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Impact of Immersiveness on Persuasiveness, Politeness, and Social Adherence in Human-Agent Interactions within Small Groups

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Abstract

Politeness is critical for shaping human-human interactions and therefore seems an important consideration in human interactions with Embodied Conversational Agents (ECAs). However, the impact of artificially-generated politeness behaviors on humans in Virtual Environments (VE) is not clear. We explore the impact of immersiveness on the perceived politeness and consequent persuasive abilities of ECAs in a small group context. A user study with two main conditions, immersive and non-immersive, was conducted with 66 participants. In the immersive condition, participants were fully immersed in virtual reality (HMD, walking freely), while in the non-immersive condition, participants used a desktop computer interface (screen display, mouse and keyboard control). In both conditions, the primary agent in a group of two ECAs invited participants to join the group using six politeness behaviors derived from Brown and Levinson's politeness theory. While the results of the study did not indicate any significant differences between the immersive and non-immersive conditions in terms of persuasiveness and offensiveness, in the immersive condition, participants perceived the ECAs as less friendly and found their requests to be less clear. On the other hand, participants in the immersive condition reported a greater sense of freedom. Furthermore, the non-immersive condition showed higher adherence to social norms compared to the immersive condition. These findings emphasize the significance of examining immersiveness on the persuasiveness of ECAs and their perceived politeness and social adherence by humans in human-agent interactions within small groups.

CCS Concepts

• ***Human-centered computing*** → ***Empirical studies in HCI; Virtual reality; User studies;***

1. Introduction

In both the physical world and virtual environments (VEs), small group interactions play a pivotal role in shaping our social experiences [McG84, SRBC15]. Gathering together in the same location, physical or real, in small groups [Ken90] underlies many social activities, from conversations to collaborations. Understanding and replicating the experiences and benefits of situated group interactions in VEs opens great possibilities, but also comes with challenges. One challenge relates to understanding the potential impacts of immersiveness [Sla03], the extent to which humans feel fully engaged in these digital environments, on social interactions. Understanding the impact of immersiveness on human perception, behavior, and experience in VR is foundational to attempts to create meaningful virtual interactions that reflect the best aspects of our real-world experiences. For example, politeness [BL78] strategies and their associated behaviors are a powerful means in the physical world for supporting efficient social interactions, maintaining collaborative relationships between individuals, and even supporting gentle persuasion attempts [OKH09]. Questions arise about how these behaviors and their interpretations transfer to the virtual world, especially when the behaviors are enacted by agents that are virtual representations of humans, such as Embodied Conversational Agents (ECAs) [Cas01].

This study investigates these aspects in small group situations by considering the following question: What is the impact of the immersiveness of the VE (*immersive* condition: HMD, walking freely versus *non-immersive* condition: screen display, mouse and keyboard control) on the perceived politeness and persuasiveness of an ECA that invites a human into a small group of agents?

To address this question, a user study was performed in which 66 participants were placed in a VE and invited by an ECA to join its small conversational group. The scenario involved a social dilemma in which participants had to decide between (1) expending more effort to join the group in a socially acceptable manner conforming to the ECA's request (i.e., by taking an *inconvenient* route around the group), (2) taking a least effort but *unsocial route* (i.e., joining the group by walking straight through its center, violating the *o-space* of the group) that nevertheless conforms to the ECA's request, or (3) by taking a *convenient* route to join the group at the *closest* side, thus balancing effort and social acceptance while violating the ECA's request to join the group at the *furthest* side.

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Table 1: *Experiment design: 2x6 factorial mixed between (i.e., immersiveness) and within (i.e., politeness behaviors) subject design*

		ECA's politeness behaviors *(Within factor)*
		Six levels, see Table 3
Immersiveness *(Between factor)*	**Condition 1:** Immersive (Virtual Reality: HMD, walking freely)	Dependant variables: *persuasiveness*, *clarity*, *face loss*, *positive face*, *negative face*, and *social adherence*
	Condition 2: Non-immersive (Desktop: screen display, mouse-keyboard)	Dependant variables: *persuasiveness*, *clarity*, *face loss*, *positive face*, *negative face*, and *social adherence*

This study provides knowledge towards crafting social experiences in immersive VEs that take place with groups of virtual agents such as ECAs.

2. Related work

When individuals come together to engage in communication, they may form what are known as *free-standing conversational groups*. The management of space within and between individuals in a group has been a subject of investigation in several studies [Hal66, Ken90]. According to Kendon [Ken90], F-formation comprises three social spaces: the *o-space*, which is a convex empty space surrounded by individuals engaged in a social interaction exclusive to group members; the *p-space*, which encompasses the area around the *o-space* and contains the group members; and the *r-space*, which extends beyond the *p-space* and is intended for the public. The joining behavior of individuals in free-standing conversational groups adheres to politeness codes and social norms. These dictate how to invite a newcomer to join an ongoing free-standing group, how to approach and position oneself in relation to the group, and how to navigate the social and personal spaces of group members. In this study, individuals must navigate social spaces, such as the o-space, when joining a group of ECAs in a virtual environment. ECAs are virtual characters designed to interact with humans in a natural and engaging manner. By simulating human-like behavior and appearance, ECAs may establish a sense of presence and foster effective communication [BYMS06]. The CASA (Computers Are Social Actors) paradigm, as demonstrated in prior research [NST94, RN96, LN10], highlights the human tendency to attribute human-like qualities to computers and other technological devices. Consequently, individuals integrate elements relevant to human interactions, such as politeness [NMC99], into their interactions with these devices, which may also influence their decision-making. In order to investigate this in our study, the ECA invites participants to join the group using six distinct politeness behaviors related to politeness strategies derived from the theory of Brown and Levinson [BL78].

When replicating the group situations in virtual settings, the potential impact of the immersive aspect of virtual reality is an especially important consideration. We explore the concept of immersiveness and its impact on participants' perceptions and responses to virtual agents in the context of Human-Agent Interaction (HAI). The concept of immersion, as defined by Slater [Sla03], pertains to the objective extent of sensory realism delivered by a virtual reality (VR) system. Several studies [WYG20, GSV*03, BYMS06, KB18] have demonstrated the positive impact of immersion on participants' perception and response towards virtual agents, emphasizing the need to consider it in the design of studies related to HAI. While the effects of *immersiveness* on social and collaborative interactions in virtual environments have been explored in several research works [WOGG*22, WLV*21, SS15, NR21, BLB*02, TM23], the extent to which *immersiveness* may influence HAI in relation to *politeness* behaviors in small group situations has not been extensively investigated.

Multiple studies have investigated social behaviors and norms in individual or group scenarios involving robots [AIK*04, YP19, TN18, RMSL15, CMG*19] or ECAs [RAN05, CRO*16, TOG21, AMTT12]. These studies have examined the impact of social cues such as gaze, facial expressions, and body posture on users' perception of agents' social presence and their willingness to interact with them [RPA*15, She20]. Overall, research in HAI has demonstrated the critical role of social behaviors and norms in shaping interactions with ECAs and robots [NCRI22, VRTB18, VLF*09, TSGZ16].

Additionally, previous studies [ZPP20, IZP22] using a similar experimental protocol to this work have investigated the impact of politeness behaviors of ECAs on the routes taken by human participants when joining a virtual conversational group. However, these studies have not considered how immersiveness may impact the perceived politeness and persuasiveness of ECAs, which is the central theme of this study.

3. Experiment

3.1. Design

This study employed a 2x6 factorial mixed between and within subject design (refer to Table 1) to examine the impact *immersiveness* on the *persuasiveness* of an ECA and participants' perceptions of its *politeness* and their *social adherence*. The study's independent variables include the *immersiveness* (with two levels: *immersive* and *non-immersive*) and the ECA's *politeness* behaviors (with six levels, see Table 3 for overview). These behaviors are based on the theory of Brown and Levinson [BL78], who identified five strategies to communicate needs while minimizing face-threatening acts: non-performance of the act (`NOT`), indirect communication (`IND`) using indirect language, negative politeness (`NEG`) focused on avoiding imposition, positive politeness (`POS`) emphasizing friendliness, and direct communication (`DIR`) using clear and direct language.

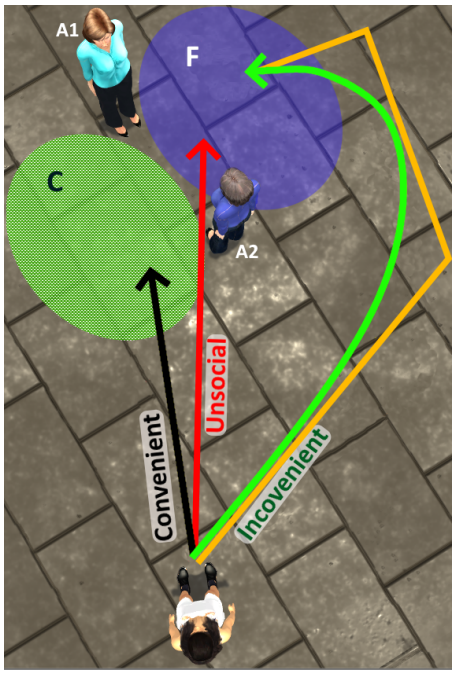

Figure 1: *Top-down perspective of the ECAs' positioning (top) and the avatar controlled by the participant (bottom). While the primary ECA (A1) invites participants to join the group at the furthest side F by conducting verbal and non-verbal behaviors, participants have a choice to join the group at the closest side (green oval, C) or furthest side (blue oval, F). Potential routes to join the group are marked as the convenient route in black, the unsocial route in red, and the inconvenient route in the immersive condition in green, and in the non-immersive condition in orange. Due to the keyboard control method in the non-immersive condition, the segmented trajectory represented in orange represents the actual inconvenient path taken to reach F (see Table 2). **Note:** Top-down view for illustration; actual experiment used a first-person perspective.*

Participants' perception of the ECA's politeness is evaluated through dependent variables: *clarity*, *face loss*, *positive face*, and *negative face*. Participants in both conditions were recruited from online platforms and the pool of university staff and students. As a token of appreciation, they were provided compensation in the form of vouchers or cinema tickets.

An indoor virtual room that was used as a basis for the scenario was developed in Unity 3D game engine[†]. Two ECAs, specifically Greta agents[‡], were employed and positioned in the center of the virtual room, forming a face-to-face group arrangement. These Greta agents were selected from a pool of eight distinct character appearances, comprising four female and four male agents. Depending on the gender of the participant, two Greta agents of the same gender as the participant were randomly assigned to the group

† https://www.unity.com/

‡ https://github.com/isir/greta/wiki

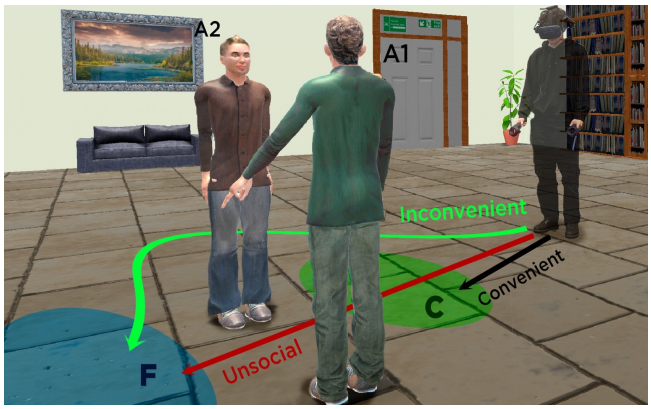

Figure 2: *A participant in a virtual reality environment (immersive condition) is invited by A1 to join a group at the furthest side F by conducting verbal and non-verbal behaviors. The participant has a choice to join the group at the closest side (green oval, C) or furthest side (blue oval, F) (see Table 2). **Note:** Third-person view is for illustration only; actual experiment used a first-person perspective.*

Table 2: Experiment dilemma*: joining alternatives and their associated trade-offs, as perceived by participants (see Figure 1).*

Routes	Persuasion	Social adherence	Effort
Convenient	No	Yes	Low
Unsocial	Yes	No	Medium
Inconvenient	Yes	Yes	High

for each trial. The primary ECA (A1) directly faced the participants and utilized a combination of verbal and non-verbal politeness behaviors to invite them to join the group (refer to Figure 1 and Figure 3). A1 consistently invited participants to the *furthest* side of the group, except for the `BSL` conditions. Moreover, A1 maintained eye contact with and smiled at the participant throughout the experiment. In both conditions, participants were informed that the ECAs were fully autonomous and were presented with the same first-person perspective of the environment (see Figure 3).

Both conditions included six politeness behaviors, as depicted in Table 3, where each behavior represented specific politeness strategies and corresponding verbal and nonverbal behaviors of the ECA. All participants went through all six behaviors, and the order of presentation was counterbalanced using a Latin Square design to minimize order effects. Each of the six behaviors was repeated three times, resulting in a total of 18 trials for each participant. The same sequence of the six conditions used in the first block was replicated in the subsequent two blocks of the experiment. The repetition of behaviors aimed to investigate the consistency of participants' responses over time and assess whether they would become tired or frustrated with repeated actions. This design choice aimed to enhance the robustness of the results by examining the durability of participants' behaviors and their potential impact on the outcomes.

The study was designed to present participants with a dilemma

Figure 3: ***Main ECA's (A1) behavior:*** *in each case A1 invites the participant to join the group by conducting verbal and non-verbal behaviors related to the following politeness strategies derived from the politeness theory of Brown and Levinson [BL78] (see Table 3), from left to right: (a) no face-threatening act (`NOT`); (b) indirect (`IND`); (c) negative face (`NEG`); (d) positive face (`POS`); (e) direct (`DIR`).*

Table 3: *ECA's behaviors and their associated politeness strategies, verbal and nonverbal behaviors derived from Brown and Levinson [BL78]. *Note: the ECAs conducted the same reaction (gaze at the participant and smile) throughout the entire duration of each trial.*

Behaviors	Strategy	Verbal behavior	Nonverbal behavior
1. Baseline (BSL)	NOT	None	None*
2. Indirect (IND)	IND	"Welcome back!"	Open palm up
3. Asking (ASK)	NEG	"Would you like to come here?"	Open palm sideways
4. Proposing (PRO)	POS	"This place is waiting for you!"	Open palm sideways and partly downward
5. Commanding (CMD)	DIR	"Come here!"	Pointing directly at a specific point with the index finger
6. Pointing (PNT)	DIR	None	Pointing directly at a specific place with the index finger

where they had to make a choice among three options. The first option requires more effort as they have to join the group in a socially acceptable manner, taking a longer route around the group (*inconvenient* route). The second option involves a lower effort but socially *unsocial* route, where they could walk straight through the center of the group, violating the group's *o-space*. Despite this violation, it still conforms to the ECA's request. The third option offers a balance between effort and social acceptance. Participants could take a more *convenient* route to join the group at the *closest* side. However, this option violates the ECA's request to join to the *furthest* side (see Table 2 and Figure 1). It's important to note that participants had complete freedom in choosing where and how to join the group. Furthermore, to account for the potential impact of handedness on the experiment, both conditions incorporated a variation in participants' starting locations, alternating between the left and right sides of the group. It was ensured that the ECA A1 consistently invited participants to the side that was farthest from their specific initial location[§].

3.2. Metrics

The compliance of participants with the ECA's request to join the group at the *furthest* side in each trial was recorded. This allowed for the calculation of *persuasiveness* rate. The frequency of *o-space* crossings, representing the instances where participants walked between the primary and secondary ECAs, was also recorded. Based on these measurements, the success rates of the ECA's request and adherence to social behavioral norms were calculated. Moreover, after participants had joined the group, they were asked to respond to four Likert scale questions using a 7-point scale ranging from "strongly disagree" to "strongly agree". These questions pertained to their perception of the politeness exhibited by the ECA in that specific trial. The questions that were asked along with their associated metrics are as follows:

1. **"I could precisely understand the speaker's wants."** This question aimed to assess the *clarity* of the robot's requests.
2. **"I got offended by the speaker's action."** This question was designed to measure the extent of *face loss* or offensiveness perceived in the ECA's requests.
3. **"The speaker wanted to increase intimacy with me."** This question aimed to determine the level of satisfaction related to *positive face*, which encompasses friendly or warm behavior.
4. **"The speaker respected my freedom of action."** This question was intended to evaluate the level of satisfaction related to *negative face*, which pertains to respecting the other's choice, freedom of action, or exhibiting a more distant behavior.

In the *immersive* condition, participants used VR controllers inside the virtual environment (VE) to provide their feedback on the four statements mentioned earlier. On the other hand, in the *non-immersive* condition, participants interacted with the screen using a

§ Link to video demonstration: https://youtu.be/CybC-GC9aI0

mouse and keyboard, and they provided their feedback on the same screen where they interacted.

3.3. Immersive condition: VR

Figure 2 depicts a participant immersed in the VE. To enable participants to have unrestricted movement within the VE, an HTC VIVE Pro headset with a wireless adapter was utilized in this study. This setup allowed participants to walk freely within the VE. Various potential walking routes in the VE are depicted in Figure 2. Taking the *inconvenient* route required ∼14 steps, the *unsocial* route ∼10 steps, and the *convenient* route ∼7 steps. To ensure their safety and prevent collisions with real-world objects in a physical room measuring 10x12 m^2, two methods were employed: the Redirected Walking method [RKW01] and the freeze-turn method [BRKD19]. These techniques were implemented to ensure that participants could navigate the VE freely without unintentionally colliding with physical objects. Moreover, the participants were instructed to begin the experiment in a specific location and facing a particular direction in the actual room (towards the group in VR) before putting on the VR headset. For each trial, once they joined the group of ECAs in the VE, a questionnaire was presented to them at the starting position. To interact with the questionnaire user interface, they had to walk back to the initial position and face the original orientation. This ensured that they were in the correct position and orientation to start the next trial.

3.4. Non-immersive condition: Desktop

Participants interacted with the virtual scenario using a keyboard and observed the environment through a monitor. They had the ability to control their avatar's movement by pressing the up and down keys to move forward or backward, while the right and left keys allowed them to rotate the avatar's body to the right or left. As a result, participants had the option to take a direct path toward the *closest* side (C) to join the group. However, when approaching the *furthest* side (F), their trajectory typically consisted of segmented movements, as illustrated by the orange curve in Figure 1, rather than smooth and continuous movements, represented by the green curve. The chosen method of navigating the avatar was specifically designed to increase participants' level of effort needed to join the group at the *furthest* side. Taking the *inconvenient* route required ∼15 seconds, the *unsocial* route ∼10 seconds, and the *convenient* route ∼7 seconds.

4. Results

To ensure privacy, the collected data from each participant was anonymized in both conditions, and participants provided written consent prior to the start of the experiment.

4.1. Participants in the immersive condition

The immersive condition involved 36 participants who had a proficient level of English with ages ranging from 18 to 39 (average age of 26 ± 4.5). Among them, approximately 36% (n = 13) were women, and approximately 64% (n = 23) were men. Furthermore, about 58% of the participants had basic (n = 14) or no (n = 7) prior experience with AI systems, while the remaining participants had intermediate (n = 11) or advanced (n = 4) experience in the field. In terms of virtual reality (VR), a larger number of participants had basic (n = 21) or no (n = 7) experience, compared to those with intermediate (n = 3) or advanced (n = 3) experience.

4.2. Participants in the non-immersive condition

The non-immersive condition involved 30 participants with proficient English skills. The sample consisted of 18 females and 12 males, with ages ranging from 22 to 43 years old (average age of 29 ± 6). Regarding their understanding and familiarity with AI systems and ECAs, 20% reported having no knowledge, 27% had basic knowledge, 40% had intermediate knowledge, and 13% had advanced knowledge.

4.3. Method

Mixed repeated measures ANOVAs were conducted on the data collected from the study. The analysis included politeness *behaviors*, which had six different levels as indicated in Table 3), as a within-subject factor. Additionally, *immersiveness* with two levels (*immersive* and *non-immersive*) was treated as a between-subject factor. The dependent variables measured in the study were *Persuasiveness*, *Clarity*, *Face loss*, *Positive face*, *Negative face*. To ensure the comparability of the *immersive* and *non-immersive* groups, we conducted a group homogeneity assessment, which revealed no significant differences in terms of the dependent variables.

4.4. Persuasiveness

Figure 4 provides a detailed illustration of the *persuasiveness* of the ECAs in both experimental conditions and their corresponding associated politeness behaviors. Overall, the analysis showed that the *immsersiveness* did not have a significant main effect on the *persuasiveness* level of the ECA, $F(1, 64) = 0.001$, $p = 0.978$. Table 4 provides a comprehensive breakdown of the *success* rate (*Persuasiveness*) categorized by block and study. Across all conditions, in the *immersive* condition, participants were successfully persuaded to join the group at the furthest side in 54% of the trials. On the other hand, the *non-immersive* condition achieved a slightly higher persuasion success rate of 58%. This suggests a slight, non-significant overall trend where the *non-immersive* condition was slightly more effective in persuading participants to join the group at the *furthest side* compared to the *immersive* condition. Furthermore, the *persuasiveness* of the ECAs in the *immersive* condition exhibited a minor decline across the blocks, whereas, in the case of *non-immersive* condition, it showed an increase.

4.5. Social adherence

Table 4 also provides data concerning *o-space crossings* rates and the adherence to social conventions among cases where participants were successfully persuaded to join the group at the *furthest* side. In the *immersive* condition, participants adhered to social conventions by not crossing the *o-space* in an average of 74% of the trials. In contrast, the *non-immersive* condition achieved a higher level of social adherence, with participants not crossing the o-space in all

Table 4: *Breakdown of success rate and o-space crossings rate, categorized by block and study. Across all conditions, in the immersive condition, participants were successfully persuaded to join the group at the furthest side in 54% of the trials, while the non-immersive condition achieved a persuasion success rate of 58%. Among the cases where participants were successfully persuaded to join the group at the furthest side, they adhered to social conventions by not crossing the o-space in an average of 74% of the trials in the immersive condition, and 100% in the non-immersive condition.*

Block (trials)	**I (1-6)**		**II (7-12)**		**III (13-18)**		**Total**	
Study	VR	Desktop	VR	Desktop	VR	Desktop	VR	Desktop
Requested	170	137	170	143	169	145	509	425
Successful	98	73	89	84	87	88	274	245
Success rate	58%	53%	52%	59%	51%	61%	54%	58%
O-space crossings	25	0	27	0	18	0	70	0
Social adherence	74%	100%	70%	100%	79%	100%	74%	100%

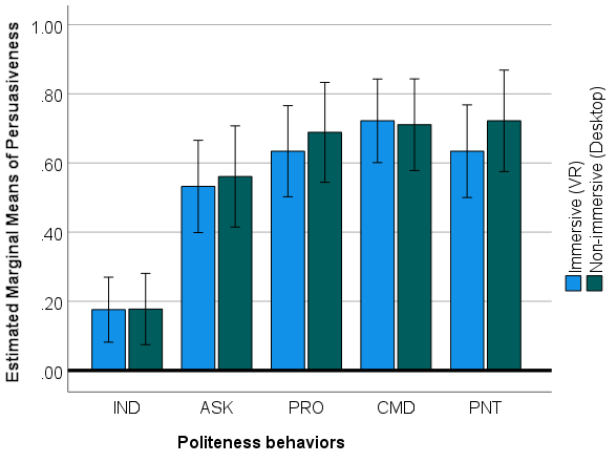

Figure 4: Persuasiveness *of the ECA's request in both experimental conditions and their associated politeness behaviors. The Y-axis plots the average value over all participants and trials of the* persuasiveness *boolean value. Note: In all graphs, error bars represent 95% confidence intervals (CI).*

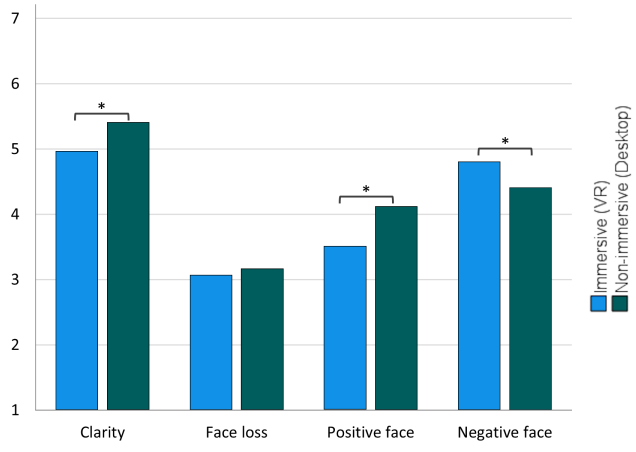

Figure 5: Overall Perceived Politeness. *Impact of* immersiveness *on the perception of the clarity, offensiveness (i.e.,* Face loss*), friendliness (i.e.,* Positive face*) of the ECA's request and the participants' perceived freedom of action (i.e.,* Negative face*). Note: All the ratings are on a scale of 1-7, where 7 represents the most favorable rating. Nevertheless, for the Face loss, lower values are preferable as they indicate less loss of face.*

the trials. This indicates that participants in the *non-immersive* condition consistently maintained social boundaries by refraining from crossing the o-space, while participants in the *immersive* condition showed a lower level of adherence to social norms. Furthermore, despite the lower level of social adherence observed in the *immersive* condition, participants in both *immersive* and *non-immersive* conditions consistently chose to adhere to social norms, even after being exposed to different politeness behaviors across three separate blocks of each study.

4.6. Politeness

Figure 5 illustrates the results regarding the *perceived politeness* of the ECAs. The subsequent subsections provide a detailed presentation of these results for each specific measure.

4.6.1. Clarity

In terms of *clarity*, the analysis revealed a significant main effect of *immersiveness*, $F(1, 64) = 5.030$, $p = 0.028$. Specifically, our findings indicated that the requests from the ECAs in the *immersive* condition were perceived to be less clear compared to the *non-immersive* condition. This suggests that immersion had a detrimental effect on the *clarity* of ECA's requests, while the *non-immersive* setting resulted in clearer requests from the ECAs. Figure 6 provides a detailed illustration of the variable, including both experimental conditions and their corresponding politeness behaviors.

4.6.2. Face loss

In terms of *face loss*, the analysis yielded no significant main effect of the *immersiveness*, $F(1, 64) = 0.258$, $p = 0.614$. The results suggest that the *immersiveness* did not influence the level of perceived offensiveness or *face loss* experienced by the participants. However, despite this finding, the ECAs were perceived to be slightly less offensive in their `CMD` and `PNT` behaviors in the *immersive* condition. Figure 7 provides a detailed illustration of the variable,

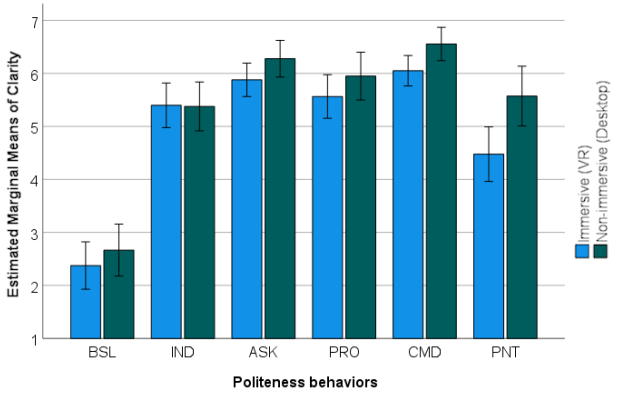

Figure 6: Clarity *of the ECA's request in both experimental conditions and their associated politeness behaviors.*

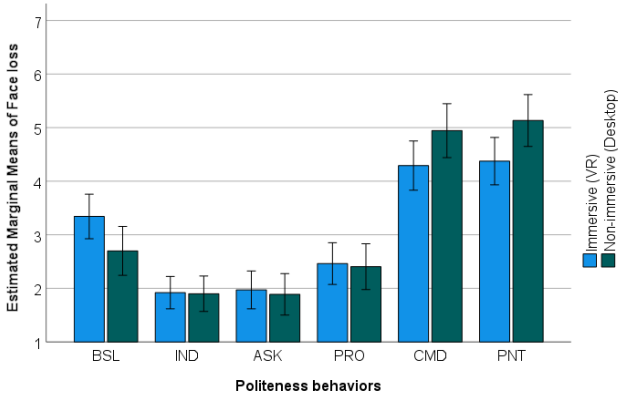

Figure 7: *Perceived offensiveness (i.e.,* Face loss*) of the ECA's request in both experimental conditions and their associated politeness behaviors. Only in this case, lower values are preferred.*

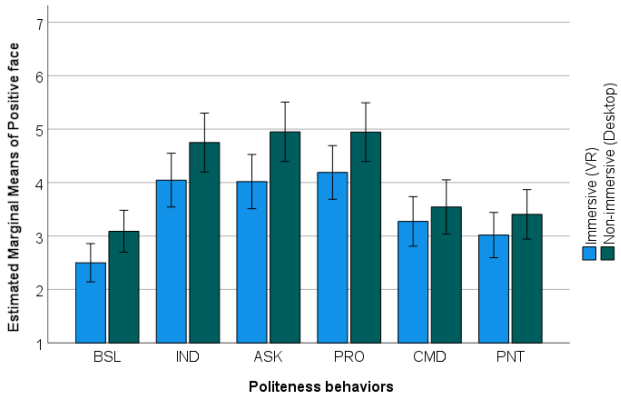

Figure 8: *Perceived friendliness (i.e.,* Positive face*) of the ECA's request in both experimental conditions and their associated politeness behaviors.*

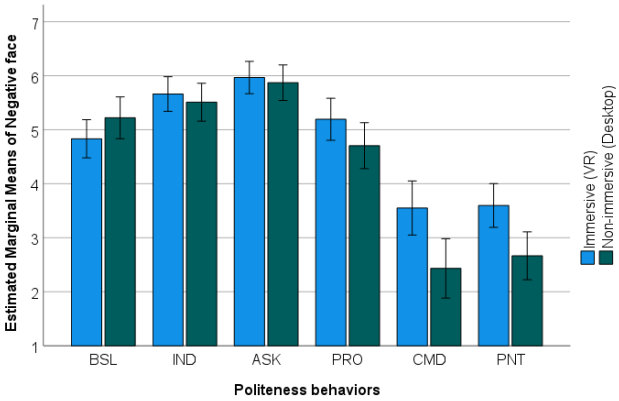

Figure 9: *Perceived freedom of action (i.e., Negative face) in both experimental conditions and their associated politeness behaviors.*

including both experimental conditions and their corresponding associated politeness behaviors.

4.6.3. Positive face

Regarding *positive face*, the analysis revealed a significant main effect of *immersiveness*, $F(1, 64) = 4.939$, $p = 0.030$. Our findings suggest that the requests from the ECAs were perceived as less friendly in the *immersive* condition compared to the *non-immersive* condition. This suggests that the *immersion* had a negative impact on the perception of *positive face*, whereas the *non-immersive* setting resulted in requests that were perceived as more friendly by the participants. Figure 8 provides a detailed illustration of the variable, including both experimental conditions and their corresponding associated politeness behaviors.

4.6.4. Negative face

The analysis revealed a significant main effect of the *immersiveness* on *Negative face*, $F(1, 64) = 4.620$, $p = 0.035$. Our results suggest that participants felt less constrained and restricted in their freedom of action in the *immersive* condition. Figure 9 provides a detailed illustration of the variable, including both experimental conditions and their corresponding associated politeness behaviors.

5. Discussion

Table 5 presents a comparison between the two immersiveness conditions, addressing the primary research question of this study. Although there were no significant differences between the main conditions, the results did indicate a decline in *persuasiveness* over the course of blocks in the *immersive* condition, while an increase was observed in the *non-immersive* condition. This could be attributed to the fact that participants did not need to physically exert themselves to reach that location in the *non-immersive* condition. However, in the *immersive* condition where participants were required to physically walk to the location, the persuasion rate slightly declined over different blocks. This decline could potentially be attributed to a fatigue effect, as participants may have experienced physical tiredness or decreased motivation over the course of the study. Consistent with psychological research [Hul43], which suggests that

Table 5: *Comparison of two conditions*

Condition	**Immersive**	**Non-immersive**
Persuasiveness	No difference	No difference
Social adherence	Lower	Higher
Clarity	Lower	Higher
Face loss	No difference	No difference
Positive face	Lower	Higher
Negative face	Higher	Lower

individuals tend to choose options that require less effort or work when presented with choices that offer similar rewards. Indeed, the lower level of social adherence observed in the *immersive* condition compared to the *non-immersive* one could be attributed, at least in part, to the physical effort required in the *immersive* condition. When participants are required to physically exert themselves, such as walking to a specific location, they may be more likely to prioritize their own convenience or personal comfort over strict adherence to social norms. This could result in a lower level of social adherence in the *immersive* condition. These results have important implications for the development of persuasive systems [OKH09], as they indicate that simply relying on *immersiveness* alone may not always result in positive responses from participants.

Consistent with prior research [WYG20,Li15,BHKS11,Wyk21], our findings align with the idea that immersiveness enhances participants' perception of freedom of action (i.e., *Negative face*) in deciding how to join the group. However, the immersion resulted in decreased *clarity* of the ECA's requests. Specifically, when the participants were immersed in a VE, they reported a lower level of *clarity* in understanding the requests. The slightly overall lower level of *persuasiveness* of ECAs in the *immersive* condition may be attributed to participants' greater perception of freedom of action and a reduced sense of constraint when choosing which side to join the group and a lower level of *clarity* in understanding the ECA's requests.

The ECAs in the *non-immersive* condition exhibited a higher level of perceived friendliness as indicated by *positive face*. This finding aligns with a body of literature that explores the contrasts between online and digital communication versus face-to-face interactions. Some studies suggest that digital communication can evoke more negative emotions compared to in-person interactions [BWDC12, PNM*12]. However, there are also studies that present paradoxical outcomes, demonstrating both positive and negative effects of online communication [KKB*02]. Additionally, Roos [Roo23] found that extroverted individuals and those with stronger social support had better outcomes when using social media, while introverts and individuals with less support had worse outcomes, highlighting the potential influence of personality on digital communication. Furthermore, several studies have investigated the role of politeness in communication and have found that perceptions of politeness can differ between cyber and face-to-face interactions [Gra07, GH17]. These studies highlight the complex nature of online communication and its potential impact on social dynamics, emphasizing the need to consider factors such as personality traits and communication style when examining the effects of digital interactions.

6. Future work

The concept of politeness, encompassing verbal, and non-verbal behaviors, can vary across different cultures and personalities. Consequently, participants may interpret and perceive politeness in distinct ways, affecting their judgments regarding clarity, face loss, positive face, and negative face. To enhance the validity and applicability of research findings, future studies could incorporate cross-cultural comparisons and include participants from diverse cultural backgrounds. This approach would provide valuable insights into the potential cultural variations in the perception of politeness and the effects of immersion on the persuasiveness of ECAs.

Furthermore, several studies have demonstrated the substantial influence of embodiment [DMM*19, WFSSM06] and motion [SB10] on human-robot interaction. The embodiment of agents (e.g., robot or virtual agent) enables them to express emotions, intentions, and social cues through nonverbal signals like facial expressions, gestures, and body language. In our study, we employed the Greta ECAs, which have a specific embodiment, range of motions, and voice[¶]. This aspect may have influenced our findings, as the ECA's embodiment can shape how humans perceive and engage with it. Therefore, future research could investigate the impact of agent embodiment (e.g., photorealism [ZMM19] or even its physical form [ZLL*23]) on the perception of politeness and persuasiveness of the agent.

7. Conclusion

This study aimed to investigate the impact of immersiveness on the persuasive abilities of Embodied Conversational Agents (ECAs), their perceived politeness, and the social adherence of individuals within a small group context. A user study was conducted with two main conditions: immersive in virtual reality and non-immersive on a desktop. The study utilized six politeness behaviors derived from Brown and Levinson's politeness theory, with the primary agent inviting participants to join a group. The analysis of the results, which involved 66 participants, revealed that there were no significant differences in persuasiveness and offensiveness between the immersive and non-immersive conditions. However, participants perceived the ECAs in the immersive condition, where participants were fully immersed in virtual reality, as less friendly, and their requests were perceived as less clear. Nevertheless, participants in the immersive condition reported a greater sense of freedom of action. Moreover, the study observed that social norm adherence was higher in the non-immersive condition, where participants engaged with ECAs through a computer interface. Overall, this study contributes to the understanding of the dynamics between immersiveness, persuasive abilities of ECAs, perceived politeness, and social adherence in small-group human-agent interactions. These factors have significant implications for the establishment of trust, rapport, and long-term collaborations in such scenarios.

[¶] TTS: https://www.cereproc.com/en/home

References

[AIK*04] ALTHAUS P., ISHIGURO H., KANDA T., MIYASHITA T., CHRISTENSEN H. I.: Navigation for human-robot interaction tasks. In *IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA '04. 2004* (2004), IEEE, pp. 1894–1900 Vol.2. doi:10.1109/ROBOT.2004.1308100. 2

[AMTT12] ALLEN B. F., MAGNENAT-THALMANN N., THALMANN D.: Politeness improves interactivity in dense crowds. *Computer Animation and Virtual Worlds 23*, 6 (2012), 569–578. 2

[BHKS11] BAINBRIDGE W. A., HART J. W., KIM E. S., SCASSELLATI B.: The benefits of interactions with physically present robots over video-displayed agents. *International Journal of Social Robotics 3* (2011), 41–52. 8

[BL78] BROWN P., LEVINSON S. C.: *Universals in language usage: Politeness phenomena*, 3 ed. Cambridge University Press, 1978, p. 56–311. 1, 2, 4

[BLB*02] BLASCOVICH J., LOOMIS J., BEALL A. C., SWINTH K. R., HOYT C. L., BAILENSON J. N.: Immersive virtual environment technology as a methodological tool for social psychology. *Psychological inquiry 13*, 2 (2002), 103–124. 2

[BRKD19] BOZGEYIKLI E., RAIJ A., KATKOORI S., DUBEY R.: Locomotion in virtual reality for room scale tracked areas. *International Journal of Human-Computer Studies 122* (Feb 2019), 38–49. doi:10.1016/j.ijhcs.2018.08.002. 5

[BWDC12] BAEK Y. M., WOJCIESZAK M., DELLI CARPINI M. X.: Online versus face-to-face deliberation: Who? why? what? with what effects? *New media & society 14*, 3 (2012), 363–383. 8

[BYMS06] BAILENSON J. N., YEE N., MERGET D., SCHROEDER R.: The effect of behavioral realism and form realism of real-time avatar faces on verbal disclosure, nonverbal disclosure, emotion recognition, and copresence in dyadic interaction. *Presence: Teleoperators and Virtual Environments 15*, 4 (2006), 359–372. 2

[Cas01] CASSELL J.: Embodied conversational agents: representation and intelligence in user interfaces. *AI magazine 22*, 4 (2001), 67–67. 1

[CMG*19] CORREIA F., MASCARENHAS S. F., GOMES S., ARRIAGA P., LEITE I., PRADA R., MELO F. S., PAIVA A.: Exploring prosociality in human-robot teams. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (2019), IEEE, pp. 143–151. 2

[CRO*16] CAFARO A., RAVENET B., OCHS M., VILHJÁLMSSON H. H., PELACHAUD C.: The effects of interpersonal attitude of a group of agents on user's presence and proxemics behavior. *ACM Transactions on Interactive Intelligent Systems 6*, 2 (Aug 2016), 1–33. 2

[DMM*19] DENG E., MUTLU B., MATARIC M. J., ET AL.: Embodiment in socially interactive robots. *Foundations and Trends in Robotics 7*, 4 (2019), 251–356. 8

[GH17] GRAHAM S. L., HARDAKER C.: (Im)politeness in digital communication. *The Palgrave handbook of linguistic (im)politeness* (2017), 785–814. 8

[Gra07] GRAHAM S. L.: Disagreeing to agree: Conflict, (im)politeness and identity in a computer-mediated community. *Journal of pragmatics 39*, 4 (2007), 742–759. 8

[GSV*03] GARAU M., SLATER M., VINAYAGAMOORTHY V., BROGNI A., STEED A., SASSE M. A.: The impact of avatar realism and eye gaze control on perceived quality of communication in a shared immersive virtual environment. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (2003), pp. 529–536. 2

[Hal66] HALL E. T.: *The hidden dimension*, vol. 609. Garden City, NY: Doubleday, 1966. 2

[Hul43] HULL C. L.: *Principles of behavior*, vol. 422. Appleton-century-crofts New York, 1943. 7

[IZP22] IOP A., ZOJAJI S., PETERS C.: Don't walk between us: adherence to social conventions when joining a small conversational group of agents. In *Proceedings of the 22nd ACM International Conference on Intelligent Virtual Agents* (2022), pp. 1–8. 2

[KB18] KIM G., BIOCCA F.: Immersion in virtual reality can increase exercise motivation and physical performance. In *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry: 10th International Conference, VAMR 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part II 10* (2018), Springer, pp. 94–102. 2

[Ken90] KENDON A.: *Conducting interaction: Patterns of behavior in focused encounters*, vol. 7. CUP Archive, 1990. 1, 2

[KKB*02] KRAUT R., KIESLER S., BONEVA B., CUMMINGS J., HELGESON V., CRAWFORD A.: Internet paradox revisited. *Journal of social issues 58*, 1 (2002), 49–74. 8

[Li15] LI J.: The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *International Journal of Human-Computer Studies 77* (May 2015), 23–37. doi:10.1016/j.ijhcs.2015.01.001. 8

[LN10] LEE J.-E. R., NASS C. I.: Trust in computers: The computers-are-social-actors (CASA) paradigm and trustworthiness perception in human-computer communication. In *Trust and technology in a ubiquitous modern environment: Theoretical and methodological perspectives*. IGI Global, 2010, pp. 1–15. 2

[McG84] MCGRATH J. E.: *Groups: Interaction and performance*, vol. 14. Prentice-Hall Englewood Cliffs, NJ, 1984. 1

[NCRI22] NEGGERS M. M. E., CUIJPERS R. H., RUIJTEN P. A. M., IJSSELSTEIJN W. A.: Determining shape and size of personal space of a human when passed by a robot. *International Journal of Social Robotics 14*, 2 (Mar 2022), 561–572. 2

[NMC99] NASS C., MOON Y., CARNEY P.: Are people polite to computers? responses to computer-based interviewing systems 1. *Journal of applied social psychology 29*, 5 (1999), 1093–1109. 2

[NR21] NOVICK D., RODRIGUEZ A. E.: *A Comparative Study of Conversational Proxemics for Virtual Agents*, vol. 12770 of *Lecture Notes in Computer Science*. Springer International Publishing, Cham, 2021, p. 96–105. URL: https://link.springer.com/10.1007/978-3-030-77599-5_8, doi:10.1007/978-3-030-77599-5_8. 2

[NST94] NASS C., STEUER J., TAUBER E. R.: Computers are social actors. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (1994), pp. 72–78. 2

[OKH09] OINAS-KUKKONEN H., HARJUMAA M.: Persuasive systems design: Key issues, process model, and system features. *Communications of the association for Information Systems 24*, 1 (2009), 28. 1, 8

[PNM*12] PEA R., NASS C., MEHEULA L., RANCE M., KUMAR A., BAMFORD H., NASS M., SIMHA A., STILLERMAN B., YANG S., ET AL.: Media use, face-to-face communication, media multitasking, and social well-being among 8-to 12-year-old girls. *Developmental psychology 48*, 2 (2012), 327. 8

[RAN05] REHM M., ANDRÉ E., NISCHT M.: *Let's Come Together — Social Navigation Behaviors of Virtual and Real Humans*, vol. 3814 of *Lecture Notes in Computer Science*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2005, p. 124–133. URL: http://link.springer.com/10.1007/11590323_13, doi:10.1007/11590323_13. 2

[RKW01] RAZZAQUE S., KOHN Z., WHITTON M. C.: Redirected walking. *Eurographics 2001 - Short Presentations* (2001). URL: https://diglib.eg.org/handle/10.2312/egs20011036, doi:10.2312/EGS.20011036. 5

[RMSL15] RIOS-MARTINEZ J., SPALANZANI A., LAUGIER C.: From proxemics theory to socially-aware navigation: A survey. *International Journal of Social Robotics 7* (2015), 137–153. 2

[RN96] REEVES B., NASS C.: The media equation: How people treat computers, television, and new media like real people. *Cambridge, UK 10* (1996). 2

[Roo23] ROOS J. M.: The intersection of personality traits and social media usage: Large-scale representative samples of internet users in sweden. *Psych 5*, 1 (2023), 70–79. 8

[RPA*15] RUHLAND K., PETERS C. E., ANDRIST S., BADLER J. B., BADLER N. I., GLEICHER M., MUTLU B., MCDONNELL R.: A review of eye gaze in virtual agents, social robotics and hci: Behaviour generation, user interaction and perception. In *Computer graphics forum* (2015), vol. 34, Wiley Online Library, pp. 299–326. 2

[SB10] SAERBECK M., BARTNECK C.: Perception of affect elicited by robot motion. In *2010 5th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (2010), IEEE, pp. 53–60. 8

[She20] SHERIDAN T. B.: A review of recent research in social robotics. *Current opinion in psychology 36* (2020), 7–12. 2

[Sla03] SLATER M.: A note on presence terminology. *Presence connect 3*, 3 (2003), 1–5. 1, 2

[SRBC15] SETTI F., RUSSELL C., BASSETTI C., CRISTANI M.: F-formation detection: Individuating free-standing conversational groups in images. *PloS one 10*, 5 (2015). 1

[SS15] STEED A., SCHROEDER R.: Collaboration in immersive and non-immersive virtual environments. *Immersed in media: Telepresence theory, measurement & technology* (2015), 263–282. 2

[TM23] TRIVEDI H., MOUSAS C.: Human-virtual crowd interaction: Towards understanding the effects of crowd avoidance proximity in an immersive virtual environment. *Computer Animation and Virtual Worlds* (2023), e2169. 2

[TN18] TRUONG X. T., NGO T. D.: "To approach humans?": A unified framework for approaching pose prediction and socially aware robot navigation. *IEEE Transactions on Cognitive and Developmental Systems 10*, 3 (2018), 557–572. 2

[TOG21] TERADA K., OKAZOE M., GRATCH J.: Effect of politeness strategies in dialogue on negotiation outcomes. In *Proceedings of the 21st ACM International Conference on Intelligent Virtual Agents* (2021), pp. 195–202. 2

[TSGZ16] THELLMAN S., SILVERVARG A., GULZ A., ZIEMKE T.: Physical vs. virtual agent embodiment and effects on social interaction. In *Intelligent Virtual Agents: 16th International Conference, IVA 2016, Los Angeles, CA, USA, September 20–23, 2016, Proceedings 16* (2016), Springer, pp. 412–415. 2

[VLF*09] VOLLMER A.-L., LOHAN K. S., FISCHER K., NAGAI Y., PITSCH K., FRITSCH J., ROHLFING K. J., WREDEK B.: People modify their tutoring behavior in robot-directed interaction for action learning. In *2009 IEEE 8th International Conference on Development and Learning* (Shanghai, China, 2009), IEEE, p. 1–6. 2

[VRTB18] VOLLMER A.-L., READ R., TRIPPAS D., BELPAEME T.: Children conform, adults resist: A robot group induced peer pressure on normative social conformity. *Science Robotics 3*, 21 (2018). 2

[WFSSM06] WAINER J., FEIL-SEIFER D. J., SHELL D. A., MATARIC M. J.: The role of physical embodiment in human-robot interaction. In *ROMAN 2006-The 15th IEEE International Symposium on Robot and Human Interactive Communication* (2006), IEEE, pp. 117–122. 8

[WLV*21] WILLIAMSON J., LI J., VINAYAGAMOORTHY V., SHAMMA D. A., CESAR P.: Proxemics and social interactions in an instrumented virtual reality workshop. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2021), CHI '21, Association for Computing Machinery. URL: https://doi.org/10.1145/3411764.3445729, doi:10.1145/3411764.3445729. 2

[WOGG*22] WILLIAMSON J. R., O'HAGAN J., GUERRA-GOMEZ J. A., WILLIAMSON J. H., CESAR P., SHAMMA D. A.: Digital proxemics: Designing social and collaborative interaction in virtual environments. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2022), CHI '22, Association for Computing Machinery. URL: https://doi.org/10.1145/3491102.3517594, doi:10.1145/3491102.3517594. 2

[WYG20] WU B., YU X., GU X.: Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology 51*, 6 (2020), 1991–2005. 2, 8

[Wyk21] WYKOWSKA A.: Robots as mirrors of the human mind. *Current Directions in Psychological Science 30*, 1 (2021), 34–40. 8

[YP19] YANG F., PETERS C.: Appgan: Generative adversarial networks for generating robot approach behaviors into small groups of people. In *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)* (2019), IEEE, pp. 1–8. 2

[ZLL*23] ZOJAJI S., LATUPEIRISSA A. B., LEITE I., BRESIN R., PETERS C.: Persuasive polite robots in free-standing conversational groups. In *2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (2023), IEEE. 8

[ZMM19] ZIBREK K., MARTIN S., MCDONNELL R.: Is photorealism important for perception of expressive virtual humans in virtual reality? *ACM Transactions on Applied Perception (TAP) 16*, 3 (2019), 1–19. 8

[ZPP20] ZOJAJI S., PETERS C., PELACHAUD C.: Influence of virtual agent politeness behaviors on how users join small conversational groups. In *Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents* (Oct 2020), ACM, p. 1–8. doi:10.1145/3383652.3423917. 2