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The shape of personal space

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ABSTRACT

The notion of a personal space surrounding one's ego-center is time-honored. However, few attempts have been made to measure the shape of this space. With increasing use of virtual environments, the question has arisen if real-world aspects, such as gender-effects or the shape of personal space, translate to virtual setups. We conducted two experiments, one with real people matched according to body height and level of acquaintance in a large laboratory setting, and one where subjects faced a virtual character, likewise matched to their body height. The first experiment also used a mannequin in place of the second human observer. The second experiment additionally manipulated the perspective of the subject to compare estimates of interpersonal distance between an egocentric and an allocentric perspective (in third-person view). Subjects approached (or were approached) from different angles until a comfortable distance for conversation with a stranger was reached (stop-distance task). Personal space turned out to be rather circular with a radius of about 1 m. Male pairs kept larger distances from one another than female or mixed-gender pairs. All subjects assumed larger distances to the mannequin compared to the real observer. Very comparable distances were preferred to the avatar in the virtual environment. Also, it did not matter whether the subject was engaged in active approach, was approached, or merely adjusted the distance between two avatars. Implications for theories of personal space are discussed.

1. Introduction

The way we position ourselves spatially is an important part of our social interactions with other people. When someone approaches us to ask us a question, we would want this person to stand at a comfortable distance, not too far and not too close. We sympathize with the notion that we have a bubble of personal space around us that we would like to keep clear. Likewise, when we approach others we grant such a bubble to them and avoid to assume inappropriately close interpersonal distances. Accordingly, personal space can be defined as an area around the person in which intrusion causes discomfort and arousal (Hayduk, 1978). The shape of this personal space, whether it is concentric and circular or elongated, is often ignored, or has been studied with one particular setup, which motivates our study. In two experiments, we investigated the shape of personal space in a real and in a virtual environment. We have also explored the role of different observer variables, in particular the gender and the perspective of the observers.

We will first provide an overview of relevant research and problems regarding personal space to motivate our choice of an approach paradigm within a fictitious conversation scenario. Then, we will report a large experiment comparing approach distances from different angles between two human subjects and between a human subject and a mannequin. A second experiment carried this paradigm to a virtual environment (VE) in which the subject approached or directed an avatar, allowing for easier and more flexible manipulation of independent variables.

1.1. Proxemics: The shape of personal space and gender differences

Proxemics, the study of interpersonal distances and personal space, was established during the 1950s and 1960s and has recently received renewed interest in the context of virtual reality studies. Investigators have discussed whether the shape of this space is circular (Hall, 1966), or whether it is noncircular (Bailenson, Blascovich, Beall, & Loomis, 2001; Hayduk, 1981), or if it changes depending on the setting (Little, 1965) or the individual (Kinzel, 1970). When assessed with the same method, an individual's personal space seems to be rather stable over time. In a study with incarcerated offenders, Wormith (1984)measured the shape of personal space, including approaches from left, right, front and rear, and found relatively stable test-retest-reliabilities after a ten-week interval ($r = 0.65$). Within a VE, Bailenson et al. found the shape of personal space to be noncircular and somewhat more extensive in the front than in the rear. These findings are consistent with Argyle and Dean's (1965) equilibrium theory, which identifies intimacy, the

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amount of eye-contact, and smiling as contributing factors. A high degree of eye-contact produces a high level of intimacy. If this is considered as inappropriate in a given situation, people maintain greater distances between each other. Consequently, there is a lower level of intimacy if people are approached from behind, and accordingly interpersonal distances in the rear zone should be smaller. In contrast, when conceiving of personal space in terms of a buffer zone (Horowitz, Duff, & Stratton, 1964), one might be more vulnerable when unable to see a potential intruder into personal space and might thus feel encroached upon sooner when approached from behind. This has been found to be the case in war veterans but not in healthy controls (Bogovic, Ivezic, & Filipcic, 2016).

Subjects in Bailenson et al.'s (2001) study had to solve a memory task in which they approached[1] a virtual agent in order to read a name printed on his T-shirt (when facing the front of the avatar) or a number (when facing its back), which they were asked to remember. This task has the great advantage of being indirect, as subjects were not directly asked to adjust the preferred interpersonal distance. Instead, the shortest distances assumed toward the virtual agent indicated the edges of personal space. At the same time, the task may have been a suboptimal measure of the edges of personal space because it may have required subjects to step closer than they felt comfortable in order to decipher the numbers or letters. Moreover, Bailenson et al. used only a VE with virtual agents, which tend to produce overestimation of sagittal distances (Kunz, Wouters, Smith, Thompson, & Creem-Regehr, 2009).

Research on gender differences in proxemic behavior has been quite substantial. Hayduk (1978) counts seven studies supporting the claim that men choose greater distances than women, eight non-supporting studies, and twenty studies that only partially support gender differences. Two studies found that male-female pairs stood closest, female-female pairs were intermediate, and male-male pairs showed the greatest distance from each other (Baxter, 1970; Evans & Howard, 1973). In contrast, Aliakbari, Faraji, and Pourshakibaee (2011) reported that female pairings assumed the smallest distance, followed by male-female pairings, and male-male pairs remained most distant (see also Caplan & Goldman, 1981). Other studies only found limited (Remland, Jones, & Brinkman, 1995) or no support for the existence of gender differences in interpersonal spacing (Bailenson et al., 2001; Hayduk, 1981).

1.2. Goal of the study

Note that in the above-mentioned studies, gender-effects could be confounded with body height. In comparison to a tall person, a short person's personal space has been shown to be violated more frequently (Caplan & Goldman, 1981; Hartnett, Bailey, & Hartley, 1974). Thus, body height has a considerable influence on interpersonal distances, and a woman's personal space may just be violated more frequently because statistically, women are not as tall as men. In the gender studies mentioned above, body height has not been controlled or even measured. In the present study, we investigated the influence of gender on personal space by forming three gender groups (male-male, female-male, female-female) and by controlling for body height of the subjects. Thus, we hypothesized that gender-effects will not appear when controlling for body height.

In contrast, we expected the degree of liking and acquaintance to have an influence on interpersonal spacing. Hall (1966) observed that how people feel about each other co-determines interpersonal distance. Likewise, four of six studies reviewed by Hayduk (1978) confirmed that liking the other person leads to smaller interpersonal distances. Gifford (1982) used a projective study in which he ascertained that persons used closer distances when they indicated to like the other person. Furthermore, Little (1965) showed that people who are familiar with each other stand close together. To rule out confounds that might be caused by different levels of acquaintance, we selected subjects with equal levels of acquaintance.

We expected the shape of personal space to be circular. It might be affected by additional attributes of the approaching person (see e. g. D'Angelo, Pellegrino, and Frassinetti (2017) for manipulations of body representation in a VE), as well as the presentation medium. Thus, we chose to start out in a physical environment with real people. We then moved to using avatars in a virtual environment (VE). VE's offer the advantage of being able to study social behavior with virtual confederates that remain unchanged throughout an experiment, thus controlling for many confounding variables while maintaining external validity (Blascovich et al., 2002). Although proxemic research in VE has started with a focus on observational measures of personal space (Bailenson et al., 2001), research has become more structured with the introduction of the easier to implement and experimentally superior stop-distance task. For example, Iachini, Coello, Frassinetti, and Ruggiero (2014) compared the preferred interpersonal distance toward a male avatar, a female avatar, a robotic avatar, and a cylinder (resembling the avatars in size) in a VE. They showed that female avatars are approached closer than male avatars. The robot produced distances comparable to the male avatar, and the cylinder produced the largest distances. Furthermore, they found that a passive approach-task enlarges the estimates of preferred interpersonal distance in comparison to an active approach. Iachini et al. (2016) replicated these effects in a VE and in a real environment. Note, however, that these studies focused on the frontal interpersonal distance in VE's.

Given the increasing use of VE's in the context of proxemic research, we thought it necessary to compare virtual and physical environments with respect to the shape of personal space. So far, little is known about the potential differences. In principle they could come about because of the nature of the virtual medium or because of the uncanny nature of virtual people. Thus, we decided to separate the two by introducing a mannequin into the real world context and to compare similar avatars in VE (human-looking avatar vs. a mannequin-like avatar).

Experiment 1 was designed to map out the personal space surrounding a human and a mannequin as experienced by human subjects. Experiment 2 replicated this design for the space surrounding an avatar in a virtual room presented on a large projection screen in both an egocentric (first-person) and an allocentric perspective (third-person). This was done to investigate the persistence of personal space across different levels of abstraction.

2. Experiment 1: comparing the shape of personal space for real people vs. a mannequin

Bailenson et al. (2001) reported that subjects maintained larger distances to an avatar with realistic gaze behavior as compared to an agent without realistic gaze behavior or to an object. If this effect is not an artifact of the VE, we would expect subjects to maintain greater distances to other subjects than to the mannequin whose eyes were fixed. Note however, that Iachini et al. (2014) found comparably large interpersonal distances for a robotic avatar. Hayduk (1981) found that personal space was compressed behind a person's back when this area was visually not accessible, whereas the opposite was the case in Bailenson et al.'s study. By using real people, we sought to determine if this discrepancy might by due to the unique compression of personal space in VE (see also Loomis & Knapp, 2003) or to the particular indirect method the investigators have used.

2.1. Method

2.1.1. Subjects

We recruited 66 primarily Caucasian subjects at the Psychology

[1] We will refer to this as “active approach” as opposed to “passive approach” in which the subject remains stationary and is approached by another person or avatar.

Department of Mainz University in accordance with the Declaration of Helsinki. They were given partial course credit. Gender and body height were selection criteria. For each session, we matched two subjects whose body heights differed by a maximum of 5 cm. We tested thirty-three subject pairs (ten female-male pairs, ten male-male pairs, and thirteen female-female pairs). Their mean age was 23.2 years, ranging from 18 to 45 years (male-male 22.3 years, female-male 23.9, female-female 23.5).

2.1.2. Design

The dependent variable of interpersonal distance was examined as a function of two within-subject factors: Target type (person vs. mannequin) and approach Orientation: eight levels varying in 45°-steps full circle around the passive person. In addition, we had the between-subjects factors Gender group (female-female, female-male, male-male), which was for some analyses collapsed into Gender of the subjects. Sympathy and degree of acquaintance within the subject pairs and sympathy of the mannequin were used as covariates.

2.1.3. Materials and stimuli

The life-size gender-neutral mannequin had a bald Styrofoam head with glass eyes and was mounted to a height-adjustable tripod with wheels. It wore a grey coat mostly covering the tripod. We measured the distances between the subject and the stimulus with a Toolcraft LDM 50 U laser range-finder (distance meter). It displayed distances in meters correct to three decimal places with an accuracy of ± 2 mm and a range of 0.5 m to 50 m. Furthermore, to facilitate the measurements, we used two L-shaped wooden blocks that could be positioned flush with the back of the subject's shoe. The range-finder was fixed to one of the wooden blocks, the beam pointing to the other block. On each trial, passive subjects rated the appropriateness of the distance the other subject had chosen. This was done on a scale ranging from −10 "much too distant" over 0 "adequate" to +10 "much too close".

2.1.4. Procedure

For each session, we invited two subjects of comparable body height. They wore their everyday shoes, in order to capture their normal everyday eye-height. Subjects also reported their age and rated how likable (sympathy rating) they thought the partner was on a rating scale ranging from 0 (not likable at all = sehr unsympathisch) to 10 (very likable = sehr sympathisch). Acquaintance was likewise rated from 0 "we have never met before" to 10 "we know each other well". Subjects could not see the ratings made by the partner. Each subject pair was run in a session containing four blocks in counterbalanced order, one wherein subject A approached subject B, one wherein subject B approached subject A, and two wherein subject A and B separately approached the mannequin from the eight orientations.

We placed the passive subject (or the mannequin) in the imaginary center of all starting positions (see Fig. 1), which could physically be at arbitrary locations in the large laboratory space. The active subject started out 2.5 m from this center position facing the passive subject (or mannequin). The latter encountered the eight approach Orientations in the same random order. For approach Orientation 0° the passive person was approached from the front, at 180° from behind, at the orientation of 90°, the passive subject was approached from the left, etc. Starting positions as well as the center (not visible to the subject) were marked on the floor. Distance was defined as the space between the body centers of the passive and the active subjects.

During all eight trials of each block, we allowed the passive subject to turn his/her head and eyes so that she/he was able to judge the distance chosen by the active subject. The active subject could not see the ratings made by the passive subject. The passive subject's torso remained oriented toward orientation 0°. In the condition where subjects approached the mannequin, the latter stood in the center of the circle facing 0°. The eye-height of the mannequin was adjusted to match that of the active subject.

The respective starting position was pointed out to the active subject. Toes should be directly behind the mark for the initial position. We instructed the active subject to approach the passive subject up to the point where he/she would feel most comfortable to have a conversation asking for directions. Then the passive subject had to judge the appropriateness of the assumed distance. He/she was allowed to turn head and eyes for these ratings. While the passive subject judged the distance assumed by the active subject, the experimenter placed one of the wooden blocks behind the heels of the active person. Then both subjects stepped aside, and the range finder was used to measure the distance between the positions that had been assumed. Finally, subjects rated how likable they thought the partner to be.

2.2. Results

2.2.1. Personal space of the active person

We entered interpersonal distances into two separate rmANOVAs (repeated-measures analysis of variance) with Orientation of the approach (8 levels) and Target type (person vs. mannequin) as within-subjects factors, one with Gender group (male-male, female-male, female-female) and one with Gender regardless of the pairing as between-subjects factor. In the rmANOVA with Gender group, results showed a significant main effect for Gender group [$F(2, 63) = 6.15$, $p = .004$, $\eta^2 = 0.163$]. A Bonferroni-corrected post-hoc comparison revealed that female-female pairings produced closer preferred distances than did male-male pairings [$M_{diff} = -0.221, t = -3.45$, $p = .003$]. Mixed-gender pairings were intermediate, but did not differ significantly from either of the other groups. See Fig. 2 (left panel) for average distance settings by Gender group.

Neither the main effect of approach Orientation nor the Gender group-by-Orientation interaction reached significance, indicating that the shape of personal space is generally circular and that there are no orientations that stand out. As visible in Fig. 2 (right panel), male-male pairs seemed to deviate from circularity; they set larger distances when approaching the other person from behind. However, this trend did not reach significance [Orientation Greenhouse-Geisser corrected $F(2.98, 187.9) = 2.30$, $p = .079$, $\eta^2 = 0.035$; Gender group-by-Orientation interaction Greenhouse-Geisser corrected $F(5.97, 187.9) = 1.38$, $p = .225$, $\eta^2 = 0.042$].

The second rmANOVA resembled the first analysis but the factor Gender was pooled across pairs. This showed that women stepped generally closer toward a person than did men [$F(1, 64) = 9.51$, $p = .003$, $\eta^2 = 0.129$]. No difference in the shape of personal space between males and females was found [Gender-by-Orientation interaction Greenhouse-Geisser corrected $F(3.18, 203.74) = 1.61$, $p = .185$, $\eta^2 = 0.025$]. Thus, males just had a scaled-up size of personal space. To further examine if women stepped closer in mixed-gender interactions or only in all female pairs, we ran another rmANOVA in which we only included the data of the mixed-gender interactions. Results showed no significant effect, that is the just mentioned gender effect was carried by female-female pairs. Consistent with Iachini et al. (2014) subjects maintained shorter distances between each other than to the mannequin (see Fig. 3), (main effect of Target type, $F(1,64) = 109.60$, $p < .01$, $\eta^2 = 0.631$).

Besides the main effect of Target, the interaction effect for Target by Orientation reached significance [$F(3.66, 230.24) = 9.21$, $p < .001$, $\eta^2 = 0.128$], as illustrated in Fig. 3. Contrasts indicated that subjects standing frontally at orientation 0° ($M = 1.24$ m, $SD = 0.30$) maintained greater distances to the mannequin than when standing obliquely to the mannequin at orientation 45° ($M = 1.21$ m, $SD = 0.26$). In contrast, distances chosen in subject-subject interactions were shorter frontally (orientation 0°, $M = 1.00$ m, $SD = 0.19$) than obliquely [orientation 45°, $M = 1.03$ m, $SD = 0.19$; $F(1,64) = 5.51$, $p = .022$, $\eta^2 = 0.079$]. Moreover, a comparison of orientations 225° and 270° showed that subjects stood slightly closer to the back of the mannequin (orientation 225°, $M = 1.18$ m, $SD = 0.29$) than to its side

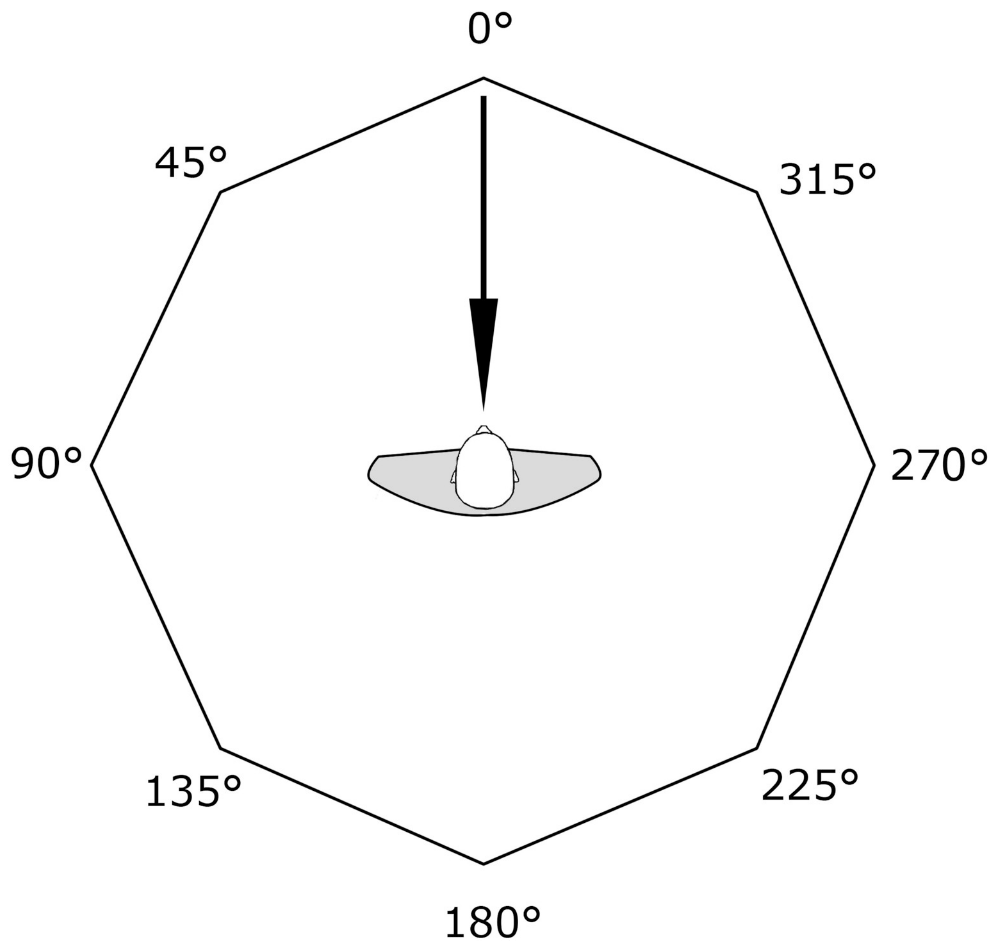


Fig. 1. Orientation of approach directions with reference to the person/mannequin being approached. The arrow indicates the approach path for the head-on 0° orientation. 90° indicated an approach from the passive subject's left.

(orientation 270°, $M = 1.23$ m, $SD = 0.26$), whereas subjects chose shorter distances to the person when they approached from orientation 270° ($M = 1.01$ m, $SD = 0.23$) than from orientation 225° ($M = 1.05$ m, $SD = 0.26$), for a comprehensive post-hoc comparison of all orientations across target-types see Table 1 in the supplementary material.

2.2.2. *Sympathy and acquaintance*

Subjects rated each other as much more sympathetic ($M = 7.73$, $SD = 1.45$) than they rated the mannequin ($M = 3.30$, $SD = 2.40$). A Pearson correlation of the sympathy of the mannequin with the average distances chosen from the mannequin indicates that subjects who liked the mannequin chose more proximal distances than subjects who disliked the mannequin ($r = -0.301$, $p = .040$). In contrast, there was no significant correlation between sympathy and average distances maintained from the human subjects ($r = 0.045$, $p = .723$). This could be explained by the low variance of the human sympathy ratings as compared to those for the mannequin. In the former case, subjects had only chosen ratings from five to ten on a scale that reached from zero to ten. Judgments of the mannequin were spread from the minimum of zero to a maximum of nine. Degree of acquaintance of the interacting

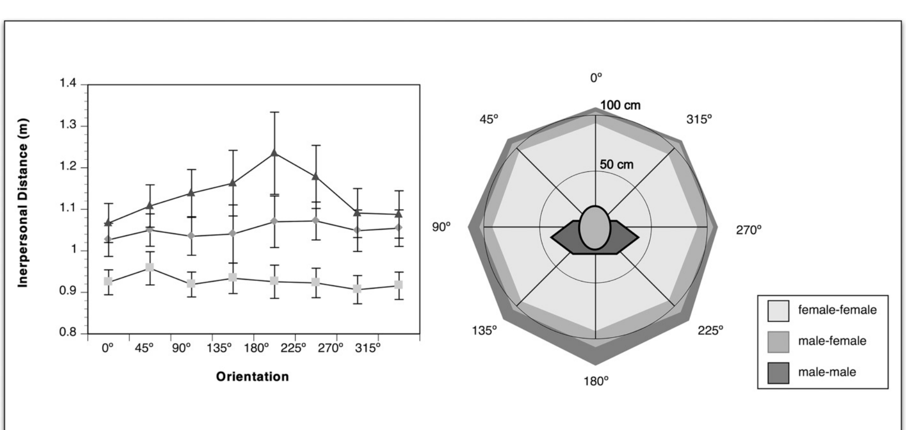
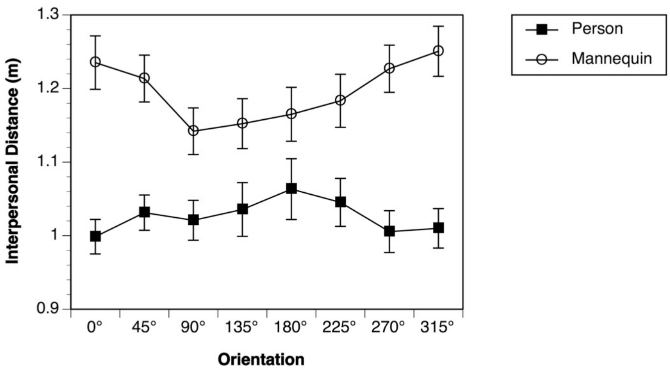


Fig. 2. Left Panel: Mean distances assumed by the person in active approach as measured from the passive person, separate for the three Gender groups (female-female, female-male, male-male) and the eight approach Orientations. The orientation of 0° corresponds to a frontal approach, 90° is an approach from the left, etc. Error bars indicate standard error of the mean (SEM). Note that the ordinate is truncated at 0.8 m.
Right Panel: Corresponding radar plot of the mean distances as a function of the eight approach orientations, illustrating the close-to-circular shape of personal space. The orientation of 0° corresponds to the person's front. The outer circle indicates a personal space of 1 m radius.



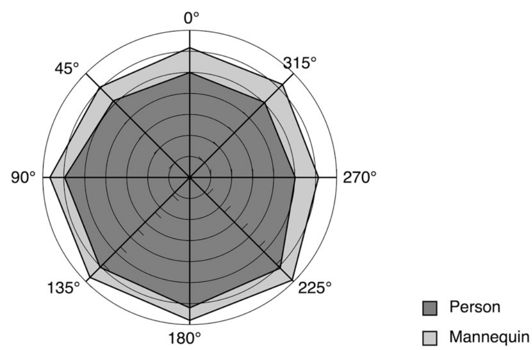


Fig. 3. Mean interpersonal distances (SEM) for the eight approach Orientations, plotted separately for approaches to the Targets person vs. mannequin.

subjects had no significant effect on interpersonal distances in this study.

2.2.3. Personal space of the passive person

Fig. 4 shows the average appropriateness ratings given by the passive person, which we tested for significance via three one-sample *t*-tests, one for each gender group. Since we had asked the passive subjects to judge the appropriateness of the distance assumed by the active person, data from the passive subjects were tested against zero. Deviations from zero would indicate that they considered the distance to be inappropriately close or far, or in other words, that the personal space of the active and the passive partner differed. Results of the rather

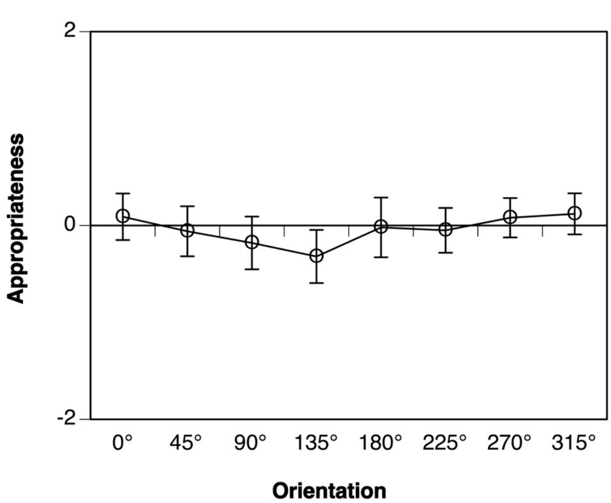


Fig. 4. Mean appropriateness ratings of the passive person as a function of approach Orientation, on a scale ranging from −10 "much too distant" over 0 "appropriate" to 10 "much too close". Errors bars show SEM.

liberal *t*-tests demonstrated that the personal space did not differ significantly between the active and the passive subjects (all $p > .05$). Moreover, we ran a rmANOVA on appropriateness ratings with two factors: Orientation with eight levels and Gender group as a between-subjects factor with three levels (female-female, female-male, male-male). Results showed no effects that approached significance (all $p > .05$).

2.3. Discussion

The shape of personal space was remarkably close to a circular zone around the subject with a radius of about 1 m. This was the case for active as well as for passive approaches. However, all-female pairs preferred closer distances than did male pairs. Mixed-gender pairs assumed intermediate distances. Overall, subjects kept larger distances from the mannequin than from a human. Small deviations from the circular shape occurred when facing mannequins; subjects remained more distant when approaching the mannequin from the front compared to oblique approaches. The opposite was true when approaching another person. Across the board, sympathy ratings of the mannequin were lower than those of the human subjects. The less the mannequin was liked the farther the chosen distances from the mannequin. Our results confirm previous studies suggesting that women maintain shorter interpersonal distances than do men (Aliakbari et al., 2011; Iachini et al., 2016; Uzzell & Horne, 2006). Subjects kept larger distances from a mannequin than to a human partner. The low sympathy ratings for the mannequin nicely reflect this behavior, as they were negatively correlated with assumed distance. Also, subjects tended to approach the mannequin more closely from slightly oblique directions compared to frontal approaches. The opposite was the case in interactions with a person. Note that our subjects were matched in tallness, such that the body-height effect was not an issue – we keep larger distance from taller men (Pazhoohi et al., 2018).

Our main interest was in the active person, the passive subjects merely reacted to the distances assumed by the active person and gave ratings of appropriateness. Thus, it is conceivable that the passive persons may have been very tolerant of deviations from comfortable distance rather than being truly satisfied with the setting chosen by the active subject, amounting to socially desirable responding. Only a study dedicated to the level of concordance of appropriateness ratings in the passive person and interaction distance in the active person will be able to fully rule out asymmetries in active vs. passive person's perception of appropriate interpersonal distance.

The finding that personal space is circular is consistent with the results of Hall (1966) but differs from other studies (Bailenson et al., 2001; Hayduk, 1981). These discrepancies can be attributed to the different methodological approaches. Bailenson et al. measured interpersonal distances indirectly (approach to read a word printed on the avatar's shirt), such that task demands could have been responsible for the slightly flattened space behind the subject. We eliminated this potential confound by asking subjects directly for a judgment of interpersonal distance. Additionally, the studies differ according to the possibility of maintaining eye contact. Eye contact has a substantial influence on interpersonal distances in that realistic gaze behavior leads to greater interpersonal distances (Argyle & Dean, 1965; Bailenson et al., 2001). Hayduk (1981) reports close to circular personal space except for a condition where subjects were not allowed to look behind themselves. In the latter case, personal space was much compressed behind the subject as compared to the subject's front. Since Hayduk used a passive approach scenario, it could be that the subjects were simply not noticing the experimenter as readily when she was approaching from behind. However, Bailenson's group likewise found interpersonal distances to be shorter in the case of an active rear approach, which also precluded eye-contact. In the present study, we allowed passive subjects to turn their head and eyes so that they could establish visual contact. This is more realistic with regard to everyday situations. However, note that the mannequin could not move and maintained its orientation.

3. Experiment 2: The shape of personal space in a virtual environment

Interpersonal distance preference may strongly depend on the social or laboratory context. Preferred distance to a human observer in the physical setup of Experiment 1 was approximately 1 m, whereas it was merely half that to an avatar in Bailenson et al. (2001). In contrast, Iachini et al. (2016) found interpersonal distances of about 1.1 m in both virtual and real environments when considering arm length. In our second experiment, we ported the task of Experiment 1 to a VE. Thus, Experiment 2 was conducted to explore whether the findings of the circular personal space as well as the gender effects hold up in a VE of comparable setup. We also took advantage of the VE to easily implement egocentric and allocentric approaches. That is, we asked subjects either to approach an avatar until a comfortable distance had been reached (egocentric approach), or to make the avatar approach a second avatar (allocentric approach). With respect to the nature of the avatar (human vs. mannequin), we expected subjects to keep larger distances from the mannequin than from the person avatars, as was the case in Exp. 1. By adding a quick personality assessment of the avatars, we explored the relation of interpersonal distance and perceived personality traits (inspired by Iachini, Pagliaro, & Ruggiero, 2015).

3.1. Method

3.1.1. Subjects

Twenty students (10 males, 10 female) at the Johannes Gutenberg-University Mainz received partial course credit for their participation. The only selection criterion was gender. Their age ranged from 19 to 51 years (M = 25.05 years, SD = 7.65 years). All subjects were uninformed about the hypothesis of the experiment; however, two subjects had already participated in the first experiment.

3.1.2. Apparatus

The virtual avatars were displayed on a large rear-projection screen (2.6 m wide and 1.95 m tall) and rendered on a DELL Precision 390 computer with an NVIDIA QuadroFX 5500 graphics board. The stereoscopic projection was generated by a 3D rear-projector (projection design F10 AS3D) with a resolution of 1400 × 1050 pixels and a color depth of 32 bits. Subjects wore LCD shutter glasses (XPAND X102) whose exposure times were synchronized with the projector's refresh rate of 120 Hz via an infrared sensor, thus providing each eye with 60 frames per second.

The virtual position of the avatar was 0.15 m behind the screen. In order to equate the distances with those used in Experiment 1, we determined the starting position of the subjects to be 2.35 m in front of the screen in the egocentric approach conditions. At this distance, the avatar subtended a visual angle of 44° vertically for an average observer. In the allocentric approach conditions, subjects stood behind a yellow line marked on the floor at 1.5 m in front of the screen. The position of the subjects was tracked by an optical motion tracking system using the Microsoft Kinect 1. The tracker was calibrated for each subject at the 1.50 m position. The projection was rendered according to the subject's position.

To obtain the body center position from the foot placement data (measured at the heel of the subject) we subtracted half a foot length where applicable. In order to ascertain comparability with the data from Experiment 1, we correlated the distances measured using the Toolcraft LDM 50 U laser with those obtained by the Microsoft Kinect tracking system. They were nearly perfectly correlated (N = 19, r = 0.997, $p < .001$), demonstrating the validity of the measures taken with the optical body tracking system. Note that the mean value measured via foot placement was by 4.92 cm larger than the value obtained by body tracking. That is, the center of the torso was slightly forward compared to the center of the foot. For one subject (not included in the correlation analysis), the Kinect position tracker malfunctioned and failed to properly track. We replaced these missing values with the distances measured using the Toolcraft LDM 50 U laser, taking into account also the systematic difference, that is by adding 4.92 cm.

3.1.3. Design

The dependent variable of interpersonal distance was examined as a function of three fully crossed within-subject factors:

Avatar type had three levels (male avatar, female avatar, virtual copy of the mannequin used in Experiment 1). Note that this refers to the primary avatar approached by the subject (or by the second avatar).

Orientation of the passive avatar had six levels; the angles used were 45°, 90°, 135°, 225°, 270° and 315°. Note that the approach direction was entirely determined by the orientation of the avatar, as the projection screen and the physical movement path of the subject remained constant (see Fig. 5).

Approach type was varied at three levels, which were blocked. In the first block, subjects physically walked and approached the avatars (egocentric approach). In the second and third block respectively, they moved a second female or a second male avatar toward the target avatar (allocentric approach). The order of the blocks was randomized as well as the order of all trials within a block.

3.1.4. Procedure

Before the start of the experiment, we measured the subjects' body height, heel height, height of the eyes above the ground, inter-pupillary distance, and foot length. The individual inter-pupillary distance was measured to appropriately customize the stereoscopic disparity of the display for each subject. Foot length was used to calculate the approximate body center of the subject, which was then used to determine the distance between the subject's and the avatar's center. We assumed that the former would coincide with the center of the foot.

The experimenter then provided a pair of shutter glasses and verified that they worked properly, such that the subjects could clearly see

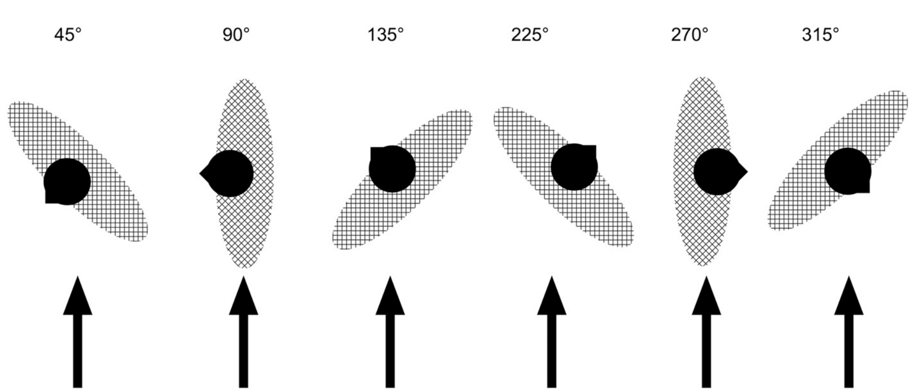


Fig. 5. Egocentric Approach: The arrows indicate the subject's approach direction in front of the projection screen. The torso indicates the avatar's Orientation with respect to the subject. The passive avatar was either male, female, or a mannequin. The subject approached the avatar actively. Note that we chose Orientation values to correspond to those used in Exp. 1. A 90°approach indicates an approach from the left, as seen by the passive avatar.

the three-dimensional virtual world. After all blocks had been completed, subjects filled out a questionnaire about sympathy and attractiveness of the avatars as well as a few questions about their own personality. We employed the NEO-FFI (Borkenau & Ostendorf, 1993; Costa Jr & McCrae, 1992), which uses 60 questions to measure the Big Five personality traits of Extraversion, Neuroticism, Agreeableness, Openness to experience, and Conscientiousness on 5-point Likert scales ranging from strongly disagree to strongly agree.

3.2. Egocentric approach (block 1)

At the starting point, the subject stood 2.5 m in front of and facing the avatar. Subjects were then asked to raise and lower their arms in order to allow the Kinect system to track their body center properly. A green light on the screen signaled to start walking slowly toward the avatar until a comfortable distance had been reached. The distance was supposed to be comfortable for a scenario in which the subject would ask a stranger for directions without being crowded or distracted by other pedestrians. Subjects were allowed to correct their position, including backwards movement, until they were satisfied with the distance. This final position was recorded. In addition, the experimenter measured the approach distance with the laser distance meter, as had been done in Experiment 1.

3.3. Allocentric approach (blocks 2 and 3)

A second avatar was introduced. Subjects moved this second avatar (female in Block 2, male in Block 3) toward the original target avatar while remaining stationary at 1.5 m from the screen. We call this an allocentric approach as the observer is no longer involved actively. From an initial distance of approximately 2.5 m between the avatars, subjects moved the second avatar from the left toward the right using the arrow keys on a keypad, until an appropriate distance had been reached (see Fig. 6). As in Experiment 1, the distance had to be appropriate for a conversation between strangers, one asking for directions. The subjects' station point was indicated by a tape mark on the floor. The different orientation levels were realized by turning the original avatar within the VE, thus allowing the second (approaching) avatar to always follow the same path, frontoparallel to the subject. The stationary avatar was in front of the subject, the approaching avatar to her/his left. The approaching avatars consisted of the same virtual models as the original avatars, with the exception that the mannequin only featured as the stationary but not as the moving avatar. Again, interpersonal distance between the avatars' body centers was the dependent variable as measured in the VE.

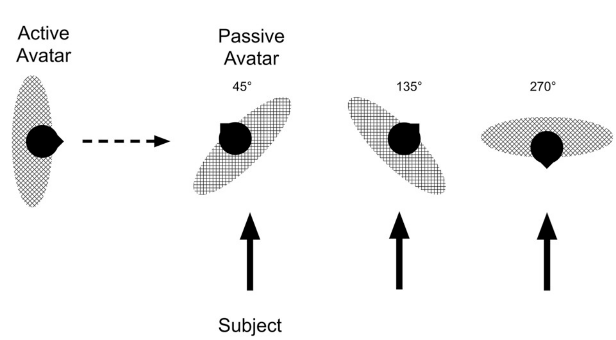


Fig. 6. Allocentric Approach: The dotted arrow indicates the approach direction of the active avatar. Three sample Orientations of the passive target avatar (45°, 135°, 270°) are shown with reference to the approach direction of the active avatar. The subject used arrow keys to move the active avatar toward the passive avatar. The active avatar was either male (Block 2) or female (Block 3). The passive avatar was alternated randomly among being male, female, or a mannequin within each block. Note that an approach Orientation of 45°indicates an approach from the left front, as seen from the passive avatar. This corresponds to the Orientation labelling used in Exp. 1.

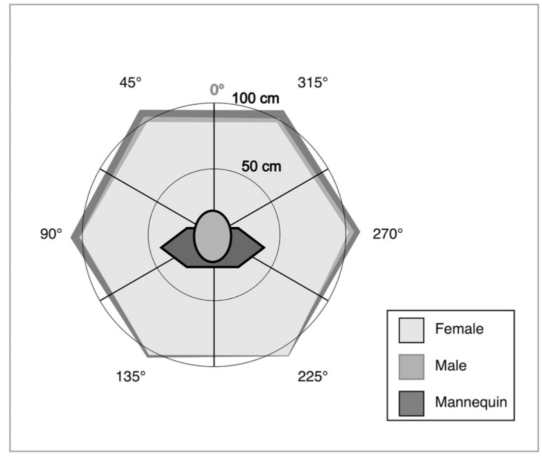


Fig. 7. Radar plot of the distances chosen for allocentric approach toward a passive avatar/mannequin, averaged across gender of the active approaching avatar.

3.4. Results and discussion

The mean distances chosen for the allocantric approach are illustrated in Fig. 7. We conducted a three-factor repeated-measures ANOVA. Within-subjects factors were Avatar type (3 levels), approach Orientation (6 levels) and Approach type (3 levels). Furthermore, we added the between-subjects factor Gender. Results were Greenhouse-Geisser-corrected where necessary.

Only Avatar type of the passive avatar produced a large main effect $F(1.13,\ 20.29) = 8.85$, $p = .006$, $\eta^2 = 0.33$). The shortest distance ($M = 1.01$ m, $SD = 0.24$) was kept from the female avatar, the largest ($M = 1.08$ m, $SD = 0.25$) from the mannequin. Subjects maintained an intermediate distance to the male avatar ($M = 1.03$ m, $SD = 0.24$). This order was found in all blocks and equally for male and female subjects. Gender of the subjects did not show any significant influence.

Avatar type and approach Orientation interacted significantly [$F(6.01,108.10) = 5.44$, $p < .001$, $\eta^2 = 0.23$], indicating that the female avatar was approached closer from the rear than from the front while the others were not, see Fig. 8. No other main effects or interactions occurred. This might indicate that the personal space around the avatars deviates from circularity. There was indeed a trend to move closer to the avatar at the 315° position [$F(2.01,\ 36.12) = 3.09$, $p = .057$, $\eta^2 = 0.15$]. To verify if it is justified to conclude that personal space is not always circular, which amounts to rejecting the null-hypothesis, we carried out an additional Bayesian analysis. We performed a repeated-measures Bayesian ANOVA (Rouder, Morey, Verhagen, Swagman, & Wagenmakers, 2016) on the mean approach distances as a function of approach orientation. The Bayes factor comparing null- and alternative hypothesis suggested that the data were 12.287: 1 in favor of the null-hypothesis, making it about twelve times more likely to be true as compared to the alternative hypothesis of differing means. Thus, the data are in agreement with personal space being circular.

The diameter of personal space was the same for egocentric and passive allocentric approach. A distance of $M = 1.01$ m ($SD = 0.28$ m) was chosen as comfortable interpersonal distance in the egocentric approach condition compared to $M = 1.04$ m ($SD = 0.23$) in passive allocentric approach.

Inter-individual variability of interpersonal distance was consistent across Approach types. Individual mean distance in the egocentric approach (Block 1) was highly correlated with the mean distance in the allocentric approaches, Block 2, $r = 0.84$, $p < .001$ and Block 3, $r = 0.81$, $p < .001$. Individual mean allocentric distance in Block 2 and

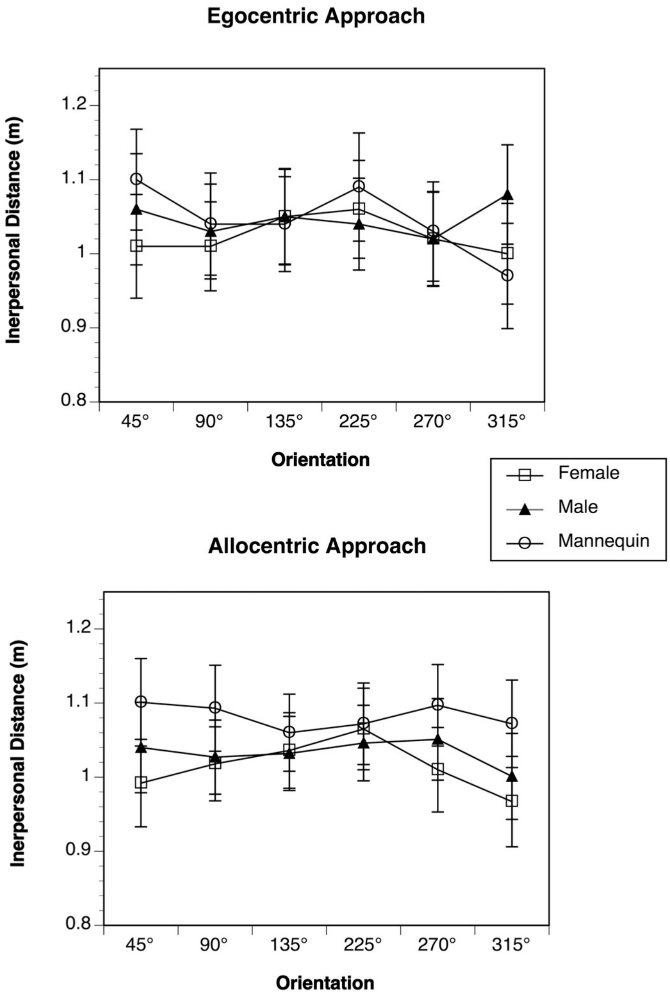


Fig. 8. Mean approach distance (truncated) as a function of the passive Avatar type and approach Orientation, plotted separately for egocentric (left pane) and allocentric (right panel) approaches. Error bars indicate standard errors of the mean (± 1 SEM).

Block 3 was also highly correlated, $r = 0.95$, $p < .001$. Therefore, we chose to average interpersonal distance across Approach type for analysis of the questionnaire data.

Personality, sympathy, and attractiveness scores had no overall effect on the preferred interpersonal distance. Next, we explored the potential effect of personality scores by calculating regression coefficients for all big five values (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) with regard to rated sympathy and attractiveness. When calculating regression coefficients separately for each Avatar type, more extraverted and less agreeable subjects (which corresponds to an approach temperament; see Elliot & Thrash, 2002) kept shorter distances from the female and the male avatar, but not from the mannequin avatar (see Table 1). This pattern in the results indicates that the mannequin was not approached and processed with comparable social attributes.

On average, an overall distance of $M = 1.04$ m ($SD = 0.24$ m) was chosen as a comfortable interpersonal distance with respect to the virtual avatar. This corresponds closely to the preferred distance between real people as obtained in Exp. 1. There was no difference at all between the egocentric approach and the allocentric approach, suggesting that the adequate distance perceived between others corresponds to that perceived with respect to the own person. The shape of personal space proved circular, albeit with a trend toward closer approach distances at the 315° avatar orientation. Extroverted and less open subjects assumed closer distances to virtual realizations of people. However, such personality effects disappeared when facing the virtual mannequin. Furthermore, interpersonal distance seemed to be unaffected by rated sympathy and attractiveness of the avatars.

Gender of the subjects did not produce a main effect, nor did it interact with the gender of the avatar. This is interesting given the salient gender effects found in Exp. 1. Presumably, the avatars were not able to imitate the gender-specific social dimension of personal space. The avatars might have had more of a neutral appearance although we had taken care to provide them with clearly gendered body proportions, facial features, and clothing. This is reflected in the trend that male avatars produced larger distances than female avatars, but equally so for male and female subjects. Note that Miller, Chabriac, and Molet (2013) were able to find gender differences in a VE, albeit in an opposite direction from those we found in Exp. 1.

Table 1
Significant regression coefficients for personality and judged interpersonal distance.

	Male avatar		Female avatar	
	β	*p*	β	*p*
Extraversion	−1.002	.049	−1.129	.047
Agreeableness	1.420	.021	1.277	.038

4. General discussion

Personal space is circular. Apart from small unsystematic fluctuations, the method of asking a subject to approach another for the purposes of conversation yields preferred distances of about 1 m. This preference does not change when the approach direction, that is the orientation of the other person, is changed. It also remains robust across active and passive approach, as witnessed by the appropriateness impressions of the passive person. However, subjects maintain larger distances from a mannequin as compared to a real person. Moreover, gender matters insofar as the pairing of two males produced the largest interpersonal distances. Two women preferred the shortest distance between themselves, and mixed-gender pairs ranged in the middle. Note that these gender differences did not amount to more than about 10 cm above or below the average of approximately 1 m.

In our second experiment, there was no difference at all between the egocentric approach when the subject had to physically approach the avatar and the allocentric approach, wherein the subject moved one avatar toward another in a virtual environment (VE). We attribute this excellent portability to the allocentric VE scenario to several factors. For one, in VEs the sagittal but not (or much less so) the frontoparallel dimension is often foreshortened. For this reason, we had chosen not to include approaches that were straight-on among the stimuli of our second experiment. This may have prevented a measurable foreshortening in the sagittal direction. Secondly, during the last decade, the graphics and resolution of VEs have much improved, such that the stimulus better mimics physical objects. Differences between real-world viewing and VEs may in the past have been due to inferior graphics rather than to systematic experiential differences. Thirdly, other direct within-subjects comparisons of egocentric and allocentric interpersonal distance have produced either comparable effects across measures or strong correlations between measures (Candini et al., 2017; Nandrino, Ducro, Iachini, & Coello, 2017; Welsch, Hecht, & von Castell, 2018). Thus, subjects may be able to relate their self-referenced preferred conversation distance to that observed in others. Note that this ability is limited when it comes to the modulating effect of gender pairing. Whereas all-male subject pairs preferred the largest interpersonal distance in the real world, we found no such gender effect conveyed by the avatars. We do not know if observers perceive avatars – for their artificial nature – to be more or less gender-neutral, but so it seems when inspecting the data from our second experiment. Note that, Iachini et al. (2014, 2016) found an interaction of subject gender and avatar gender but others did not (Cartaud, Ruggiero, Ott, Iachini, & Coello, 2018; Welsch et al., 2018). Thus, the specific rendering of the avatars in VEs may be crucial. It seems that not so much the artificiality of the stimulus but rather the social dimension evoked by the task determines preferred interpersonal distance.

Our results can best be interpreted within a field-theoretical framework, according to which personal space should be conceived of as a psychological field surrounding the person (see Hall, 1966; Hayduk, 1983). The size of this field is influenced by personal characteristics (openness and agreeableness) and situational characters (e.g. gender of the approached, human vs. mannequin, sympathy). Furthermore, this personal space can be estimated in others. The shape of personal space does not vary across the egocentric or allocentric approach. Proxemic theories that characterize personal space as a safety-boundary (Dosey & Meisels, 1969; Horowitz et al., 1964; Lloyd, Coates, Knopp, Oram, & Rowbotham, 2009) would have predicted systematic variations in the shape of personal space and cannot accurately predict the increase in preferred interpersonal distance toward the mannequin. Moreover, intimacy-theory (Argyle & Dean, 1965) would have predicted less intimacy toward the mannequin as compared to real or virtual people and thus shorter preferred interpersonal distances. However, we found the reverse pattern in our results. Thus, we expect personal space to behave much like a dynamically self-constructing field in psychosocial space. This field surrounds the person and can be characterized in terms of its shape, density, and elasticity with repelling and attracting forces (Hayduk, 1983).

Previous research on the influence of gender on interpersonal distances has not been conclusive, partially because body height had not been factored into the equation. With this control, our male-male pairs consistently maintained larger distances than did female-female pairs, which lends credence to similar reports (see e.g. Aliakbari et al., 2011; White, 1975). The case is different for mixed-gender pairs. Whereas some studies found mixed-gender pairs to interact more closely than all-female pairs (Baxter, 1970; Evans & Howard, 1973), we could not confirm this finding. Considering that the latter studies did not control for or match body height, our present findings call into doubt a robust attraction effect of mixed gender. Instead, since men are on average taller than women, men might step closer when they are taller than the woman. The taller person has been found more likely to invade the shorter person's personal space (Caplan & Goldman, 1981). This is consistent with recent findings of Pazhoohi et al. (2018). They confronted subjects with male avatars varying in body height and shoulder width. Male subjects preferred larger distances to taller avatars, but female subjects did not. Shoulder width made no difference. We controlled for body height. Thus, the general effect that women seek closer distances than men is fully explained by the fact that women approach each other more closely in same-gender pairs. Note that gender role, rather than biological sex, between which we did not differentiate, might show better-defined effects (see Uzzell & Horne, 2006).

Quite remarkably, and consistent with the results of Iachini et al. (2014), both men and women maintained the farthest distances with respect to the mannequin. The sympathy ratings given for the mannequin in the current Exp. 1 were much lower than those given for the human partners. Moreover, subjects who rated the mannequin low in sympathy kept even larger distances from it than did subjects who described the mannequin as more sympathetic. The former often volunteered remarks that the mannequin was uncanny. Some perceived it as feminine, some as masculine, and others as a gender-neutral object rather than as a human being. This real-world version of the "uncanny valley"-effect (see Moore, 2012; Seyama & Nagayama, 2007) could have been alleviated by instructing the subjects to perceive the mannequin in a social context. This lends credibility to both the sensitivity of the stop-distance task and to the processing of our virtual humans as social agents.

Besides the influence of liking (sympathy), it is conceivable that visual contact had an impact on interpersonal distances chosen from the mannequin. The mannequin could not provide any feedback to the approaching subject, which might have led to social insecurity and therefore to larger distances. Some subjects also considered the unrealistic glass eyes of the mannequin as scary. Looking straight into the mannequin's eyes (orientation 0°) might have caused discomfort, compared to approaches from the side or the rear.

How perfectly circular is personal space? In Exp. 1, it was circular with the exception that male-male pairs did not approach quite as closely when facing the rear of the target person. Note that this only partially extended to the mannequin. All approaches toward the mannequin afforded farther distances, and frontal and rear approaches both produced even larger distances. In Exp. 2 there was a trend for the 315° position to produce slightly closer distances. That is, when the passive avatar was localized to the subject's right and more or less facing the subject, the latter was comfortable with closer advances of the active avatar moving in from the left. This may be because in these cases the subject could best identify with the passive avatar, as asked for by the instructions. In sum, with some very minor idiosyncrasies, personal space can be considered as circular.

5. Limitations and future studies

In our study we have traced the horizontal boundaries of personal space. However, studies of Cochran and Urbanczyk (1982) and Cochran, Hale, and Hissam (1984) indicate that personal space also extends in a vertical direction. These vertical boundaries of personal space still need to be measured, to reveal for example whether personal space is spherical or if it extends upwards along the body in a cylindrical shape. Moreover, considering that there are effects of room size on preferred frontal distance (Sommer, 1962; White, 1975; Worchel, 1986), and that personal space can be conceived of as a partition of the available space, the shape of personal space may vary as a function of the shape and size of the room.

The differences in preferred interpersonal distance cannot be attributed to perspective foreshortening or compression caused by the VE display technology. Although our avatars were seemingly not attributed with social characteristics the interpersonal distances chosen by human observers in genuine and in virtual reality were surprisingly similar (see also Iachini et al., 2016). Likewise, the allocentric approach differed little from the egocentric approach. In other words, our ability to judge interpersonal distances is quite stable and rather independent of station point. This lends credibility to the recent cross-cultural study performed by Sorokowska et al. (2017) (see also Hasler & Friedman, 2012; Iachini et al., 2016) who presented paper-and-pencil versions of two human silhouettes. Such paper-pencil tasks can yield comparable effects to real-life measures and IPD measured in VE's (see Iachini et al., 2016). Among others, their subjects had to mark the distance appropriate for a social situation (conversation). The German subjects in their sample produced social distance preferences at about 1 m, which corresponds to our laboratory data. Note that this value depends on the scenario that is presented to the observer. In crowded spaces, much closer distances are acceptable, whereas in non-social situations larger distances are preferred (see e. g. the VE-study by Pazhoohi et al., 2018, who found distances above 2 m).

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2018.12.009.

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References

Aliakbari, M., Faraji, E., & Pourshakibaee, P. (2011). Investigation of the proxemic behavior of Iranian professors and university students: Effects of gender and status. *Journal of Pragmatics, 43*, 1392–1402.

Argyle, M., & Dean, J. (1965). Eye contact, distance and affiliation. *Sociometry, 28*(3), 289–304.

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium theory revisited: Mutual gaze and personal space in virtual environments. *Presence Teleoperators and Virtual Environments, 10*(6), 583–598.

Baxter, J. (1970). Interpersonal spacing in natural settings. *Sociometry, 33*(4), 444–456.

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

Bogovic, A., Ivezic, E., & Filipcic, I. (2016). Personal space of war veterans with PTSD - some characteristics and comparison with healthy individuals. *Psychiatria Danubina, 28*(1), 77–81.

Borkenau, P., & Ostendorf, F. (1993). *NEO-Fünf-Faktoren Inventar (NEO-FFI) nach Costa und McCrae.* Göttingen: Hogrefe.

Candini, M., Giuberti, V., Manattini, A., Grittani, S., di Pellegrino, G., & Frassinetti, F. (2017). Personal space regulation in childhood autism: Effects of social interaction and person's perspective: The flexibility of personal space in autism. *Autism Research, 10*(1), 144–154. https://doi.org/10.1002/aur.1637.

Caplan, M. E., & Goldman, M. (1981). Personal space violations as a function of height. *Journal of Social Psychology, 114*, 167–171.

Cartaud, A., Ruggiero, G., Ott, L., Iachini, T., & Coello, Y. (2018). Physiological response to facial expressions in peripersonal space determines interpersonal distance in a social interaction context. *Frontiers in Psychology, 9*. https://doi.org/10.3389/fpsyg.2018.00657.

Cochran, C. D., Hale, W. D., & Hissam, C. P. (1984). Personal space requirements in indoor versus outdoor locations. *Journal of Psychology, 117*, 121–123. https://doi.org/10.1080/00223980.1984.9923667.

Cochran, C. D., & Urbanczyk, S. (1982). The effect of availability of vertical space on personal space. *Journal of Psychology, 111*, 137–140. https://doi.org/10.1080/00223980.1982.9923525.

Costa, P. T., Jr., & McCrae, R. R. (1992). *Neo personality inventory–revised (neo-pi-r) and neo five-factor inventory (neo-ffi) professional manual.* Odessa, FL: Psychological Assessment Resources.

D'Angelo, M., di Pellegrino, G., & Frassinetti, F. (2017). Invisible body illusion modulates interpersonal space. *Scientific Reports, 7*(1), 1302.

Dosey, M. A., & Meisels, M. (1969). Personal space and self-protection. *Journal of Personality and Social Psychology, 11*(2), 93–97. https://doi.org/10.1037/h0027040.

Elliot, A. J., & Thrash, T. M. (2002). Approach-avoidance motivation in personality: Approach and avoidance temperaments and goals. *Journal of Personality and Social Psychology, 82*(5), 804–818. https://doi.org/10.1037/0022-3514.82.5.804.

Evans, G. W., & Howard, R. B. (1973). Personal space. *Psychological Bulletin, 80*, 334–344.

Gifford, R. (1982). Projected interpersonal distance and orientation choices: Personality, sex, and social situation. *Social Psychology Quarterly, 54*(3), 145–152.

Hall, E. (1966). *The hidden dimension.* New York: Doubleday.

Hartnett, J. J., Bailey, K. G., & Hartley, C. S. (1974). Body height, position, and sex as determinants of personal space. *The Journal of Psychology, 87*(1), 129–136.

Hasler, B. S., & Friedman, D. A. (2012). Sociocultural conventions in avatar-mediated nonverbal communication: A cross-cultural analysis of virtual proxemics. *Journal of Intercultural Communication Research, 41*(3), 238–259. https://doi.org/10.1080/17475759.2012.728764.

Hayduk, L. A. (1978). Personal space: An evaluative and orienting overview. *Psychological Bulletin, 85*(1), 117–134.

Hayduk, L. A. (1981). The shape of personal space: An experimental investigation. *Canadian Journal of Behavioural Science, 13*(1), 87–93.

Hayduk, L. A. (1983). Personal space: Where we now stand. *Psychological Bulletin, 94*(2), 293–335.

Horowitz, M. J., Duff, D. F., & Stratton, L. O. (1964). Body-buffer zone: Exploration of personal space. *Archives of General Psychiatry, 11*(6), 651–656.

Iachini, T., Coello, Y., Frassinetti, F., & Ruggiero, G. (2014). Body space in social interactions: A comparison of reaching and comfort distance in immersive virtual reality. *PLoS One, 9*(11), e111511. https://doi.org/10.1371/journal.pone.0111511.

Iachini, T., Coello, Y., Frassinetti, F., Senese, V. P., Galante, F., & Ruggiero, G. (2016). Peripersonal and interpersonal space in virtual and real environments: Effects of gender and age. *Journal of Environmental Psychology, 45*, 154–164. https://doi.org/10.1016/j.jenvp.2016.01.004.

Iachini, T., Pagliaro, S., & Ruggiero, G. (2015). Near or far? It depends on my impression: Moral information and spatial behavior in virtual interactions. *Acta Psychologica, 161*, 131–136.

Kinzel, A. F. (1970). Body-buffer zone in violent prisoners. *American Journal of Psychiatry, 127*, 59–64. https://doi.org/10.1176/ajp.127.1.59.

Kunz, B. R., Wouters, L., Smith, D., Thompson, W. B., & Creem-Regehr, S. H. (2009). Revisiting the effect of quality of graphics on distance judgments in virtual environments: A comparison of verbal reports and blind walking. *Attention, Perception, & Psychophysics, 71*(6), 1284–1293.

Little, K. B. (1965). Personal space. *Journal of Experimental Social Psychology, 1*, 237–247.

Lloyd, D. M., Coates, A., Knopp, J., Oram, S., & Rowbotham, S. (2009). Don't stand so close to me: The effect of auditory input on interpersonal space. *Perception, 38*(4), 617–620. https://doi.org/10.1068/p6317.

Loomis, J. M., & Knapp, J. M. (2003). Visual perception of egocentric distance in real and virtual environments. *Virtual and adaptive environments. 11. Virtual and adaptive environments* (pp. 21–46).

Miller, H. C., Chabriac, A. S., & Molet, M. (2013). The impact of facial emotional expressions and sex on interpersonal distancing as evaluated in a computerized stop-distance task. *Canadian Journal of Experimental Psychology, 67*(3), 188–194. https://doi.org/10.1037/a0030663.

Moore, R. K. (2012). A Bayesian explanation of the 'Uncanny Valley' effect and related psychological phenomena. *Scientific Reports, 2*, 864. https://doi.org/10.1038/srep00864.

Nandrino, J.-L., Ducro, C., Iachini, T., & Coello, Y. (2017). Perception of peripersonal and interpersonal space in patients with restrictive-type anorexia: Interpersonal space perception in anorexia. *European Eating Disorders Review, 25*(3), 179–187. https://doi.org/10.1002/erv.2506.

Pazhoohi, F., Silva, C., Lamas, J., Mouta, S., Santos, J., & Arantes, J. (2018). The effect of height and shoulder-to-hip ratio on interpersonal space in virtual environment. *Psychological Research*. https://doi.org/10.1007/s00426-017-0968-1.

Remland, M., Jones, T., & Brinkman, H. (1995). Interpersonal distance, body orientation, and touch: Effects of culture, gender, and age. *The Journal of Social Psychology, 135*(3), 281–297.

Rouder, J. N., Morey, R. D., Verhagen, J., Swagman, A. R., & Wagenmakers, E.-J. (2016). Bayesian analysis of factorial designs. *Psychological Methods*. https://doi.org/10.1037/met0000057 (No Pagination Specified).

Seyama, J. I., & Nagayama, R. S. (2007). The uncanny valley: Effect of realism on the impression of artificial human faces. *Presence Teleoperators and Virtual Environments, 16*(4), 337–351.

Sommer, R. (1962). The distance for comfortable conversation - a further study. *Sociometry, 25*(1), 111–116. https://doi.org/10.2307/2786041.

Sorokowska, A., Sorokowski, P., Hilpert, P., Cantarero, K., Frackowiak, T., Ahmadi, K., ... Blumen, S. (2017). Preferred interpersonal distances: A global comparison. *Journal of Cross-Cultural Psychology, 48*(4), 577–592. https://doi.org/10.1177/0022022117698039.

Uzzell, D., & Horne, N. (2006). The influence of biological sex, sexuality and gender role on interpersonal distance. *British Journal of Social Psychology, 45*(3), 579–597.

Welsch, R., Hecht, H., & von Castell, C. (2018). Psychopathy and the regulation of interpersonal distance. *Clinical Psychological Science, 6*(6), 835–847.

White, M. J. (1975). Interpersonal distance as affected by room size, status, and sex. *The Journal of Social Psychology, 95*(2), 241–249.

Worchel, S. (1986). The influence of contextual variables on interpersonal spacing. *Journal of Nonverbal Behavior, 10*, 230–254. https://doi.org/10.1007/BF00987482.

Wormith, J. S. (1984). Personal space of incarcerated offenders. *Journal of Clinical Psychology, 40*(3), 815–827.