., Han, E., Miller, M. R., Hancock, J. T., & Bailenson, J. N. (2023). Descriptive linguistic patterns of group conversations in VR. *2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, 785–786. https://doi.org/10.1109/VRW58643.2023.00235

DeVeaux, C., Markowitz, D. M., Han, E., Miller, M. R., Hancock, J. T., & Bailenson, J. N. (2024). Presence and pronouns: An exploratory investigation into the language of social VR. *Journal of Language and Social Psychology*, *43*(4), 405–427. https://doi.org/10.1177/0261927X241248646

Dewez, D., Fribourg, R., Argelaguet, F., Hoyet, L., Mestre, D., Slater, M., & Lécuyer, A. (2019). Influence of personality traits and body awareness on the sense of embodiment in virtual reality. *2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, 123–134. https://doi.org/10.1109/ISMAR.2019.00-12

Dodgson, N. A. (2004). Variation and extrema of human interpupillary distance. *Stereoscopic Displays and Virtual Reality Systems XI*, *5291*, 36–46. https://doi.org/10.1117/12.529999

Eisinga, R., Grotenhuis, M. te, & Pelzer, B. (2013). The reliability of a two-item scale: Pearson, Cronbach, or Spearman-Brown? *International Journal of Public Health*, *58*(4), 637–642. https://doi.org/10.1007/s00038-012-0416-3

Endler, N. S., & Magnusson, D. (1976). Toward an interactional psychology of personality.

Psychological Bulletin, *83*(5), 956–974. https://doi.org/10.1037/0033-2909.83.5.956

Endler, N. S., & Parker, J. D. (1992). Interactionism revisited: Reflections on the continuing crisis in the personality area. *European Journal of Personality*, *6*, 177–198. https://doi.org/10.1002/per.2410060302

Foulsham, T., Walker, E., & Kingstone, A. (2011). The where, what and when of gaze allocation in the lab and the natural environment. *Vision Research*, *51*(17), 1920–1931. https://doi.org/10.1016/j.visres.2011.07.002

Francis, V., & Paton-Cole, V. (2021). Innovation and immersive vocational education training for construction site supervisors. In S. M. Ahmed, P. Hampton, S. Azhar, & A. D. Saul (Eds.), *Collaboration and Integration in Construction, Engineering, Management and Technology* (pp. 179–183). Springer International Publishing. https://doi.org/10.1007/978-3-030-48465-1_30

Freeman, G., Zamanifard, S., Maloney, D., & Acena, D. (2022). Disturbing the peace: Experiencing and mitigating emerging harassment in social virtual reality. *Proceedings of the ACM on Human-Computer Interaction*, *6*(CSCW1), 85:1-85:30. https://doi.org/10.1145/3512932

Funder, D. C. (2009). Persons, behaviors and situations: An agenda for personality psychology in the postwar era. *Journal of Research in Personality*, *43*(2), 120–126. https://doi.org/10.1016/j.jrp.2008.12.041

Gosling, S. D., Rentfrow, P. J., & Swann, W. B. (2003). A very brief measure of the Big-Five personality domains. *Journal of Research in Personality*, *37*(6), 504–528. https://doi.org/10.1016/S0092-6566(03)00046-1

Green, M. C., & McAllister, C. A. (2020). Presence. In *The International Encyclopedia of Media*

Psychology (pp. 1–5). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119011071.iemp0058

Han, E., & Bailenson, J. N. (2024). Lessons for/in virtual classrooms: Designing a model for classrooms inside virtual reality. *Communication Education*, *73*(2), 234–243. https://doi.org/10.1080/03634523.2024.2312879

Han, E., Miller, M. R., DeVeaux, C., Jun, H., Nowak, K. L., Hancock, J. T., Ram, N., & Bailenson, J. N. (2023). People, places, and time: A large-scale, longitudinal study of transformed avatars and environmental context in group interaction in the metaverse. *Journal of Computer-Mediated Communication*, *28*(2), zmac031. https://doi.org/10.1093/jcmc/zmac031

Han, E., Miller, M. R., Ram, N., Nowak, K. L., & Bailenson, J. N. (2022). *Understanding group behavior in virtual reality: A large-scale, longitudinal study in the metaverse* (SSRN Scholarly Paper 4110154). https://papers.ssrn.com/abstract=4110154

Han, E., Strate, I., Nowak, K. L., & Bailenson, J. N. (2024). How different training types and computer anxiety influence performance and experiences in virtual reality. *Media and Communication*, *12*, 8730. https://doi.org/10.17645/mac.8730

Harjunen, V. J., Spapé, M., Ahmed, I., Jacucci, G., & Ravaja, N. (2017). Individual differences in affective touch: Behavioral inhibition and gender define how an interpersonal touch is perceived. *Personality and Individual Differences*, *107*, 88–95. https://doi.org/10.1016/j.paid.2016.11.047

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators and Virtual Environments*, *1*(2), 262–271. https://doi.org/10.1162/pres.1992.1.2.262

Herrera, F., Bailenson, J. N., Weisz, E., Ogle, E., & Zaki, J. (2018). Building long-term empathy:

A large-scale comparison of traditional and virtual reality perspective-taking. *PLoS ONE*, *13*(10), e0204494–e0204494. https://doi.org/10.1371/journal.pone.0204494

Howard, M. C., & Van Zandt, E. C. (2021). A meta-analysis of the virtual reality problem: Unequal effects of virtual reality sickness across individual differences. *Virtual Reality: The Journal of the Virtual Reality Society*, *25*(4), 1221–1246. https://doi.org/10.1007/s10055-021-00524-3

Jun, H., Miller, M. R., Herrera, F., Reeves, B., & Bailenson, J. N. (2022). Stimulus sampling with 360-videos: Examining head movements, arousal, presence, simulator sickness, and preference on a large sample of participants and videos. *IEEE Transactions on Affective Computing*, *13*(3), 1416–1425. IEEE Transactions on Affective Computing. https://doi.org/10.1109/TAFFC.2020.3004617

Kang, S., Yoon, B., Kim, K., Gratch, J., & Woo, W. (2025). How collaboration context and personality traits shape the social norms of human-to-avatar identity representation. *IEEE Transactions on Visualization and Computer Graphics*, 1–10. IEEE Transactions on Visualization and Computer Graphics. https://doi.org/10.1109/TVCG.2025.3549904

Katz, D., Hyers, B., Patten, E., Sarte, D., Loo, M., & Burnett, G. W. (2024). Relationship between demographic and social variables and performance in virtual reality among healthcare personnel: An observational study. *BMC Medical Education*, *24*(1), 227. https://doi.org/10.1186/s12909-024-05180-0

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology*, *3*(3), 203–220. https://doi.org/10.1207/s15327108ijap0303_3

Kolasinski, E. M. (1995). *Simulator sickness in virtual environments.* https://apps.dtic.mil/sti/citations/ADA295861

Kourtesis, P., Papadopoulou, A., & Roussos, P. (2024). Cybersickness in Virtual Reality: The Role of Individual Differences, Its Effects on Cognitive Functions and Motor Skills, and Intensity Differences during and after Immersion. *Virtual Worlds*, *3*(1), Article 1. https://doi.org/10.3390/virtualworlds3010004

Kruzan, K. P., Whitlock, J., Bazarova, N. N., Miller, K. D., Chapman, J., & Won, A. S. (2020). Supporting self-injury recovery: The potential for virtual reality intervention. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–14. https://doi.org/10.1145/3313831.3376396

Kuznetsova, A., Brockhoff, P. B., Christensen, R. H. B., & Jensen, S. P. (2020). *lmerTest: Tests in linear mixed effects models* (Version 3.1-3) [Computer software]. https://CRAN.R-project.org/package=lmerTest

Lawson, A. (2025). *Individual Differences in the Effectiveness of Learning in Virtual Reality*.

Lawson, A. P., & Mayer, R. E. (2025). Effect of Pre-Training and Role of Working Memory Characteristics in Learning with Immersive Virtual Reality. *International Journal of Human–Computer Interaction*, *41*(4), 2523–2540. https://doi.org/10.1080/10447318.2024.2325176

Lawson, A. P., & Mayer, R. E. (2024). Individual differences in executive function affect learning with immersive virtual reality. *Journal of Computer Assisted Learning*, *40*(3), 1068–1082. https://doi.org/10.1111/jcal.12925

Lee, K., & Ashton, M. C. (2018). Psychometric properties of the HEXACO-100. *Assessment*, *25*(5), 543–556. https://doi.org/10.1177/1073191116659134

Lee, K. M. (2004). Presence, explicated. *Communication Theory*, *14*(1), 27–50. https://doi.org/10.1111/j.1468-2885.2004.tb00302.x

Lee, M., Kim, E., Choe, J., Choi, S., Ha, S., & Kim, G. (2022). Psychological effects of green experiences in a virtual environment: A systematic review. *Forests*, *13*(10), Article 10. https://doi.org/10.3390/f13101625

Levine, T. R., & Markowitz, D. M. (2024). The role of theory in researching and understanding human communication. *Human Communication Research*, *50*(2), 154–161. https://doi.org/10.1093/hcr/hqad037

Lewin, K. (1935). *A dynamic theory of personality* (pp. ix, 286). McGraw-Hill.

Markowitz, D. M., Laha, R., Perone, B. P., Pea, R. D., & Bailenson, J. N. (2018). Immersive virtual reality field trips facilitate learning about climate change. *Frontiers in Psychology*, *9*, 2364–2364. https://doi.org/10.3389/fpsyg.2018.02364

Matz, S. C., & Harari, G. M. (2021). Personality–place transactions: Mapping the relationships between Big Five personality traits, states, and daily places. *Journal of Personality and Social Psychology*, *120*(5), 1367–1385. https://doi.org/10.1037/pspp0000297

Maxwell, H., Weaver, B., Gagnon, S., Marshall, S., & Bédard, M. (2021). The validity of three new driving simulator scenarios: Detecting differences in driving performance by difficulty and driver gender and age. *Human Factors*, *63*(8), 1449–1464. https://doi.org/10.1177/0018720820937520

Meagher, B. R. (2020). Ecologizing social psychology: The physical environment as a necessary constituent of social processes. *Personality and Social Psychology Review*, *24*(1), 3–23. https://doi.org/10.1177/1088868319845938

Miller, M. R., Herrera, F., Jun, H., Landay, J. A., & Bailenson, J. N. (2020). Personal identifiability of user tracking data during observation of 360-degree VR video. *Scientific Reports*, *10*(1), Article 1. https://doi.org/10.1038/s41598-020-74486-y

Miller, M. R., Sonalkar, N., Mabogunje, A., Leifer, L., & Bailenson, J. (2021). Synchrony within Triads using Virtual Reality. *Proc. ACM Hum.-Comput. Interact.*, *5*(CSCW2), 400:1-400:27. https://doi.org/10.1145/3479544

Moore, R. C., Hancock, J. T., & Bailenson, J. N. (2023). From 65 to 103, older adults experience virtual reality differently depending on their age: Evidence from a large-scale field study in nursing homes and assisted living facilities. *Cyberpsychology, Behavior, and Social Networking*, *26*(12), 886–895. https://doi.org/10.1089/cyber.2023.0188

Moreno, R., & Mayer, R. E. (2002). Learning science in virtual reality multimedia environments: Role of methods and media. *Journal of Educational Psychology*, *94*(3), 598–610. https://doi.org/10.1037/0022-0663.94.3.598

Murray, N. P., Hunfalvay, M., & Bolte, T. (2017). The reliability, validity, and normative data of interpupillary distance and pupil diameter using eye-tracking technology. *Translational Vision Science & Technology*, *6*(4), 2. https://doi.org/10.1167/tvst.6.4.2

Newman, M., Gatersleben, B., Wyles, K. J., & Ratcliffe, E. (2022). The use of virtual reality in environment experiences and the importance of realism. *Journal of Environmental Psychology*, *79*, 101733. https://doi.org/10.1016/j.jenvp.2021.101733

Oh, S. Y., Bailenson, J., Weisz, E., & Zaki, J. (2016). Virtually old: Embodied perspective taking and the reduction of ageism under threat. *Computers in Human Behavior*, *60*, 398–410. https://doi.org/10.1016/j.chb.2016.02.007

Oishi, S., & Graham, J. (2010). Social ecology: Lost and found in psychological science. *Perspectives on Psychological Science*, *5*(4), 356–377.

https://doi.org/10.1177/1745691610374588

Okken, V., van Rompay, T., & Pruyn, A. (2013). Room to move: On spatial constraints and self-disclosure during intimate conversations. *Environment and Behavior*, *45*(6), 737–760. https://doi.org/10.1177/0013916512444780

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology*, *110*(6), 785–797. https://doi.org/10.1037/edu0000241

Peck, T. C., & Good, J. J. (2023). Measuring embodiment: Movement complexity and the impact of personal characteristics. *IEEE Transactions on Visualization and Computer Graphics*, 1–13. IEEE Transactions on Visualization and Computer Graphics. https://doi.org/10.1109/TVCG.2023.3270725

Peck, T. C., Seinfeld, S., Aglioti, S. M., & Slater, M. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition*, *22*(3), 779–787. https://doi.org/10.1016/j.concog.2013.04.016

Peck, T. C., Sockol, L. E., & Hancock, S. M. (2020). Mind the gap: The underrepresentation of female participants and authors in Virtual Reality research. *IEEE Transactions on Visualization and Computer Graphics*, *26*(5), 1945–1954. IEEE Transactions on Visualization and Computer Graphics. https://doi.org/10.1109/TVCG.2020.2973498

Ratan, R., Beyea, D., Li, B. J., & Graciano, L. (2020). Avatar characteristics induce users' behavioral conformity with small-to-medium effect sizes: A meta-analysis of the proteus effect. *Media Psychology*, *23*(5), 651–675. https://doi.org/10.1080/15213269.2019.1623698

Rauthmann, J. F., Sherman, R. A., & Funder, D. C. (2015). Principles of situation research: Towards a better understanding of psychological situations. *European Journal of*

Personality, *29*(3), 363–381. https://doi.org/10.1002/per.1994

Reeves, B., Yeykelis, L., & Cummings, J. J. (2016). The use of media in media psychology. *Media Psychology*, *19*(1), 49–71. https://doi.org/10.1080/15213269.2015.1030083

Rosenberg, R. S., Baughman, S. L., & Bailenson, J. N. (2013). Virtual superheroes: Using superpowers in virtual reality to encourage prosocial behavior. *PLOS ONE*, *8*(1), e55003–e55003. https://doi.org/10.1371/journal.pone.0055003

Ruthenbeck, G. S., & Reynolds, K. J. (2015). Virtual reality for medical training: The state-of-the-art. *Journal of Simulation*, *9*(1), 16–26. https://doi.org/10.1057/jos.2014.14

Rydell, R. J., & McConnell, A. R. (2005). Perceptions of entitativity and attitude change. *Personality and Social Psychology Bulletin*, *31*(1), 99–110. https://doi.org/10.1177/0146167204271316

Schwebel, D. C., Johnston, A., McDaniel, D., & McClure, L. A. (2024). Child pedestrian safety training in virtual reality: How quickly do children achieve adult functioning and what individual differences impact learning efficiency? *Journal of Safety Research*, *89*, 135–140. https://doi.org/10.1016/j.jsr.2024.01.012

Slater, M. (2004). How colorful was your day? Why questionnaires cannot assess presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, *13*(4), 484–493. https://doi.org/10.1162/1054746041944849

Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), 3549–3557. https://doi.org/10.1098/rstb.2009.0138

Slater, M., Khanna, P., Mortensen, J., & Yu, I. (2009). Visual realism enhances realistic response in an immersive virtual environment. *IEEE Computer Graphics and Applications*, *29*(3), 76–84. IEEE Computer Graphics and Applications. https://doi.org/10.1109/MCG.2009.55

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLOS ONE*, *5*(5), e10564–e10564. https://doi.org/10.1371/journal.pone.0010564

Slater, M., & Steed, A. (2000). A virtual presence counter. *Presence*, *9*(5), 413–434. Presence. https://doi.org/10.1162/105474600566925

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, *6*(6), 603–616. https://doi.org/10.1162/pres.1997.6.6.603

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, *42*(4), 73–93. https://doi.org/10.1111/j.1460-2466.1992.tb00812.x

Van Der Heide, B., Schumaker, E. M., Peterson, A. M., & Jones, E. B. (2013). The proteus effect in dyadic communication: Examining the effect of avatar appearance in computer-mediated dyadic interaction. *Communication Research*, *40*(6), 838–860. https://doi.org/10.1177/0093650212438097

van Sintemaartensdijk, I., van Prooijen, J.-W., Nee, C., Otte, M., & van Lange, P. (2022). Personality and burglary: A virtual reality study. *Personality and Individual Differences*, *196*, 111712. https://doi.org/10.1016/j.paid.2022.111712

VIVE. (2023). *Adjusting the IPD on the headset*. https://www.vive.com/us/support/vive-pro-eye/category_howto/adjusting-the-ipd-on-the-headset.html

Walsh, W. B., Craik, K. H., & Price, R. H. (Eds.). (2014). *Person-environment psychology: New directions and perspectives* (2nd ed.). Psychology Press.

https://doi.org/10.4324/9781410605771

Wang, P., Miller, M. R., Queiroz, A. C. M., & Bailenson, J. N. (2024). Socially late, virtually present: The effects of transforming asynchronous social interactions in virtual reality. *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, 1–19. https://doi.org/10.1145/3613904.3642244

Wang, Y.-M., Chiu, W.-C., Lin, H.-H., Wang, Y.-S., Wang, Y.-Y., & Chen, I.-F. (2022). Determinants of students' adoption of virtual reality-based learning systems: An individual difference perspective. *Innovations in Education and Teaching International*, *ahead-of-print*(ahead-of-print), 1–11. https://doi.org/10.1080/14703297.2022.2098512

Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and cybersickness in virtual reality are negatively related: A review. *Frontiers in Psychology*, *10*. https://www.frontiersin.org/articles/10.3389/fpsyg.2019.00158

Weibel, D., Wissmath, B., & Mast, F. W. (2010). Immersion in mediated environments: The role of personality traits. *Cyberpsychology, Behavior, and Social Networking*, *13*(3), 251–256. https://doi.org/10.1089/cyber.2009.0171

Widyanti, A., & Hafizhah, H. N. (2022). The influence of personality, sound, and content difficulty on virtual reality sickness. *Virtual Reality*, *26*(2), 631–637. https://doi.org/10.1007/s10055-021-00525-2

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., Gouveia, F. R., Biocca, F., Sacau, A., Jäncke, L., Baumgartner, T., & Jäncke, P. (2007). A process model of the formation of spatial presence experiences. *Media Psychology*, *9*(3), 493–525. https://doi.org/10.1080/15213260701283079

Wrzus, C., Wagner, G. G., & Riediger, M. (2016). Personality-situation transactions from adolescence to old age. *Journal of Personality and Social Psychology*, *110*(5), 782–799. https://doi.org/10.1037/pspp0000054

Yee, N., & Bailenson, J. N. (2007). The proteus effect: The effect of transformed self-representation on behavior. *Human Communication Research*, *33*(3), 271–290. https://doi.org/10.1111/j.1468-2958.2007.00299.x

Zheng, J. M., Chan, K. W., & Gibson, I. (1998). Virtual reality. *IEEE Potentials*, *17*(2), 20–23. IEEE Potentials. https://doi.org/10.1109/45.666641

Figure 1

Participant Conditions and Stimulus Sampling

96 environments (192 total, including environments with/without seating)

Figure 2

Histograms for Key Dependent Variables Across Weeks

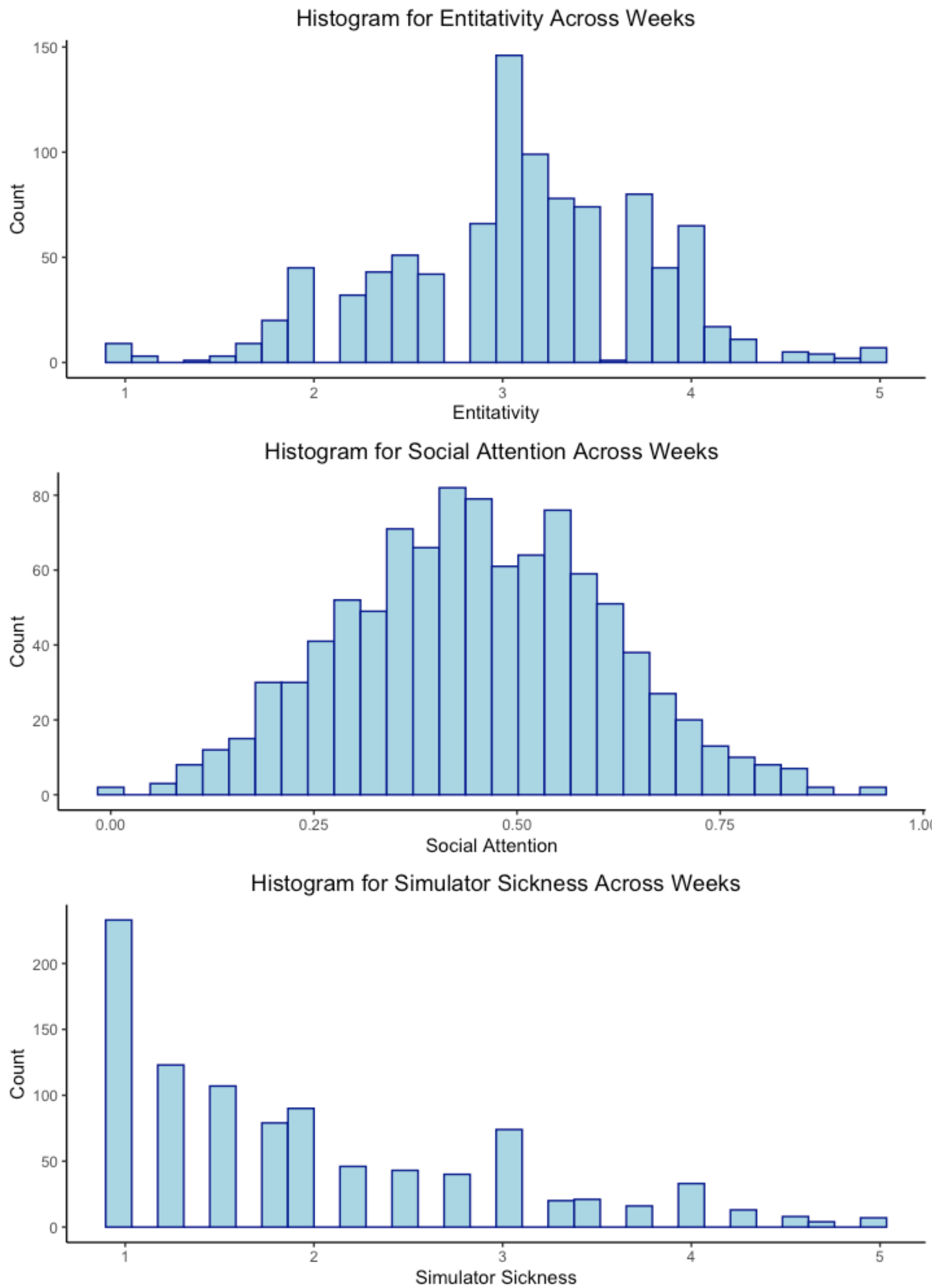


Figure 3

Histograms for Person-Level Variables

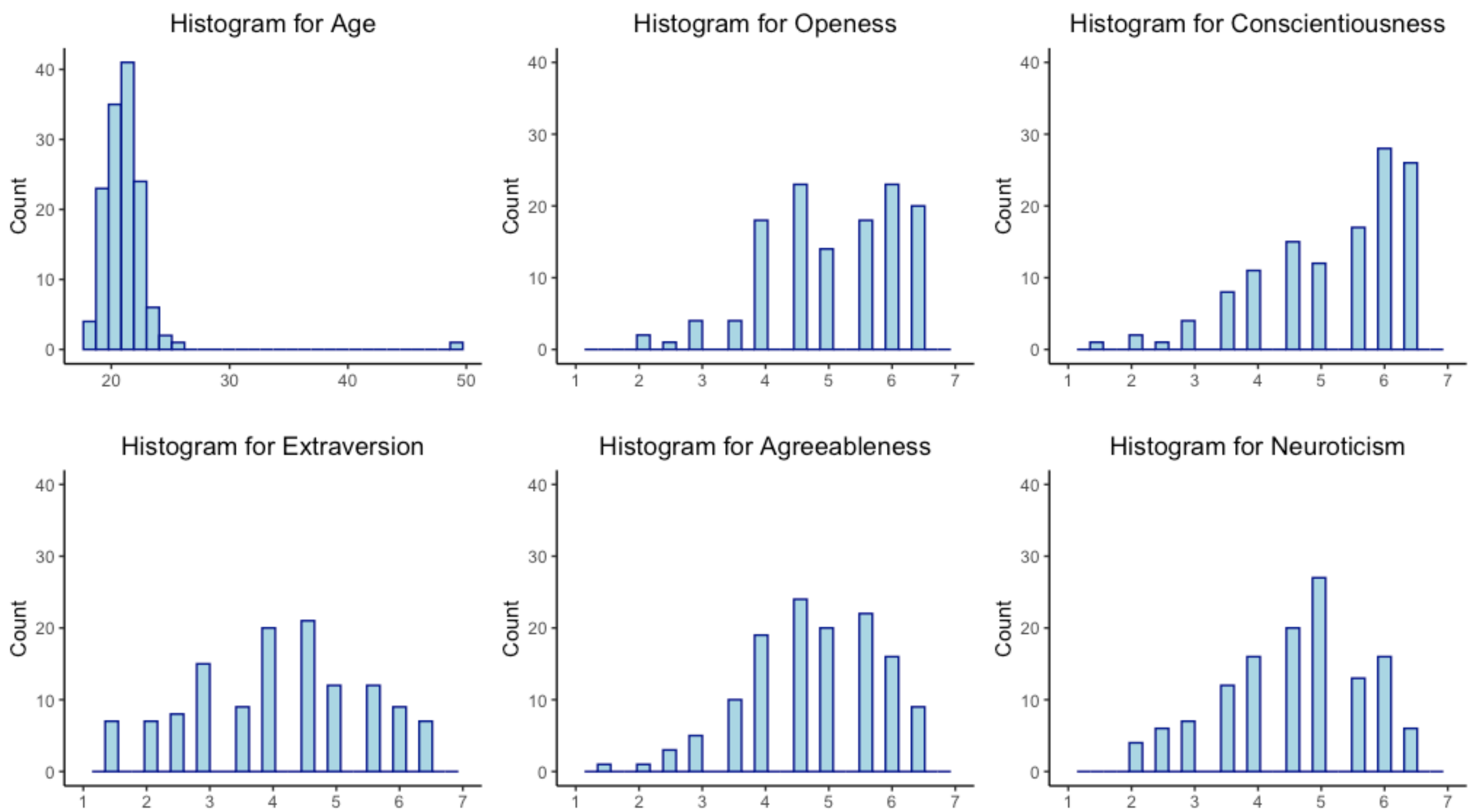
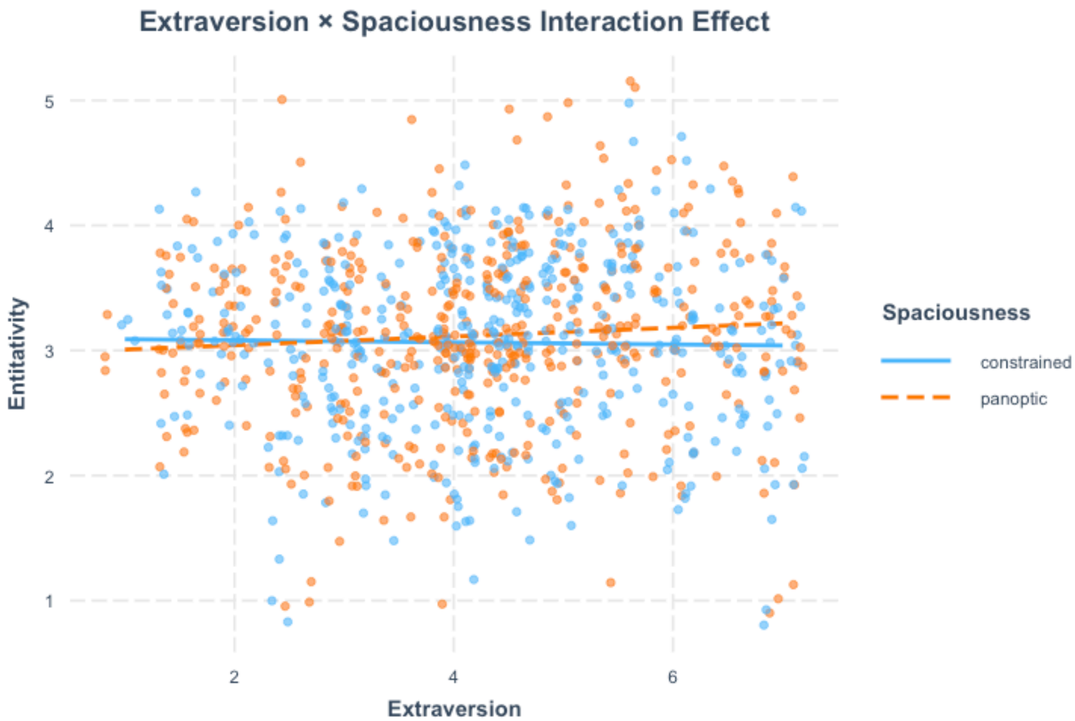


Figure 4

Visualized Interaction Effect Predicting Entitativity



Note. Dots are jittered for interpretability.

Figure 5

Visualized Interaction Effects Predicting Social Attention

Note. Dots are jittered for interpretability.