Interacting with Virtual Agents in Shared Space: Single and Joint Effects of Gaze and Proxemics

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Abstract. The Equilibrium Theory put forward by Argyle and Dean, posits that in human-human interactions, gaze and proxemic behaviors work together in establishing and maintaining a particular level of intimacy. This theory has been evaluated and used in Virtual Reality settings where people interact with Virtual Humans. In this study we disentangle the single and joint effects of proxemic and gaze behavior in this setting further, and examine how these behaviors affect the perceived personality of the agents. We simulate a social encounter with Virtual Humans in immersive Virtual Reality. Gaze and proxemic behaviors of the agents are manipulated dynamically while the participants' gaze and proxemic responses are being measured. As could be expected, participants showed strongest gaze and proxemic responses when agents manipulated both at the same time. However, agents that only manipulated gaze elicited weaker responses compared to agents that only manipulated proxemics. Agents that exhibited more directed gaze and reduced interpersonal distance were attributed higher scores on intimacy related items than agents that exhibited averted gaze and increased interpersonal distance.

Keywords: immersive VR · Proxemics · Gaze · Virtual humans

1 Introduction

With immersive Mixed and Virtual Reality (iVR) technology becoming more pervasive also in the consumer's home, new challenges for the design of virtual embodied agents and avatars arise. These agents can now be placed in a shared space with the user, rather than in a remote space that is accessed through a regular screen. Tracking of body and hand motion allows users to perceive and direct actions from and towards agents in an immediate fashion. With space being a shared resource, virtual agents interacting with humans in such environments must be aware of the space they occupy and how behaviors in that space are perceived by their human interaction partners. This raises the question of which positioning and movement behaviors are appropriate for virtual agents in iVR. Computational models for positioning and movement of virtual agents in on-screen simulations have been proposed in the past [1,2] using 'social force'-based models based on Hall's proxemics [3] and Kendon's theories on positioning [4].

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Theories from social psychology include other modalities in models of social spatial behavior. The equilibrium theory (ET) states that interpersonal distance and eye contact can be used to regulate a perceived level of intimacy between interaction partners [5]. For example, high levels of perceived intimacy induced by reduced interpersonal distance can be compensated by regulative behaviors, such as averting gaze or by increasing interpersonal distance through a change in posture or position. This theory has been tested and extended in various studies with varying methodologies and results supporting its general validity [6–8]. ET has been revisited in iVR in one prior study [9], where first evidence was found that the theory also applies to interactions between humans and virtual agents.

Little work has been done to examine the individual and joint effects of such regulative behaviors. In the current paper, we discuss a study to investigate the relationship between two such behaviors in iVR settings: regulation of interpersonal distance and regulation of eye contact. We base our hypotheses on the predictions of the ET. If the agent breaks the equilibrium state by increasing or decreasing the perceived intimacy of the user, we expect the user to exhibit compensation behavior which we measure in the users gaze direction and distance towards the agent. We then test what combination of behaviors in agents elicit strongest regulative responses in the regulation of users' behaviors, and how typical behaviors affect perception of the agents' personality and interpersonal attitudes. The contributions of our findings are further support of the consistency of Equilibrium Theory for interaction with virtual agents in iVR settings and new insights in how perceived agent personality is affected by proxemic and gaze behaviors. These translate to useful insights for designers of embodied agents in iVR settings.

2 Related Work

Before discussing in more detail the design of the present study, we give an overview of related work on examining gaze and proxemics in social interaction and in interaction with artificial agents specifically.

Gaze describes the visual attention of a human manifested in the direction of the eyes and by extension the orientation of head and body, typically in a social context [10]. Two recent surveys summarize research on gaze from a psychological [11] and a technical [12] perspective. It becomes apparent from both that a large body of research on social gaze deals with determining and describing intentions and attention during social interactions.

But what are the effects of different gaze behavior in social interaction? Work by Ioannou *et al.* [13] comparing humans using mutal gaze or averted gaze, found that facial temperature of participants was higher during the former. In [14], the orientation of an information-presenting robot was manipulated to create joint attention with visitors to an exhibition piece. They found that this resulted in spatial reconfiguration of the visitors, following the principles of Kendon's F-formations [4].

Interpersonal Distance is the distance individuals keep towards each other in social situations. *Proxemics*, first coined by Hall [15], describes different interaction distances and relates them to different kinds of interaction, when implicit cultural and social norms are adhered to. Proxemics are used to automatically infer or model relationships between humans [16], for virtual avatars [1,2] but also in human-robot interaction [17].

Besides gaze, Cafaro et al. have looked at the effects of proxemics, and smiles during first encounters with virtual agents and found effects on users' perception of agent's interpersonal attitudes [18] and subsequent relational decisions [19].

However, there is only little research where proxemics behavior was intentionally manipulated to measure or predict behavioral responses in others. A study in iVR and augmented reality found that participants increase the loudness of their voice when a virtual agent is further away [20]. Kastanis and Slater [21] discuss a virtual agent that used reinforcement learning to learn how best to manipulate participants' position. They found that an agent that was allowed to get within 38 cm of participants could learn to move most of them to the desired position in a short time.

3 Conceptual Framework

In the present study we are interested in disentangling the single and joint effects of gaze and proxemic further. To this end, we exhibit different gaze and proxemic behavior in the agent, and look at both the gaze and proxemic responses in the participant. We will call such a change in the agent behavior a *manipulation*. Changes in the user's gaze and proxemic behavior following a manipulation we call the *user response*. Based on the ET, we hypothesise that after a change in the behavior of an agent that impacts the intimacy level of the situation - for example coming closer to the user - the human user performs compensation behaviors - for example stepping back or averting gaze - to maintain the same level of intimacy.

Agent Behaviors. We define the behavior of each agent as a combination of gaze and proxemic behaviors. For gaze, we define behaviors with neutral (G^0), high (G^+), and low (G^-) intimacy. Similarly, we define proxemic behaviors with neutral (P^0), high (P^+), and low (P^-) intimacy.

The realizations of these behaviors were based on a pilot study with colleagues (n = 5) that were aware of the studies goals. Participants were placed in a prototype of the experiment apparatus with a virtual agent. The experimenter let the agent alternate between different prepared versions of each behavior, interviewing the participant on how they perceived the behavior of the agent in terms of intimacy compared to the other realizations.

For proxemic behaviors, we let the agent move across the zones in Hall's model. We found that keeping a distance of 75 cm between users and agents was perceived as neutral (P^0). Decreasing the distance to 40 cm was perceived as noticably more intimate (chosen for P^+, see Fig. 1c). This coincides with Hall's

(a) R. agent: G^+ (b) L. agent: G^- (c) R. agent: P^+ (d) L. agent: P^-

Fig. 1. Screenshots of realized agent manipulations.

intimate space and the distance used in [21]. At a distance of 110 cm the agent was found to be noticeably less intimate and was used for P^- (see Fig. 1d).

For gaze, we found that having the agent switch between gazing at the user and averting its gaze in random intervals between 2 and 5 s was perceived as neutral (G^0). Participants found it more intimate when the agent would always respond with mutual gaze if directed gaze at the agent by the user was detected (chosen for G^+, see Fig. 1a). In this version of gaze behavior, the agent would also prolong that gaze for 1.5 s even after directed mutual gaze was interrupted by the user. Note that this version was also chosen over a version where the agent would continuously direct his gaze at the user, as this was perceived as 'creepy'. Conversely, for G^-, we selected a behavior where the agent would always avert his gaze if directed gaze by the user was detected (see Fig. 1b), which was found as less intimate than the neutral version by the participants.

For the final manipulations in the experiment, we chose six combinations of the gaze and proxemic behaviors described above where one or both modalities would deviate from the neutral behavior (G^0P^0) in terms of increasing and decreasing intimacy: G^-P^-, G^0P^-, G^-P^0, and G^+P^0, G^0P^+, G^+P^+.

User Responses. We measure regulation of eye-contact and interpersonal distance in the user when the agent performs a manipulation. The *Gaze Response* R_G of a user is the change in his or her head angle towards the agent. This may be looking more towards the agent (smaller angle) or looking more away from it (larger angle). We call compensating displacement of the user's whole or upper body the *Proxemic Response* R_P of the user. This may be moving away from the agent (positive response) or towards an agent (negative response).

Hypotheses. We formulate our hypotheses as predictions of user's behavioral responses to different gaze and proxemic behaviors exhibited by a virtual agent. Our main hypothesis is:

H1 Users regulate their gaze and interpersonal distance during interaction differently towards agents that exhibit either high or low intimacy behaviors.

We make prediction of the single and joint effects of the behaviors that the high and low intimacy agents exhibit based on the ET:

- $H1_a$ Increasing proximity of the agent (G^0P^+) will be compensated for by the user with a more positive R_P (moving away) – compared to a smaller, possibly negative R_P (moving closer) when agents perform G^0P^-.
- $H1_b$ Increasing gaze of the agent towards the user (G^+P^0) will be compensated for by the user with higher R_G towards the agent (looking away) – compared to smaller R_G when agents perform G^-P^0.
- $H1_c$ Besides R_P, also different levels of R_G will be observed in response to G^0P^+ and G^0P^- manipulations.
- $H1_d$ Besides R_G, also different levels of R_P will be observed in response to G^+P^0 and G^-P^0 manipulations.
- $H1_e$ When the two non-contradicting behaviors are combined, user's responses will 'add up', i.e. R_P to G^+P^+ is higher than to $G^0P^+$and R_G to G^+P^+ is lower than to G^+P^0, etc.

To further examine the assumptions of Argyle and Dean that the underlying assumptions of compensating behavior is indeed the perceived intimacy level, we are further interested whether this is also reflected in the user's perception of the agent's personality and interpersonal attitudes. Our hypothesis is:

- H2 Users rate agents that exhibit high intimacy behaviors higher on items related to intimacy.

4 Method

These hypotheses were tested in an immersive VR environment experiment where participants could interact freely with two virtual agents that exhibit the different manipulations. We included intimacy of agent as a within subject variable. One agent had the *high* intimacy manipulations assigned, the other had *low* intimacy manipulations. They did not change their assigned role during the experiment. This choice was made to be able to compare how the different more and less intimate behaviors affect the user's perception of the agent (H2).

4.1 Materials

The experiment took place in the room shown in Fig. 2. An Oculus Rift DK2 head mounted display (HMD) is tethered to the experiment PC which is situated in the truss. The tether is 2.6 m in length from the top centre of the room. The translation was tracked using a NaturalPoint OptiTrack system of six IR cameras. This way, free movement and tracking is possible in most of the 4×5 m experiment area, the extreme corners being the exception.

The room displayed in the virtual environment was a generic apartment asset with a bigger empty space next to the living room area, which was mapped onto the experiment space. A transparent 3D model of the truss was placed

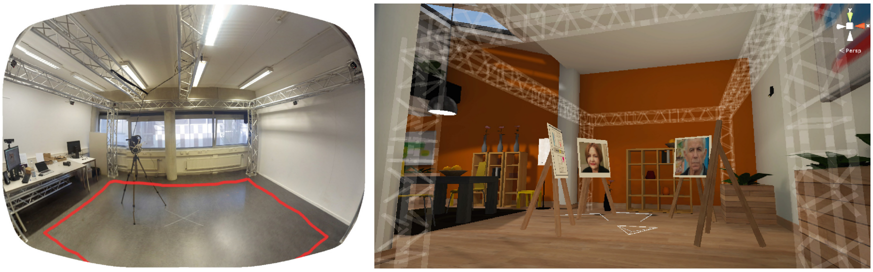

Fig. 2. Left: the physical room. Right: the virtual room.

in correspondence with its real-world position and dimensions to give users a reference in VR of where they are situated in the physical world (see Fig. 2).

The virtual agents used in our iVR setup were generated using the Unity Multipurpose Avatar system (UMA, [22]). The avatars were generated from the same base mesh to look very similar, yet discriminable with slight adjustments to face, hair and attire. To conform to the characters from the scenario described in the next section, both agents were chosen to be male. To prevent the size of the agents relative to the user having an effect on the intimacy or dominance level, their height was adjusted in a calibration step before the start of the experiment to match the height of the participant.

4.2 Task and Scenario

Participants were not told that the experiment was about examining their movement and gaze behavior. Instead, they were given a listening task to focus on, based on a scenario that the two agents would act out. The scenario was taken from the 1957 movie *12 Angry Men*. In this movie, 12 male members of a jury have a discussion about whether or not they were presented sufficient evidence during the court case to sentence the defendant to death. Audio clips of speech segments were extracted from parts of the movie. To prevent dominance mediated by voice to be a factor in the perception of the agents, segments were selected where the argument was less heated. This resulted in 30 clips arguing for 'not guilty' (avg. length = 11.49 s) and 29 clips arguing for 'guilty' (avg. length = 11.51 s) side of the argument. The clips were spoken by the agents chronologically, alternating between the sides of the arguments to make up a consistent conversation between the agents (total duration = 12 m). It was suggested to the participant that the two agents would each attempt various 'strategies' in order to convince the participant of their side of an argument. The task given to the participant was to listen carefully, as they would be asked for their decision afterwards.

4.3 Agent Behavior Manipulations

During the experiment, the agents formed a group with the user by positioning themselves on the base corners of an equilateral triangle. The length of the triangle's legs was 75 cm, corresponding to the *neutral* distance found in the pilot study. The triangle did not rotate with the user. It always faced the long side of the room. The angle of the user's corner was 60°, which was chosen to ensure that when the user centres his view between the agents, both are in view.

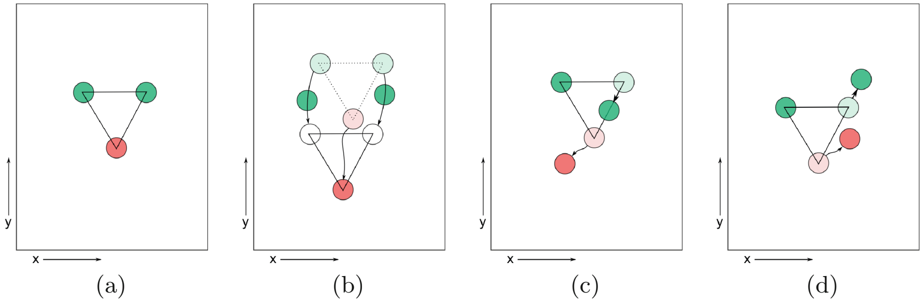

Fig. 3. The room from a top-down perspective. Two agents (upper circles) form a triadic formation with the user (lower circle) (a), establishing the neutral formation when no manipulation is in place (G^0P^0), also when user is moving (b), but the formation-triangle does not follow the user during gaze or proxemic manipulations (c and d, depicting G^0P^+ and G^0P^-).

Agents would change their gaze and proxemic behaviors at moments that coincided with the dialog turns from the scenario. The behavior changed for the entirety of the turn. This resulted in *episodes* of different agent behavior. At the beginning of every second dialog turn, both agents would employ the *neutral* behavior to 'reset' the group formation (neutral episode, see Fig. 3b). On every other turn, exactly one of the two agents manipulated his behavior (manipulation episodes), by performing one of the three behavior combinations that correspond with his assigned *agent intimacy.* For example, the 'high' agent chose from G^+P^0, G^0P^+ and G^+P^+ - as described in Sect. 3. Each of the three assigned behavior combinations were shown exactly four times throughout the experiment, in randomized order.

Which of the two agents would manipulate its behavior during manipulation episodes was alternated in turns. Since these depend on the dialog turns, the between subject variable 'talking agent' was unintentionally introduced: Within subjects, one of the agents changed his level of intimacy only when he is also the currently talking agent, whereas the other changed his level of intimacy only when he was not currently talking. Whether it was the 'high' or the 'low' agent that manipulated only during talking was randomised between subjects.

4.4 Participants

35 participants were convenience-sampled from students and staff, all of which were completely naive to the study's goals. They were between 19 and 30 years old ($m = 21.4$). Five were female. Of the 35, two were discarded from the data. One decided to stop the experiment early because of motion sickness, and another misunderstood the instructions, continuously moving around and exploring the room also during the main experiment.

4.5 Behavioral Measures

During the experiment we recorded the participants' and agents' head positions and orientations in the virtual world using the tracking system of the iVR. We continuously calculated the distance between the user's head and the individual agents' heads as well as the angle of the user's gaze away from the individual agents (see Sect. 3).

We observed significant outliers in the proxemic responses of the remaining 33 participants. By reviewing video material and experiment notes, some of these outliers were found to be strong responses in the beginning of the experiment. Towards the end of experiment runs, outliers were also found to be caused by participants stepping around agents when 'cornered' by them at the bounds of the tracking area. Although these changes in position seem motivated by the intimate situation, they diverged significantly from the typical proxemic response in other episodes, where participants would either lean or take one or two small steps. From the analysis were excluded all episodes where R_P was bigger than 50 cm (n = 6).

4.6 Questionnaire

In addition to the behavioral measures, we are interested in individual's perception of the agents' personalities. A 13 item agent-personality questionnaire which has been successfully used before to measure perception of personality and interpersonal attitudes in both human [23] and virtual human [24, 25] communication partners was used. One extra item on politeness was added [26], and one for 'intimacy'. For each agent, identified by a picture, participants would indicate their agreement with the item on a 7-point Likert-scale. Scores of the intimacy related constructs measured by this questionnaire were used to answer H2.

4.7 Data Analysis

The experiment was designed so that we could compare the effects of the six agent manipulations as a six level within-subject factor 'Agent Intimacy' on the two user measures R_G and R_P. However, due to the introduction of the talking agent as a between subject variable (see Sect. 4.3), this approach would not be sound, as one might expect the talking agent to gain more attention than the non talking agent, biasing the gaze response. Indeed, we found that users would

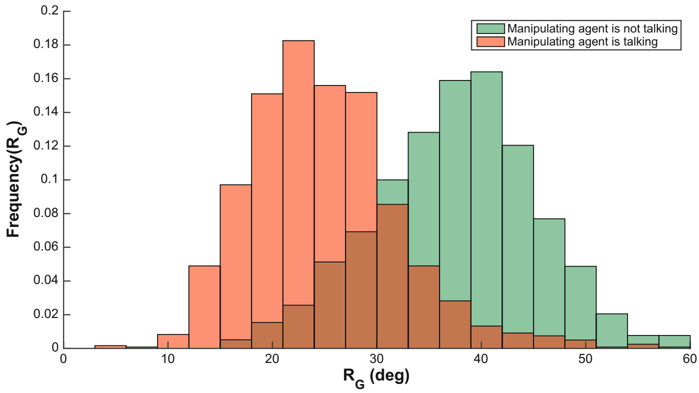

Fig. 4. Histograms of R_G for episodes where the manipulating agent *is* the talking agent and *is not* the talking agent.

typically look towards the currently talking agent (Fig. 4). Consequently, it was chosen to focus on comparing participants' gaze responses only inside the group of agents that manipulated their behavior during their own turn of speech, and only allow for comparison of R_P regardless of the talking agent variable.

5 Results

In Table 1 we present the mean R_P and R_G of all participants and episodes where the manipulating agent was also the talking agent. The measurements violate the assumption of sphericity and normality for both measures at many levels, therefore, under the assumption that the between subject variable *talking agent* does not represent a bias (for the R_P measures), we used the nonparametric Friedman and Wilcoxon signed-rank tests to test our hypotheses.

Table 1. Mean gaze response R_G and proxemic response R_P per agent manipulation from all episodes where the manipulating agent was also the talking agent.

Manip	Mean R_G (SD) in °	Mean R_P (SD) in cm	n	Outliers
G^+P^+	30.17 (6.41)	8.56 (11.70)	55	1
G^0P^+	28.57 (7.38)	8.43 (13.89)	53	2
G^+P^0	27.01 (7.73)	0.36 (9.50)	56	0
G^-P^0	25.23 (6.16)	−0.37 (5.79)	75	1
G^0P^-	25.16 (7.56)	−2.97 (8.89)	76	0
G^-P^-	23.52 (5.72)	−3.48 (6.51)	74	2

Behavioral Measures. To test for significance, we performed tests for each of the two measures R_G and R_P. As explained in Sect. 4.7, we only allow comparison between all six manipulations to examine the difference between R_P regardless of the *talking agent*. Then we performed tests comparing only pairs of high and low manipulations respectively, and only when the manipulating agent was also the *talking agent* (to reveal differences without the bias it introduces). Since here, we're not comparing high and low intimacy agent, these do only allow to test aspects of H1$_e$.

As described above, the agent would act out each manipulation four times during the experiment. The nonparametric test compares pairs of responses to these manipulations. To not artificially inflate our sample size, we compare only one of the four participant responses. These samples however can only be compared when they are not paired with removed outliers. In our data, as described in Sect. 4.5, outliers were observed in the first and second instance of each manipulation, possibly because of a novelty effect, as well as in the fourth, because of the effect of the borders of the experiment area (participants being 'cornered'). Responses during the third instance of each manipulation contain no outliers. Therefore, the responses to the third instance of each manipulation were used for comparison in the nonparametric tests.

Differences Between All Six Manipulations. A Friedman test revealed that there was a statistically significant difference in displacement magnitude (H1$_{a,d,e}$) as a response to different levels of agent behavior intimacy, $\chi^2(5) = 32.84$, $p < .001$. A Wilcoxon signed-rank test showed that in the 33 participants, the displacement magnitude in response to G^0P^+ behaviors was significantly more positive (i.e.: moving away) than that to G^0P^- ($Z = -3.368$, $p = .001$).

Differences Between High Manipulations (H1$_e$). A Friedman test revealed that there was a statistically significant difference in response displacement magnitude between the high-intimacy behaviors, $\chi^2(2) = 7.00$, $p = .030$. A Wilcoxon signed-rank test showed that in the 14 participants where the *high* agent manipulated his behaviors while also being the talking agent, the displacement magnitude in response to G^+P^+ episodes was significantly greater than the displacement magnitude in response to G^+P^0 ($Z = -2.542$, $p = .011$). In the same population, between the pair of G^+P^0 and G^0P^+ manipulations, we found that the former would elicit significantly less positive displacement magnitude ($Z = -2.229$, $p = .026$) than the latter, meaning that those in G^+P^0 would move away significantly less. The difference between the pair of G^+P^+ and G^0P^+ behavior was not found to be significant ($Z = -.910$, $p = .363$). No significant difference in gaze angle was revealed ($\chi^2(2) = 2.29$, $p = 0.319$).

Differences Between Low Manipulations (H1$_e$). Between the low intimacy behaviors, a Friedman test did not reveal a significant difference in displacement magnitude response of the 19 participants where the *low* agent manipulated his behaviors while also being the talking agent ($\chi^2(2) = 2.95$, $p = 0.229$). No further tests comparing the individual pairs were performed.

The Friedman test, however, did reveal that there was a marginally significant difference in the participant gaze response between the *low* behaviors, $\chi^2(2) = 6.42$, $p = .040$. Upon inspection, it appears the difference is due to asymmetry of the difference of the pairs, excluding it from further examination with the Wilcoxon signed-rank test. A sign test revealed no significant difference.

Agent Personality Questionnaire. To identify intimacy related constructs in the agent personality questionnaire (H2), we performed a principal component analysis with Varimax rotation and Kaiser normalisation on the 15 items. Three factors were identified that explain 69.15 % of the variance (Table 2). The factors 'Warmth' and 'Trustworthiness' are similar to those found in a previous study using a similar questionnaire [25], a new third factor emerged with the items 'intimate', 'interesting' and 'confident'. We name this new factor 'Intimacy'.

Table 2. Three factors identified in PCA and their corresponding items with factor loadings. For each factor, consistency is reported.

Warmth	($\alpha = .92$)	Trustworthiness	($\alpha = .87$)	Intimacy	($\alpha = .57$)
Friendly	.88	Informed	.82	Intimate	.78
Approachable	.83	Credible	.82	Interesting	.68
Warm	.83	Competent	.76	Confident	.66
Likeable	.82	Honest	.71		
Polite	.79	Trustworthy	.58		
Modest	.79	Sincere	.56		

For each respondent, we calculated factor scores given to the two agents by averaging out those items that were associated with the respective factors. We performed repeated measures ANOVA with the intimacy of the agent (*high* or *low*) as the within subjects variable and agent side, the talking agent, and agent appearance as between subject variables, and the three computed factor scores as measures.

We found a main effect for the intimacy behavior of the agents on 'Warmth' ($F(1, 24) = 21.45$, $p < .01$) and 'Intimacy' ($F(1, 24) = 6.61$, $p < .05$). No interaction effects of agent appearance and agent side were found on either of the scores. There was however an interaction effect for the talking agent on 'Intimacy' scores ($F(1, 24) = 4.31$, $p < .05$). Pairwise comparison revealed that participants scored the agent with low intimacy higher on 'Warmth' related items than the high intimate agent ($m_L^W = 4.97$ vs $m_H^W = 3.57$). 'Intimacy' scores align with the intimacy behavior of the agents. Participants scored the agent with low intimacy lower ($m_I^L = 4.14$) than the agent with high intimacy ($m_I^H = 4.90$). For the interaction effect of the talking agent, pairwise comparison revealed that the high and low agents score similarly on intimacy scores when they are not the talking agent. When talking during manipulation the high agent however scores higher on intimacy ($m_I^{H \times T} = 5.25$) scores than the low agent ($m_I^{L \times T} = 3.86$).

6 Discussion

We found a number of differences in the behavioral response to the different agent behaviors (H1). While the overall means are in line with the predictions made based on the ET ($H1_{a-e}$), there is a high variance in the responses and only some could be supported with statistical significance.

We found that agents exhibiting higher proximity did cause participants to step away significantly more than agents exhibiting low proximity, where participants tended to step more towards the retreating agent ($H1_a$). Although this was expected, it is also one that had not previously been tested experimentally in iVR. As for the predicted effects of G^+P^0, G^-P^0 on R_G ($H1_b$), we could not find significant differences.

In contrast to [9], our study did not find a notable effect of different agent gaze behaviors on the proxemic response ($H1_d$). This may be explained by their use of a more sensitive measure in [9] (minimum distance rather than the mean), and the different interaction between agent and participant (walking around rather than listening). A possible explanation could be ceiling effects of how comfortable individuals were with moving in the iVR setup - possibly also depending on whether they were already at the edge of the tracking area. This interpretation is also in line with the personality scores of the high agent. Scores were low on ‘Warmth’, which had loadings of the ‘politeness’ and ‘friendliness’ items. If a smaller displacement was not sufficient to compensate intimacy, we would expect the remainder to be compensated with gaze. Given the approximate measure of gaze, such compensation may not have been sufficiently captured with the current apparatus.

Some joint effects were found. Participants stepped away more when both gaze and proxemic behaviors were manipulated in a high-intimate fashion, compared to the responses to only high gaze manipulation, supporting some aspects of $H1_e$. Lastly, we found that indeed, participants rated the high agent higher on intimacy related items, supporting H2.

Limitiations and Recommendations. We recommend some changes to the experimental protocol to those that aim to replicate the experiment or adapt aspects of this study design. The extend to which head direction can serve as a proxy for eye-gaze is questionable. Slight gaze aversions away from the agent’s face may only be captured with true eye-gaze tracking inside the headset. The two agent design may mitigate this shortcoming as more head movement is required when gaze is averted from one agent to another. For single agent designs however, actual eye-gaze tracking is recommended. For group interactions, we recommend to be aware of the effect of the talking agent on the gaze of dialog partners that we observed, as participants might not notice stimuli by non-talking agents in the group. In this study, the introduction of the talking agent variable is a limitation as it complicated the analysis. Advantages of a single agent design are better generalizability of the findings as compared to the group setting in the present work. It is further suggested to examine the effects of the high and low agent by implementing an agent with mixed intimacy behaviors.

7 Conclusions

Proxemic and gaze behaviors deserve attention when designing virtual humans in immersive VR settings where users and agents share the same space. On the one hand, these behaviors have effect on how users position themselves in the space, and given the spatial restrictions that most virtual (and physical) spaces have, the desire to change space may not always be satisfiable, which may lead to extreme responses, such as the outliers we observed. What is more, proxemic behaviors also affect how the agent's personality is perceived, which may have effect on other aspects of the interaction as well. This ET-inspired approach is a useful tool for human-agent interaction design and analysis in shared spaces. It may benefit from advances in VR technology such as in-headset gaze estimation and physiological sensors, which may be used reveal more on the interaction between proxemics, gaze and intimacy.

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