Original Manuscript

Journal of Language and Social Psychology
1–23

DOI: 10.1177/0261927X241248646
journals.sagepub.com/home/jls
Sage

Presence and Pronouns: An Exploratory Investigation into the Language of Social VR

Cyan DeVeaux[1], David M. Markowitz[2], Eugy Han[1], Mark Roman Miller[3], Jeffrey T. Hancock[1], and Jeremy N. Bailenson[1]

Abstract

As social virtual reality (VR) continues to grow as a medium for digital communication, sustaining presence among communicators remains one of the main constructs that researchers and practitioners use to assess the quality of user experience. In the present paper, we explore language patterns as a behavioral link to presence. We accomplished this through an exploratory text analysis of over 4,800 min of conversation in social VR, consisting of over 130,000 spoken words from 126 participants. We observed that the use of self-references and collective references positively correlated to social presence and spatial presence. Furthermore, median interpersonal distance between communicators was positively associated with using impersonal pronouns, suggesting that participants who stood farther apart from their interlocutors tended to speak in more impersonal terms. Our work sheds light on the possible psychological mechanisms behind presence and the potential of using speech data to help build systems that enhance user engagement.

Keywords

social virtual reality, language, presence

[1]Department of Communication, Stanford University, Stanford, USA
[2]Department of Communication, Michigan State University, East Lansing, USA
[3]Department of Computer Science, Illinois Institute of Technology in Chicago, Chicago, USA

Corresponding Author:
Cyan DeVeaux, Stanford University, 450 Jane Stanford Way Bldg 120, Stanford, CA 94305, USA.
Email: cyanjd@stanford.edu

Social virtual reality (VR) platforms provide immersive, virtual scenes where users can interact with each other through head-mounted displays (HMDs). As users communicate in these three-dimensional virtual worlds, their physical body movements are tracked and rendered to their avatars. That is, when a user moves in real life, their avatar reflects this movement in VR. This novel form of avatar-mediated interaction affords non-verbal behavior which, alongside voice, can make talking to others in VR feel similar to face-to-face communication. However, social VR still exhibits qualities of digitally mediated communication that distinguish it from its real-world counterpart. Immersive VR generally enables a higher degree of customization of visual, environmental, and social stimuli that can influence communication behavior. For example, Blascovich's (2002) model of social influence in immersive virtual environments demonstrates how manipulating the social context (e.g., presence of virtual agents, behavioral realism of agents) of users in VR can impact their behavior (e.g., task performance, maintenance of personal space). VR also enables the customization of one's digital self-representation, or avatar, whose appearance and behavior has been shown to transform social interaction (Bailenson et al., 2005; Oh et al., 2016; Pan & Steed, 2017; Smith & Neff, 2018). Moreover, the ease of manipulation of environmental context in VR can shape non-verbal behavior (Miller et al., 2021; Han et al., 2023).

One form of communication behavior that has received limited attention in the social VR literature is language. As a result of social VR's unique positioning between face-to-face and digital communication, it is important to understand the language patterns that may occur in this specific context (Eichert et al., 2018; Pfeiffer, 2012) and what these patterns reveal about a user's psychological experience in VR.

In the psychology of language tradition, words serve as markers of one's focus and attention (Boyd & Schwartz, 2021). For example, people who use high rates of self-references (e.g., *I*, *me*, *myself*) tend to focus inward, have a more immediate disposition, and attend to the self more than those who use low rates of self-references (Pennebaker, 2011). By evaluating words in this way, people can glean critical social and psychological information about communicators from their natural language. Many have used language as a lens into the psychological processing of communicators, applying automated techniques to quantify word patterns across diverse settings and media (e.g., text messaging, blogs, online dating profiles). However, investigating language as a psychological indicator within immersive, virtual environments is understudied, or text analysis is an ancillary part of an empirical project, not the primary focus. The current study aims to address this opportunity by performing an automated, exploratory text analysis of over 4,800 min of in-VR group conversation taken over seven weeks during a university course. This data set has previously been used by DeVeaux and colleagues (2023) to examine group-level speaking trends in VR collaborations (e.g., distribution of speaking time and what types of words are used over time).

In the present paper, we use the same dataset as DeVeaux and colleagues (2023) to examine individual-level trends by tracing individual users and pairing their particular utterances with the effectiveness of the collaboration in VR as measured by various

constructs of presence. Specifically, we examine how one's communication style in social VR is linked to the psychological phenomena of presence. Presence can be understood as the feeling of "being there" (Heeter, 1992). As systems for computer-mediated interaction have advanced, this construct has become a valuable metric of their design and evaluation. Given the highly immersive nature of VR, presence has been at the forefront of theory in this space (Lee, 2004). Prior work has considered three dimensions of presence: self-presence, social presence, and spatial presence (Gullström & Kort, 2016; Hughes & Roy, 2020; Jicol et al., 2022, 2023). Self-presence is characterized by experiencing the virtual self as the actual self (Lee, 2004). Social presence emphasizes social actors and is the feeling of "being there" with others. Spatial presence, also known as physical presence, is the extent to which one feels present within their environment. Presence is tightly linked to technological immersion (Cummings & Bailenson, 2016), suggesting that people feel more attached and a part of their virtual environment as the fidelity of the virtual world increases.

Presence is often evaluated via self-reports, which some scholars argue offers fewer insights than questionnaires in other domains (Kramer et al., 2006; Slater, 2004), as many of the questions tend to be fairly metaphysical and difficult to understand (i.e., do participants have a ground truth for the "real world," which is often a phrase used). In particular, studies have shown that these questionnaires sometimes miss differences in manipulated independent variables that can be picked up by alternative measures, such as nonverbal behavior (Bailenson et al., 2004). It is also possible for participants to mischaracterize their cognitive and affective response to stimuli (Bailenson et al., 2004). Despite these challenges, many studies using these self-reported presence measures in collaborative and immersive virtual environments have still produced valuable findings. Questionnaires are also easy to distribute, validate, identify reliability, and share with other researchers in VR (Bailenson et al., 2004). Therefore while acknowledging this value, we argue and propose in the current paper that it is critical to consider how other measures, particularly behavioral ones, are linked to presence. We accomplish this by examining correlations between language, self-reported measures of presence, and behavioral indicators of presence (i.e., interpersonal distance). We do not seek to replace the measure of presence with verbal behavior but hope to provide another way to understand presence as a concept through the analysis of language. However, we are not the first to advocate for such an idea, as Kramer and colleagues (2006) proposed a linguistic approach to measuring presence in video and audio conferencing systems. They found that presence was related to using "we" pronouns and local deixis in language.

While the findings from Kramer and colleagues (2006) provide an initial understanding of linguistic markers associated with presence in 2D virtual environments, it is unclear how these patterns vary across the three dimensions of presence and whether they generalize to more immersive, virtual settings in social VR. Advances in natural language processing since the publication of their work also encourage the reexamination of how presence is linked to a range of consequential language dimensions that can reveal different social and psychological mechanisms of presence. Against this backdrop, we present one of the first studies to conduct a large-scale

investigation of linguistic markers of self-reported and behavioral measures of presence in social VR. Our work can be used to develop a linguistic-based measure of presence in immersive, virtual settings.

Background

The Psychology of Language

Studies suggest language patterns are predictive of many social and psychological dynamics, including personality (Ireland & Mehl, 2014), psychological distress (Cohn et al., 2004; Markowitz, 2022b), and group cohesion and identity (Ashokkumar & Pennebaker, 2022). One dimension of language that can be especially revealing of a person's social and psychological state is linguistic style. Style words, also known as function words, are indicators of how a person is communicating (rather than what they are communicating about). Style words comprise over 50% of spoken and written English (Chung & Pennebaker, 2007), and dimensions such as pronouns (e.g., *I*, *she*, *they*), articles (e.g., *a*, *the*), and prepositions (e.g., *above*, *below*) link to consequential social and psychological processes in the field. For example, a recent paper by Markowitz (2022a) observed how bias is reflected in the use of impersonal pronouns by physicians across 1.8 million caregiver reports. Physicians attending to women depersonalized their care by using more impersonal pronouns in their caregiver notes compared to physicians attending to men. Similarly, Eichstaedt and colleagues (2018) used the language in Facebook posts to predict clinical depression in patients (e.g., self-references on Facebook were positively linked to clinical depression), and Voigt and colleagues (2017) used the language from police officer body cameras to identify disparities in how Black versus White drivers were treated during traffic stops (e.g., police officers were less verbally respectful to Black civilians compared to White civilians). Altogether, style words are pervasive in human communication and are psychologically rich (Pennebaker, 2011), offering an important window into how people are thinking, feeling, and experiencing the world psychologically.

In the current work, we evaluate how style words correlate to different types of presence in social VR. Consistent with prior work (Kacewicz et al., 2014), we specifically focus on different categories of pronouns to assess how they link to various presence metrics. Pronouns — including first-person singular pronouns (self-references, or "I" words), first-person plural pronouns (collective references, or "we" words), second-person pronouns ("you" words), third-person singular pronouns ("she" or "he" words), third person plural pronouns ("they" words), and impersonal pronouns (e.g., words such as *it*, *that* or *who*) — are inherently social because they describe who or what a communicator is focusing on in their social and psychological world (Chung & Pennebaker, 2007; Pennebaker, 2011). For example, people who are high status tend to use more collective references (e.g., *we*, *our*) and fewer self-references (e.g., *I*, *me*) than people who are low status because those of higher rank need to attend to a wide range of people (Kacewicz et al., 2014; Markowitz, 2018). People who experienced a romantic breakup tended to use more self-references as the breakup unfolded

(Seraj et al., 2021). This increase in self-focus reflects such individuals' internal struggle trying to organize their thoughts and make sense of a distressing life event. Altogether, we draw on the foundation set forth by the psychology of language tradition to explore how an important social and psychological construct in VR, presence, is linked to various pronoun categories. We are among the first to do so in social VR, attempting to push our theoretical understanding of presence and its sub-categories through verbal behavior.

The Study of Language in Virtual Environments

How have words been evaluated in immersive VR and other forms of virtual environments? Some studies have considered how aspects of a virtual environment modify how people communicate within it. The majority of these studies have evaluated the impact of avatars and embodiment, the environmental context, and presence on language use. For example, avatar choice can influence what people say in virtual environments, as Smith and Neff (2018) found that people embodying avatars in immersive VR used more referential pronouns (e.g., *this*, *that*) than interlocutors without avatars. The authors attributed this finding to the role that gestures play during ambiguous pronoun use. Without an avatar, participants could nonverbally communicate and therefore used less ambiguous words when referring to objects (Smith & Neff, 2018). Other work has shown that the gender of one's avatar also influences their language. Palomares and Lee (2010) found that using a 2D avatar that matched their gender increased the use of "gender-typical language." Therefore, who or what people embody can impact how people communicate in VR.

Language is also affected by the virtual environmental context. Wu and colleagues (2015) showed that the manipulation of a 2D virtual world influenced the use of first-person plural pronouns (e.g., *we*, *our*) and agreement words (e.g., *OK*, *I agree*). Participants used these words more in an amusement park environment with bright, interactive visual stimuli compared to a dark lab environment with limited interactive content. Furthermore, there was more use of exclusive reference terms (e.g., *except*, *without*) in the less interactive environment compared to the more interactive environment (Wu et al., 2015). This evidence demonstrates that *where* people are situated in the virtual environment might impact how they communicate, a contention broadly consistent with embodied cognition research (Weisberg & Newcombe, 2017).

Prior work has identified a relationship between language and social affiliation. Alvidrez and Peña (2020) demonstrated that verbal mimicry decreased social distance and increased social attraction towards outgroup members in immersive VR. Frommel and colleagues (2020) found that verbal behavior can be used to predict affiliation in a 2D multiplayer game. Players who felt more affiliated with another player used fewer words pertaining to analytic thinking and numbers, and greater use of the pronoun "I" and words related to time.

Finally, and of relevance to our inquiry, the degree of presence one feels in a virtual environment can also relate to language use. Presence is a psychological phenomenon characterized by the sensation of "being there" (Heeter, 1992). According to Kramer

and colleagues (2006), higher ratings of presence in 2D video and audio conferencing platforms were positively correlated with the use of first person plural pronouns (e.g., *we*, *us*) and local deixis (e.g., words to signal the here and now; *this*, *these*, *here*). This evidence suggests that feeling like one is more a part of the virtual environment can increase entitativity (i.e., group cohesion) and references to one's remote environment. The importance of presence as a psychological concept and phenomenon in VR is underscored by a recent paper that evaluated the most common social VR language patterns (in terms of themes) from participants who interacted over an 8-week academic course (DeVeaux et al., 2023). Sensory processes, which included words like feels, sounds, and presence, were the second most dominant theme communicated in social VR. People talk about what and how they feel in VR, with presence being a dominant theme that people focus on.

The Current Paper

The reviewed evidence reveals that people leave traces of their behavior and psychological processing in the words used during VR experiences. Notice, these studies were largely non-interactive and reflect how individuals communicated after short exposure to stimuli. We therefore build on and dramatically expand this empirical foundation by evaluating how people communicate within the context of a social VR classroom that spans seven weeks of a university course.

There are at least three main contributions of this research. First, we examine how various pronoun categories are linked to multiple components of presence. Prior work has considered a limited number of pronoun dimensions and a unidimensional construct of presence to establish their connection. We provide a nuanced understanding of how pronouns, as markers of one's social focus and attention, link to self-presence, social presence, and spatial presence. A second contribution relates to a concern that self-reported presence measures are problematic or should be extended with behavioral data. We address this concern directly by measuring interpersonal distance, which considers the minimum distance between dyads in a person's visual field, as a behavioral form of social presence. Finally, we argue that it is a missed opportunity not to consider how words are used in virtual environments and how language patterns can offer new and complementary psychological information compared to traditional forms of behavioral measurement.

Method

Participants and Recruitment

Students enrolled in a university course taught using Meta Quest 2 VR headsets opted in to the study with a consent form approved by the university institutional review board (IRB) and a second organization in charge of general oversight of students. To ensure that there was no plausible appearance of coercion to participate, this process required that researchers and course staff did not know which students

opted in as participants in the study until after the course finished. This also meant that all students were recorded in this study, and only data associated with consenting participants were used. At the start of each recording session or upon joining an in-progress session, participants were reminded of the recording through a visual notification.

Participants were 158 consenting university students of the 171 total students enrolled this 10-week course about VR. At the beginning of the course, students were invited to participate in this IRB-approved study of how repeated exposure to VR influenced their individual and group behavior. 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 had their data included in this study. Participants (Male = 89, Female = 68, declined to or did not respond = 1) were between 18 and 49 years old ($M = 20.87$, $SD = 2.64$; $n_{18\text{-}20} = 70$, $n_{21\text{-}23} = 82$, $n_{24\text{-}49} = 5$, declined to or did not respond = 1) and identified as Asian or Asian-American ($n = 52$), White ($n = 47$), multiracial ($n = 21$), African, African-American, or Black ($n = 15$), Hispanic or LatinX ($n = 11$), Native Hawaiian or other Pacific Island ($n = 5$), Indigenous/Native American, Alaska Native, First Nations ($n = 2$), declined to or did not respond ($n = 2$), Middle Eastern ($n = 1$), a racial group not listed ($n = 1$, declined to or did not respond = 2). Participants had varying levels of experience with VR ($n_0 = 58$, $n_1 = 33$, $n_2 = 25$, $n_{3\text{-}10} = 29$, $n_{20\text{-}50} = 4$, $n_{90} = 2$, $n_{100} = 5$, declined to or did not respond = 2).[1]

Hardware and VR Equipment

Participants were provided with Meta Oculus Quest 2 headsets (503 g) and two hand controllers (126 g) for use in their personal environment (standalone head mounted display with 1832 × 1920 resolution per eye, 104.00° horizontal FOV, 98.00° FOV, 90 Hz refresh rate, and six degree-of-freedom inside-out head and hand tracking). The headsets come with a built-in microphone on the bottom side of the device near where the user's mouth is, integrated stereo speakers, and a dual 3.55 mm jack for headphones.

Avatars and Environment

All sessions were hosted in ENGAGE. ENGAGE is a collaborative social VR platform designed for professionals, educators, and corporations. Within ENGAGE, participants are represented by virtual human avatars (See Figure 1). All participants were asked to use the customization tool to make an avatar that looked and felt like their offline selves. These embodied avatars allow for participants to translate/teleport freely, draw using a 3D pen, write on personal whiteboards/stickies, add immersive effects/3D objects, and display media content. ENGAGE was selected as a platform for this study due to these features and its ease in creating and joining password-restricted sessions.

Each session took place in one of 192 uniquely-built virtual environments (See Figure 2). Each environment was built by research personnel using 3D objects.

Figure 1. Users meeting together in ENGAGE.

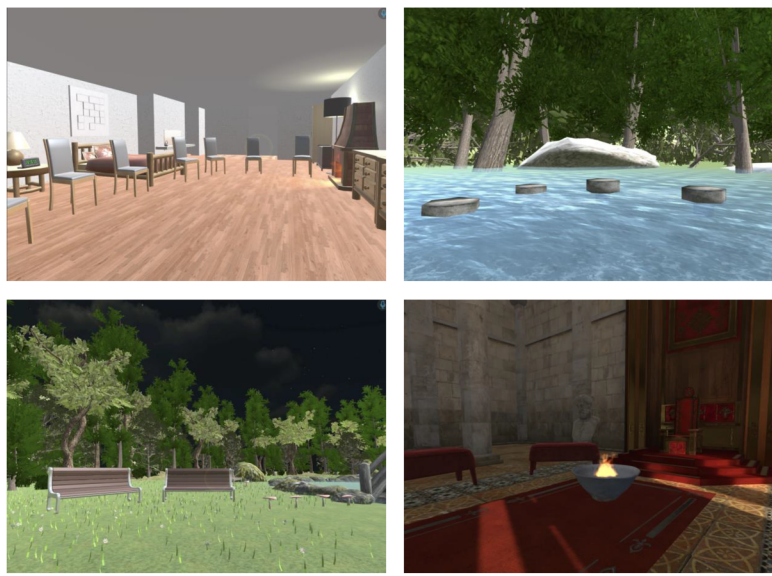

Figure 2. Four examples of the 192 uniquely built virtual environments.

As suggested by Reeves and colleagues (2016), as variance in media is growing, so should variance in media research. As the authors argue, any media chosen as a stimulus can have a list of features that may be psychologically relevant and interact with

the primary factors in an experiment. To examine the generalization of language results across stimuli, we created 192 unique environments that contained diverse thematic features, as opposed to relying on a single stimuli manipulation. Environments were not designed to create different levels of presence.

Procedure

At the beginning of the course, participants selected a discussion section group that fit their schedule and availability. A total of 24 sections met weekly for eight weeks (See Figure 3). Five to eight students were assigned to each section, consisting of both participants (e.g., consenting students) and/or non-participants (e.g., non-consenting students). However, actual sizes of sections each week varied based on attendance and rescheduling. The sessions were led by one of three instructors. Each instructor led the same eight sections every week.

Discussion sections occurred across eight weeks and, with the exception of Week 5, had a similar format. The 30-min sessions were divided into a 10-min full-group discussion and recap of the course material, a 15-min individual creative activity based on a prompt, and a 5-min sharing of the final product of the activity portion. Virtual mobility was manipulated in terms of whether sections in a given week were instructed to move freely or to sit in virtual seats during their session. Audio in sections was non-spatialized, meaning everyone could hear each other at an equal volume regardless of where they stood in virtual space. Given that Week 5 had a different discussion section structure, it was not used as data for the scope of this paper. Each week revolved around a different theme related to VR:

- Week 1 - Let's Talk about VR: Participants were acclimated to the headset and platform. The full-group discussion was on the affordances of VR and the creative activity was prototyping something that leverages the uniqueness of VR.
- Week 2 - Immersion and Presence: The full-group discussion was on what activities heightened the sense of presence in VR and the creative activity was creating something frightening that induces a feeling of high presence.
- Week 3 - Education and Virtual Field Trips: The full-group discussion was on reflecting on the experience of visiting various sites in AltspaceVR (e.g., an art exhibition, solar system) and the creative activity was considering the affordances of VR to make a concept that is difficult to understand, easy.
- Week 4 - Avatars: The full-group discussion was on ways to improve ENGAGE's avatar and the creative activity was creating something that reimagines avatars and representations of the self.
- Week 6 - Medical VR and Exposure Therapy: The full-group discussion was on how VR is used for medical applications and wellbeing and the creative activity was creating a meditation room or "safe-space."
- Week 7 - Climate Change: The full-group discussion was on the role VR could play in people's attitudes and actions towards climate change and the creative

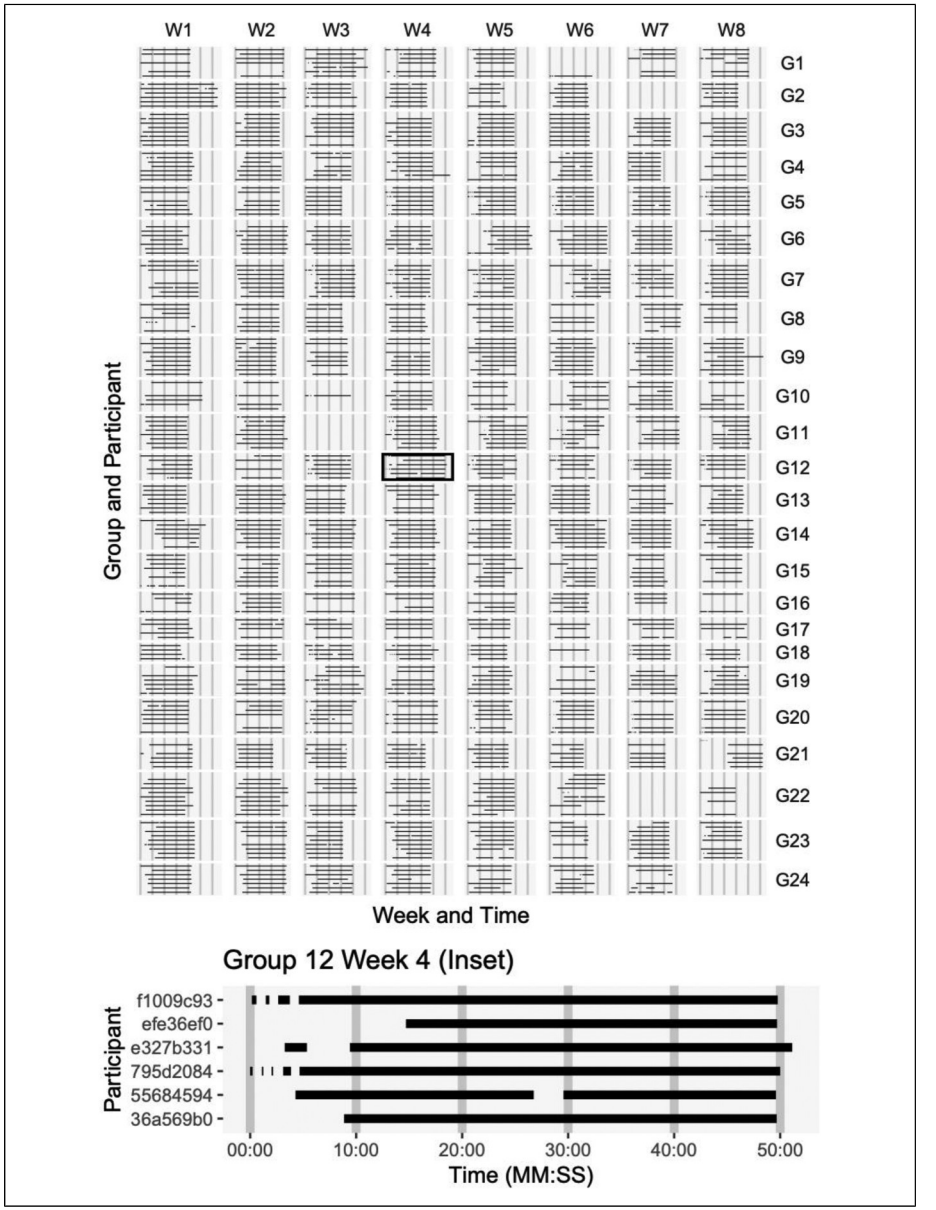

Figure 3. Figure, adapted from Miller and colleagues (2023) which used the same data set, showing the weekly sessions, duration, participants, and group size of the study. Panel 1 consists of many facets. Each facet represents a week, given by its horizontal ordering, and a group, given by its vertical ordering. Within each facet, and in Panel 2 shows a close-up of group 12 in week 4 from the context study, each participant receives a horizontal row on which a line is drawn if data is collected at that time. Vertical lines within each facet demarcate 10-min intervals of time.

activity was brainstorming ideas on how to communicate a message about climate change.
- Week 8 - Sports Training: The full-group discussion was on the role VR could play in the future of sports and fitness and the creative activity was creating and playtesting a VR-based game.

At the end of each discussion section, participants rated their perceived sense of self, social, and spatial presence using a questionnaire.

Data Analysis

Of the 168 sessions that occurred across seven weeks among 24 discussion section groups, 165 sessions were recorded using ENGAGE's recording feature and saved as .myrec files. Three sessions were not recorded properly due to technical errors. The 162 .myrec files were extracted for their stream data using archive utility software. For each .myrec file, its stream data consisted of a folder of folders that each contained an .mp3 segment of the recording's audio in two second clips. A script was run on each session's folder of folders to extract the audio clips and place them into their own folder (e.g., *week1_section1_audio*). Once the audio clips were in their own folder by week and by discussion section, a digital audio editor was used to combine each session's clips into one .mp3 file representing the entirety of the audio of the entire session. The .mp3 files of each session were then uploaded to Otter.ai, an automated text transcription software. Once Otter.ai provided an initial transcription, research personnel manually edited the transcriptions for accuracy, redacted speech from non-consenting participants, and labeled the speakers of each utterance. Subsequently, a second team of research personnel was tasked with ensuring that all of the labels were accurate. With the exception of a few transcripts with delayed start times due to recording issues, most transcripts reflected language that occurred between the official start and end of class. Along the way, three transcripts were deemed unusable due to errors and inconsistencies. The remaining 162 text transcripts were then converted into .csv files and a script was used to combine these separate files into one .csv file that kept track of usernames, language data, discussion section numbers, week numbers, presence ratings, and linguistic style. Usernames were used to ensure that no language from non-consenting students made it through to the analysis stage and to remove the language from instructors.

Using this data, we present results from conducting analyses with and without covariates. We calculated Pearson's correlations between each measure of presence and the dimension of linguistic style of focus (See Table 1). We also ran Spearman's correlations to reduce the influence of extreme values, which demonstrated consistent effects. We concluded this analysis with linear mixed models predicting presence as a function of pronoun usage (See Supplementary Tables 1-24).

Automated Text Analyses

All words were quantified with Linguistic Inquiry and Word Count (LIWC) (Pennebaker et al., 2022) an automated text analysis tool that counts words as a percentage of the total

Table 1. List of Linguistic Dimensions Measured in This Study.

LIWC abbreviation	Dimension	Most Freq. Used Exemplars
i	1st person singular	I, me, my, myself
we	1st person plural	we, our, us, lets
you	2nd person	you, your, yourself
shehe	3rd person singular	he, she, her, his
they	3rd person plural	they, their, them, themself
ipron	Impersonal pronouns	that, it, this, what

word count per text. It contains an internal dictionary of social (e.g., words related to family, friends), psychological (e.g., words related to emotion, cognition), and part of speech categories (e.g., pronouns, articles). For example, the phrase "*I had a great experience in VR"* contains 7 words and counts LIWC categories including, but not limited to, self-references (e.g., I; 14.29% of the total word count), articles (e.g., a; 14.29%), and positive tone (e.g., 14.29%). LIWC is a gold-standard dictionary-based text analysis program that has been validated and applied to thousands of studies in the social sciences (Boyd & Schwartz, 2021). We used LIWC to obtain scores for all pronoun categories.

Measures

Each of the following measures were calculated using only the data from consenting participants.

Language. Examples of all LIWC-22 pronoun measures in this study are located in Table 1, with high scores reflecting the higher use of a linguistic dimension compared to low scores. The unit of analysis was each person in each week (e.g, one person could have language analyzed up to seven times, one for each week they attended a session), with individuals with a word count of less than 25 words in a given week removed from the dataset (Week 1 $n = 136$; Week 2 $n = 118$; Week 3 $n = 106$; Week 4 $n = 110$; Week 6 $n = 92$; Week 7 $n = 99$; Week 8 $n = 77$).

Self, Social, and Spatial Presence. Self, social, and spatial presence scores were obtained using survey items on a 5-point Likert scale (1 = Strongly disagree to 5 = Strongly agree) adapted from prior work (Herrera et al., 2020; Oh et al., 2019). Self presence items consisted of level of agreement with three statements: "*I felt that my avatar represented me," "When something happened to my avatar, I felt like it was happening to me,"* and "*I felt like I was able to control my avatar as though it were my own"* (Cronbach's $\alpha = 0.78$). Social presence items consisted of agreement with three statements: "*I felt like the other people in the room were with me,"* "*I felt like I was face-to-face with others,"* and *"I felt like the other people were aware of my presence"* (Cronbach's $\alpha = 0.84$). Spatial presence items consisted of agreement with three statements: "*It felt as if I was inside the virtual world,"* "*I felt as if I could reach out and touch the objects or people in the virtual environment,"* and "*It felt as if I was visiting another place"* (Cronbach's $\alpha = 0.83$). Participants provided ratings

for each dimension of presence after their weekly discussion sections. These ratings were used to provide scores for each type of presence by calculating the mean of their respective two statements. Presence scores were obtained for each student, each week, with higher scores indicating greater perceived presence. It is worth noting that these presence dimensions were all correlated with each other (rs > .547, ps < .001).

Interpersonal Distance. Interpersonal distance was measured between head positions of participants in the same session. This process produced a time series of data. This was collapsed first into a measure per pair, which was calculated by binning the distance into bins with width of one-third meter and selecting the most common bin. This value was chosen to represent a distance that participants felt most comfortable. Then, in order to calculate a value per participant, we took the median of all pairs for which the given participant was a member. We chose to use the median to mitigate the impact of potential outliers (e.g., one person in a discussion section group standing far away). Tracking data from non-consenting students was dropped prior to calculating interpersonal distance. Therefore, interpersonal distance was not calculated if one student in a dyad was non-consenting.

Results

Descriptive statistics for all data points are located in Table 2 and Table 3. We present bivariate correlations in the main text for ease of interpretation. We also provide results based on linear mixed model calculations — controlling for student, class section, week, and virtual mobility — for transparency and for a more nuanced evaluation of the findings (see Supplementary Tables 1-11).

Language and Self-Reported Presence

After removing data points from participants with low word counts (e.g., less than 25 words[2]), those who did not report presence scores in a given week, and those who

Table 2. Descriptive Statistics for Language and Self-Reported Presence Subsample.

LIWC abbreviation	M	SD	Min	Max
i	6.853	2.915	0	18.92
we	0.791	1.014	0	6.26
shehe	0.175	0.594	0	6.77
they	0.643	0.939	0	8.16
you	1.994	1.636	0	10
ipron	7.541	2.365	0	16.84
Self Presence	2.699	0.818	1	5
Social Presence	3.299	0.865	1	5
Spatial Presence	3.257	0.824	1	5
Word Count	215.556	139.555	27	933

Note. These descriptive statistics are based on the subsample of the dataset used to calculate correlations between language and self-reported presence across all seven weeks.

Table 3. Descriptive Statistics for Language and Interpersonal Distance Subsample.

	M	SD	Min	Max
i	6.970	2.879	0	18.92
we	0.786	1.017	0	6.26
shehe	0.178	0.605	0	6.77
they	0.622	0.906	0	8.16
you	2.002	1.581	0	9.16
ipron	7.525	2.355	0	16.84
Median Interpersonal Distance	5.496	3.045	1	38.667
Word Count	214.216	138.623	27	933

Note. These descriptive statistics are based on the subsample of the dataset used to calculate correlations between language and interpersonal distance across all seven weeks.

Table 4. Pearson Correlations Between Pronoun-Related LIWC Dimensions and Presence Scores.

	Self Presence		Social Presence		Spatial Presence	
LIWC dimension	*r*	*p*	*r*	*p*	*r*	*p*
i	.050	.209	**.079**	**.050***	**.104**	**.010****
we	**.100**	**.012***	**.086**	**.032***	**.118**	**.003****
shehe	.038	.343	.003	.934	.038	.340
they	−.034	.397	−.003	.932	−.014	.719
you	−.018	.661	−.053	.183	−.030	.461
ipron	**−.093**	**.020***	−.038	.341	−.070	.082

Note. ***$p < .001$, **$p < .01$, *$p < .05$.

attended less than 5 sessions, Table 4 findings are based on 626 data points consisting of over 130,000 words from 126 participants across seven weeks.

We found a number of significant correlations between style words and presence. First-person plural pronouns had a positive correlation with each type of self ($r = .100$, $p = .012$), social ($r = .086$, $p = .032$), and spatial presence ($r = .118$, $p = .003$). That is, using words reflective of collective focus was linked to greater feelings of all types of presence among participants. First-person singular pronouns were positively correlated with social presence ($r = .079$, $p = .050$) and spatial presence ($r = .104$, $p = .010$). Therefore, the use of self-references and collective-references was associated with participants feeling a greater degree of presence with others and in their virtual environment. Impersonal pronouns had a significant negative correlation with self-presence ($r = -.093$, $p = .020$). In other words, using depersonalized language was linked to participants feeling less present within their virtual bodies. Similar patterns were found when investigating these relationships using Spearman correlations. Results using linear mixed models were mixed when compared with the correlational

results (See Supplementary Tables 1-18). The only relationship described above that was significantly maintained in a linear mixed model was predicting social presence from self-references ($B = 0.017$, $SE = 0.009$, $t = 2.042$, $p = 0.043$). (See Supplementary Table 7).

Language and Interpersonal Distance

We used median interpersonal distance as a behaviorally approximated metric of social presence. After filtering for data points that included interpersonal distance scores, language greater than 25 words, presence scores, and participants who attended 5 or more sessions, Table 5 findings are based on 566 data points consisting of over 120,000 words from 126 participants across seven weeks.

Impersonal pronouns were positively correlated with median interpersonal distance scores ($r = 0.087$, $p = .039$). In other words, the smaller the median distance a participant was from the rest of their group (e.g., the closer people were to each other), the less the participant used depersonalized language. A linear mixed model also revealed that there was a significant main effect of impersonal pronoun usage on median interpersonal distance, ($B = 0.115$, $SE = 0.051$, $t = 2.234$, $p = 0.026$) (See Supplementary Table 24). Notably, there was no significant correlation between impersonal pronouns and self-reported measures of social presence, revealing how self-report and behavioral measures can diverge when attempting to approximate the same higher-order concept. Additionally, the significant relationships between first-person plural and singular pronouns with self-reported social presence were not observed in this behavioral measure of a user's social experience (See Table 5).

It is worth noting that there was no significant association between interpersonal distance and social presence ($r = -0.010$, $p = 0.631$). This is not unusual in VR studies, and a number of papers have pointed to interpersonal distance as a more sensitive measure of the social presence construct than the self report scales. For example, Bailenson and colleagues (2004) present research when interpersonal distance behavior shows predicted social outcomes when self-report measures fail to do so. In many

Table 5. Pearson Correlations of Pronoun-Related LIWC Dimensions with Median Interpersonal Distance and Social Presence Scores.

	Median Interpersonal Distance	
	r	*p*
i	−.009	.832
we	−.018	.671
shehe	−.015	.730
they	.004	.916
you	−.044	.292
ipron	**0.087**	**.039***

Note. ***$p < .001$, **$p < .01$, *$p < .05$.

ways, VR researchers tend to focus on interpersonal distances as one of the more reliable outcome measures related to social presence (see Miller and colleagues (2023) for a recent review).

Discussion

The sensation of psychological presence is a key metric of user experience in computer-supported work environments, and social VR is becoming an increasingly relevant medium in this domain. Both Apple and Meta, two of the largest companies that have committed substantial resources to the current and future development of VR, are championing the medium to transform the future of work: as a platform for meetings, as a way for employees to codesign objects and spaces, and even to use VR to replace traditional computer screens and keyboards for traditional knowledge work (Egliston & Carter, 2022; *Introducing Apple Vision Pro*, 2023; Bailenson et al., 2024). In all of those work contexts, speech plays an integral role (DeVeaux et al., 2023), yet how speech can provide insight into a user's experience in social VR remains understudied. To address this, our paper explored how style words, which are social in nature and reflect one's attention on others in their environment, linked to presence in immersive virtual settings. We accomplished this by analyzing over 4,800 shared minutes of language data taken from 162 VR discussion sections in a seven weeks university course, alongside self, social, and spatial measures of presence. This paper presented the first study to conduct a large-scale examination of the link between language use and presence in immersive, social VR.

Our results revealed that first-person pronoun use can be especially relevant to presence in social VR. Language indicative of collective focus ("we" words) was positively associated with all dimensions of presence. That is, when social VR users feel immersed in their virtual context, they focus more on group dynamics and use more inclusive language in their communication acts. These findings aligned with Kramer and colleagues' (2006) finding that using "we" pronouns correlated to higher presence scores in a traditional video conferencing setting. We, therefore, offered a positive replication of prior research. Second, first-person singular pronouns ("I" words) were used more when participants reported higher ratings of spatial and social presence scores. This finding indicated that feeling more present among others and within a virtual environment may also be associated with greater self-awareness, self-focus, or attention to the self in the virtual world.

As our evidence suggested, impersonal pronouns (e.g., *that*, *it*, and *this*) are important indicators of presence in immersive virtual environments as well. We found this language to be negatively associated with self-presence and positively associated with interpersonal distance. This indicated that participants used more depersonalized language when they were virtually standing further away from their group and feeling less embodied in their avatars. This link between space (e.g., the physical distance between the self and others) and psychological processing (e.g., how people feel as a result of being close or distant to others) as revealed by impersonal pronouns is consistent with other work that has found people who feel more psychologically distant toward others (e.g., people who dehumanize immigrants), they tended to use more

impersonal pronouns when describing them (Markowitz & Slovic, 2020). Therefore, in our data, impersonal pronouns are a critical indicator of how the mind and body are linked as a reflection of physical and psychological distance.

Interestingly, interpersonal distance correlations yielded different results from social presence correlations. We considered interpersonal distance to be a behavioral approximation of social presence due to its relation to group dynamics. But whereas impersonal pronouns were significantly linked to interpersonal distance, "I" and "we" pronouns were significantly linked to social presence. These differences in results might be explained by previous work that has suggested that behavioral measures can reveal differences in VR user experience that surveys alone have trouble distinguishing (Bailenson et al., 2004). Discerning one's cognitive and affective experience after the fact in a survey can be challenging and cause participants to misreport their responses to stimuli. As a result, the differences reported in this paper are in line with previous work that has shown that behavior does not always align with what is reported in questionnaires (Bailenson et al., 2004). These differences can make it important to supplement findings from self-reported data with findings from behavioral measures.

Empirical and Theoretical Contributions

This paper contributes to a new theoretical understanding of the relationship between language and social VR by tracking, in real time, how people communicated with others and about the self. As researchers and other stakeholders aim to enhance users' sense of presence in social VR, we present evidence that linguistic style can reveal how well this is accomplished. Our findings showcase the importance of collective, self-focused, and impersonal pronoun use in reflecting presence within immersive virtual contexts. Our results therefore offer potential pathways to explain what people are thinking, feeling, and who they are attending to when experiencing psychological presence through the examination of language patterns.

Critically, the words investigated in the current study are unassociated with content, meaning we only evaluated one's linguistic style and how pronouns connect to presence. This is a relatively unexplored, yet promising approach to more deeply understand presence from a psychological angle. Self-report measures like presence are often criticized because they are only measuring perceptions of a psychological phenomenon, not behavior related to a psychological phenomenon. Here, we add theoretical weight to the presence literature by suggesting that how people communicate and who they attend to are linked to feelings of "being there" in a virtual environment. This is one of the largest and most systematic evaluations in social VR to take on this task, and we demonstrate the power of pronouns to reveal yet another important social and psychological dimension in the wild. To emphasize this point, it is critical to remember that pronouns are fundamentally social (Pennebaker, 2011), because they indicate who people are attending to and who they are not attending to. The fact that pronouns are associated with presence suggests that presence has an understated socialized component to it in social VR. That is, presence is typically considered a self-perception, where people who have high presence ratings tend to indicate a greater sense of the self "being there" in the virtual world.

Here, we have learned that presence is also linked to how people attend to others in the social environment. Part of presence, then, is also fundamentally social, including how much people focus on the self, the collective, and on others. This is some of the first evidence of its kind to reveal presence as socialization through language use.

The theoretical implications of this work for social VR also deserve to be underscored. We observed that across 8 weeks of an academic class, participants spoke a non-trivial amount in class. This is language data that would ordinarily be ignored by most VR scholars. We have learned important information about presence and its social connections via pronouns; it is, therefore, possible that pronouns link to other important affordances of VR (e.g., immersion, embodiment), yet most studies will not examine how people use language in such settings. We urge those in the VR research community to make use of communication patterns in virtual worlds, using what and how people speak as new opportunities to learn more about traditional VR concepts. It is possible that language can reveal mechanisms underlying various relationships observed in VR; we encourage the cross-pollination of natural language processing and VR research to examine this possibility directly.

Limitations and Future Directions

That said, there are several limitations of work. First, while our correlational results produced a number of significant findings, testing these relationships through linear mixed models did not all yield the same degree of significance. Consequently, our results should be interpreted with this in mind. Second, the language used in this study was influenced by the context in which it occurred. In particular, the language of participants was shaped by the VR-centric content of the course that conversations took place. Furthermore, discussion sections were mainly facilitated by course instructors and therefore did not involve many casual conversations. To have a more robust understanding of language in VR, future research should examine conversations that occur in more naturalistic contexts. Third, the present study only accounts for language in a VR classroom without a counterbalanced design to understand how it differs from traditional forms of instruction. For a more comprehensive understanding of how medium shapes language in the classroom, future work may explore how the relationships identified in this study compare between classes conducted in-VR, in-person, and on desktop computers.

Conclusion

VR is a perceptual medium. As such, there is a plethora of research on how people move, gesture, and experience presence in VR. However, the rise of social VR has drastically increased the use of VR as a platform for speaking and listening. While there have been a handful of previous studies that have examined language in VR, the field still knows very little about what is unique, linguistically, about the medium. Our current work provides a first deep look into how linguistic cues are linked to presence in immersive, virtual mediums. These findings can inform how scholars and practitioners use linguistic techniques to better understand social VR.

Acknowledgments

The authors would like to thank the team at ENGAGE for providing support throughout the study. The authors would also like to thank Brian Beams, Daniel Akselrad, Hanseul Jun, and Mark York for their support with the course. The authors would also like to thank Benjamin Liao, Benjamin Martinez, Ilan Ladabaum, Neha Vinjapuri, Ryan Chen, Sarah Chung, Sharon Cheng, and Umar Patel for their support with the data analysis of this study. The authors would also like to thank the reviewer for their thoughtful comments on this paper and the editor, Howie Giles, for the diligent processing of this manuscript and his dedication to the field of language and social psychology.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the National Science Foundation (grant number 1800922).

ORCID iDs

Cyan DeVeaux https://orcid.org/0000-0003-2655-9841
David M. Markowitz https://orcid.org/0000-0002-7159-7014

Supplemental Material

Supplemental material for this article is available online.

Notes

1. n_x where x signifies the number of times a participant experienced VR.
2. We selected 25 words as the threshold for filtering out data points with low word counts to remain in line with best practices in text analysis literature (Boyd, 2017).

References

Alvidrez, S., & Peña, J. (2020, December). Verbal mimicry predicts social distance and social attraction to an outgroup member in virtual reality. In *2020 IEEE international conference on artificial intelligence and virtual reality (AIVR)* (pp. 68–73). IEEE. https://doi.org/10.1109/AIVR50618.2020.00023

Ashokkumar, A., & Pennebaker, J. W. (2022). Tracking group identity through natural language within groups. *PNAS Nexus*, *1*(2), pgac022. https://doi.org/10.1093/pnasnexus/pgac022

Bailenson, J., Beams, B., Brown, J., DeVeaux, C., Han, E., Queiroz, A., Ratan, R., Santoso, M., Srirangarajan, T., Tao, Y., & Wang, P. (2024). Seeing the world through digital prisms: Psychological implications of passthrough video usage in mixed reality. *Technology, Mind, and Behavior (TMB)*. (In Press).

Bailenson, J. N., Aharoni, E., Beall, A. C., Guadagno, R. E., Dimov, A., & Blascovich, J. (2004, October). Comparing behavioral and self-report measures of embodied agents' social

presence in immersive virtual environments. In *Proceedings of the 7th Annual International Workshop on PRESENCE (Vol. 1105)*. IEEE.

Bailenson, J. N., Beall, A. C., Loomis, J., Blascovich, J., & Turk, M. (2005). Transformed social interaction, augmented gaze, and social influence in immersive virtual environments. *Human Communication Research*, *31*(4), 511–537. https://doi.org/10.1111/j.1468-2958.2005.tb00881.x

Blascovich, J. (2002). Social influence within immersive virtual environments. In R. Schroeder (Ed.), *The social life of avatars* (pp. 127–145). Computer Supported Cooperative Work. Springer. https://doi.org/10.1007/978-1-4471-0277-9_8

Boyd, R. L. (2017). Psychological text analysis in the digital humanities. In S. Hai-Jew (Ed.), *Data analytics in digital humanities* (pp. 161–189). Springer International Publishing. https://doi.org/10.1007/978-3-319-54499-1_7

Boyd, R. L., & Schwartz, H. A. (2021). Natural language analysis and the psychology of verbal behavior: The past, present, and future states of the field. *Journal of Language and Social Psychology*, *40*(1), 21–41. https://doi.org/10.1177/0261927X20967028

Chung, C., & Pennebaker, J. (2007). The psychological functions of function words. In K. Fiedler (Ed.), *Social communication* (pp. 343–359). Psychology Press.

Cohn, M. A., Mehl, M. R., & Pennebaker, J. W. (2004). Linguistic markers of psychological change surrounding September 11, 2001. *Psychological Science*, *15*(10), 687–693. https://doi.org/10.1111/j.0956-7976.2004.00741.x

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, March). Descriptive linguistic patterns of group conversations in VR. In *2023 IEEE conference on virtual reality and 3D user interfaces abstracts and workshops (VRW)* (pp. 785–786). IEEE. https://doi.org/10.1109/VRW58643.2023.00235

Egliston, B., & Carter, M. (2022). The metaverse and how we'll build it': The political economy of Meta's Reality Labs. *New Media & Society*, *0*(0). https://doi.org/10.1177/14614448221119785

Eichert, N., Peeters, D., & Hagoort, P. (2018). Language-driven anticipatory eye movements in virtual reality. *Behavior Research Methods*, *50*(3), 1102–1115. https://doi.org/10.3758/s13428-017-0929-z

Eichstaedt, J. C., Smith, R. J., Merchant, R. M., Ungar, L. H., Crutchley, P., Preoţiuc-Pietro, D., Asch, D. A., & Schwartz, H. A. (2018). Facebook language predicts depression in medical records. *Proceedings of the National Academy of Sciences*, *115*(44), 11203–11208. https://doi.org/10.1073/pnas.1802331115

Frommel, J., Sagl, V., Depping, A. E., Johanson, C., Miller, M. K., & Mandryk, R. L. (2020). Recognizing affiliation: Using behavioural traces to predict the quality of social interactions in online games. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–16. https://doi.org/10.1145/3313831.3376446

Gullström, C., & Kort, J. (2016). Where did my office go? Is it in the cloud!? workshop on spatial and social connectedness in virtual and mediated work environments. *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion*, 457–464. https://doi.org/10.1145/2818052.2855525

Han, E., Miller, M. R., DeVeaux, C., Jun, H., Nowak, K. L., & Hancock, J. T., … 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

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., Oh, S. Y., & Bailenson, J. N. (2020). Effect of behavioral realism on social interactions inside collaborative virtual environments. *Presence: Teleoperators and Virtual Environments*, *27*(2), 163–182. https://doi.org/10.1162/pres_a_00324

Hughes, M., & Roy, D. (2020). Keeper: An online synchronous conversation environment informed by in-person facilitation practices. *Companion Publication of the 2020 Conference on Computer Supported Cooperative Work and Social Computing*, 275–279. https://doi.org/10.1145/3406865.3418344

Introducing Apple Vision Pro: Apple's first spatial computer (2023). Apple Newsroom. https://www.apple.com/newsroom/2023/06/introducing-apple-vision-pro/.

Ireland, M. E., & Mehl, M. R. (2014). Natural language use as a marker of personality. In T. M. Holtgraves (Ed.), *The Oxford handbook of language and social psychology* (pp. 201–237). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199838639.001.0001

Jicol, C., Clarke, C., Tor, E., Yip, H. L., Yoon, J., Bevan, C., Bowden, H., Brann, E., Cater, K., Cole, R., Deeley, Q., Eidinow, E., O'Neill, E., Lutteroth, C., & Proulx, M. J. (2023). Imagine that! imaginative suggestibility affects presence in virtual reality. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, 1–11. https://doi.org/10.1145/3544548.3581212

Jicol, C., Feltham, J., Yoon, J., Proulx, M. J., O'Neill, E., & Lutteroth, C. (2022). Designing and assessing a virtual reality simulation to build resilience to street harassment. *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, 1–14. https://doi.org/10.1145/3491102.3502129

Kacewicz, E., Pennebaker, J. W., Davis, M., Jeon, M., & Graesser, A. C. (2014). Pronoun use reflects standings in social hierarchies. *Journal of Language and Social Psychology*, *33*(2), 125–143. https://doi.org/10.1177/0261927X13502654

Kramer, A. D. I., Oh, L. M., & Fussell, S. R. (2006). Using linguistic features to measure presence in computer-mediated communication. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 913–916. https://doi.org/10.1145/1124772.1124907

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

Markowitz, D. M. (2018). Academy awards speeches reflect social status, cinematic roles, and winning expectations. *Journal of Language and Social Psychology*, *37*(3), 376–387. https://doi.org/10.1177/0261927X17751012

Markowitz, D. M. (2022a). Gender and ethnicity bias in medicine: A text analysis of 1.8 million critical care records. *PNAS Nexus*, *1*(4), pgac157. https://doi.org/10.1093/pnasnexus/pgac157

Markowitz, D. M. (2022b). Psychological trauma and emotional upheaval as revealed in academic writing: The case of COVID-19. *Cognition and Emotion*, *36*(1), 9–22. https://doi.org/10.1080/02699931.2021.2022602

Markowitz, D. M., & Slovic, P. (2020). Social, psychological, and demographic characteristics of dehumanization toward immigrants. *Proceedings of the National Academy of Sciences*, *117*(17), 9260–9269. https://doi.org/10.1073/pnas.1921790117

Miller, M. R., DeVeaux, C., Han, E., Ram, N., & Bailenson, J. N. (2023, March). A large-scale study of proxemics and gaze in groups. In *2023 IEEE Conference Virtual Reality and 3D User Interfaces (VR)* (pp. 409–417). IEEE. https://doi.org/10.1109/VR55154.2023.00056

Miller, M. R., Sonalkar, N., Mabogunje, A., Leifer, L., & Bailenson, J. (2021). Synchrony within triads using virtual reality. *Proceedings of the ACM on Human-Computer Interaction*, *5*(CSCW2), 1–27. https://doi.org/10.1145/3479544

Oh, C., Herrera, F., & Bailenson, J. (2019). The effects of immersion and real-world distractions on virtual social interactions. *Cyberpsychology, Behavior, and Social Networking*, *22*(6), 365–372. https://doi.org/10.1089/cyber.2018.0404

Oh, S. Y., Bailenson, J., Krämer, N., & Li, B. (2016). Let the avatar brighten your smile: Effects of enhancing facial expressions in virtual environments. *PloS one*, *11*(9), e0161794. https://doi.org/10.1371/journal.pone.0161794

Palomares, N. A., & Lee, E.-J. (2010). Virtual gender identity: The linguistic assimilation to gendered avatars in computer-mediated communication. *Journal of Language and Social Psychology*, *29*(1), 5–23. https://doi.org/10.1177/0261927X09351675

Pan, Y., & Steed, A. (2017). The impact of self-avatars on trust and collaboration in shared virtual environments. *PloS one*, *12*(12), e0189078. https://doi.org/10.1371/journal.pone.0189078

Pennebaker, J. W. (2011). The secret life of pronouns. *New Scientist*, *211*(2828), 42–45. https://doi.org/10.1016/S0262-4079(11)62167-2

Pennebaker, J. W., Boyd, R. L., Booth, R. J., Ashokkumar, A., & Francis, M. E. (2022). Linguistic inquiry and word count: LIWC-22 [Computer software]. Pennebaker Conglomerates. https://www.liwc.app.

Pfeiffer, T. (2012). Using virtual reality technology in linguistic research. *2012 IEEE Virtual Reality Workshops (VRW)*, 83–84. https://doi.org/10.1109/VR.2012.6180893

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

Seraj, S., Blackburn, K. G., & Pennebaker, J. W. (2021). Language left behind on social media exposes the emotional and cognitive costs of a romantic breakup. *Proceedings of the National Academy of Sciences*, *118*(7), e2017154118. https://doi.org/10.1073/pnas.2017154118

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

Smith, H. J., & Neff, M. (2018). Communication behavior in embodied virtual reality. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 1–12. https://doi.org/10.1145/3173574.3173863

Voigt, R., Camp, N. P., Prabhakaran, V., Hamilton, W. L., Hetey, R. C., Griffiths, C. M., Jurgens, D., Jurafsky, D., & Eberhardt, J. L. (2017). Language from police body camera footage shows racial disparities in officer respect. *Proceedings of the National Academy of Sciences*, *114*(25), 6521–6526. https://doi.org/10.1073/pnas.1702413114

Weisberg, S. M., & Newcombe, N. S. (2017). Embodied cognition and STEM learning: Overview of a topical collection in CR:PI. *Cognitive Research: Principles and Implications*, *2*(1), 38. https://doi.org/10.1186/s41235-017-0071-6

Wu, J., Mattingly, E., & Kraemer, P. (2015). Communication in virtual environments: The influence of spatial cues and gender on verbal behavior. *Computers in Human Behavior*, *52*, 59–64. https://doi.org/10.1016/j.chb.2015.05.039

Author Biographies

Cyan DeVeaux is a Ph.D. candidate in the Department of Communication at Stanford University and a member of the Virtual Human Interaction Lab. DeVeaux's multidisciplinary research focuses on embodied and social experiences in augmented and virtual reality.

David M. Markowitz is an associate professor in the Department of Communication at Michigan State University. Professor Markowitz uses language data from natural repositories to make inferences about what people are thinking, feeling, and experiencing psychologically. His work has appeared in outlets such as the *Proceedings of the National Academy of Sciences*, J*ournal of Communication*, and *Journal of Language and Social Psychology*, and he was selected as a "Rising Star" of the Association for Psychological Science in 2022.

Eugy Han is a Ph.D. candidate at the Virtual Human Interaction Lab at Stanford University. Han's research focuses on social and spatial (physical and virtual) contexts and how they influence psychological and behavioral outcomes during social interactions in virtual spaces.

Mark Roman Miller is an Assistant Professor at the Illinois Institute of Technology specializing in virtual and augmented reality through the lenses of communication, security, and data science. Professor Miller investigates the vast data generated by virtual and augmented reality devices, uncovering scientific insights into emotions and nonverbal communication while recognizing the privacy risks associated with this data.

Jeffrey T. Hancock is the founding director of the Stanford Social Media Lab and is a Professor in the Department of Communication at Stanford University. Professor Hancock and his group work on understanding psychological and interpersonal processes in social media.

Jeremy N. Bailenson is the founding director of the Virtual Human Interaction Lab and the Thomas More Storke Professor in the Department of Communication at Stanford University. Professor Bailenson studies the psychology of Virtual and Augmented Reality, in particular how virtual experiences lead to changes in perceptions of self and others.