No faces, just body movements—Effects of perceived emotional valence of body kinetics and psychological factors on interpersonal distance behavior within an immersive virtual environment

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Abstract

In an immersive virtual environment, it was investigated how the perception of body kinetics contributes to social distance behavior when the facial expression and other physical properties of a social interaction partner cannot be perceived. Based on point light displays, both the subject and the social interaction partner were depicted as stick figures, both moving simultaneously in the same space. In addition, the effects of relevant psychological factors of the perceiver on social distance behavior were examined. The results were consistent with those from studies with facial expressions or realistic full-body interactants. A greater distance was maintained from characters with emotionally negative expressions of body kinetics. Stationary objects stimuli, which were also included in the study, were mostly passed closer than neutral agents. However, the results are not entirely clear and require further investigation. Depressive symptom burden and factors mainly related to anxiety and avoidance showed effects on social distance in an IVE. The CID, a test often used to assess the interpersonal distance at which a person is comfortable, correlated with that overt behavior. In summary, the results of the study provide experimental evidence that the perception of body kinetics has a similarly significant influence on the regulation of social distance as, for example, facial affect. Implementing this study in real life would be incredibly complex, if not impossible. It is interesting to see that the comparatively simple method used in this study to create and operate an immersive virtual environment turned out to be suitable for studying at least simple types of social behavior based on body movements.

Keywords Interpersonal distance · Emotion perception · Body movements · Social cognition · Immersive virtual environment

Introduction

Social Distance Behavior

The distance that is maintained between themselves and others during social interaction is automatically and reliably regulated (Hall, 1966; Hayduk, 1983; Kennedy, Gläscher, Tyszka, Adolphs, 2009). It is believed that interpersonal distance control behavior provides an approach to everyday social perception in social interaction. Interpersonal distance has been shown to be related to arousal (Patterson, 1976; Scott, 1993), privacy (Altman, 1975; Ly, 2007), interpersonal intimacy (Patterson, 1977), stress coping (Evans & Howard, 1973), trauma (Vranic, 2003), self-disclosure (Skotko & Langmeyer, 1977), and emotion regulation (Evans & Wener, 2007; Tajadura-Jiménez et al., 2011). Kaitz et al. (2004) stressed that attachment (Bretherton, 1985) and interpersonal distance behaviors aim to regulate emotional stress. Using the stop-distance paradigm, Kaitz et al. (2004) showed that people with fearful-avoidant, insecure attachment express less tolerance for close interpersonal distance.

The role of personality traits turned out to be rather ambiguous. Previous studies reported that introverts prefer more personal space than extroverts (Leipold, 1963; Patterson and Holmes, 1966). However, Porter et al. (1970) found no evidence of such a relationship. Locus of control was found to be related to

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interpersonal distance (Duke, Marshall P. & Nowicki, Stephen, 1972). The external control was associated with greater distances than the internal control. In this study, the *Comfortable Interpersonal Distance Scale* (CID) was used to measure the need for interpersonal distance (this method is described in more detail in the Methods section).

The role of non-verbal communication was discussed (proxemic mode of non-verbal communication; Mortensen, 2008). Approach behavior was interpreted as a desire for interaction. Appearance, facial expression or language convey such a desire. The interpersonal distance can indicate different stages of the interaction, e.g. beginning, end, mood change or other. Limiting factors are the quality of perception (Argyle, 1990). Depending on the physical distance, more or fewer modalities can be used for communication (near distance: warmth, smell; far distance: sight).

Recognizing Emotions through Body Movements

A remaining question is what traits of an intruder into another person's personal space are relevant. Bryan et al. (2012), summarized the literature and found that the observed interpersonal distance behavior cannot easily be associated with certain features from the multimodal perceptions normally associated with the experimental settings (Bryan et al., 2012). Neither the stop technique nor the questionnaires, nor the CID or other methods explicitly address this problem. In addition to language, non-verbal signals vary widely and are known to play an important role in social interaction. Keeping a certain distance from another person can be observed as a non-verbal signal in social interaction (Argyle, 1990). While facial expression has been studied extensively in relation to emotion perception and social interaction, other body signals have been studied less frequently. More recently, the problem of the role of gestures and particularly body movements in the perception of emotions and social interaction has been addressed. Humans are able to extract subtle information from body shape and kinetics (e.g. identity, gender, affect, intention, and others) and use this information to act (Troje, 2002). Recent studies of body kinetics have used point light displays or point light video. It has been shown that reducing body movement to a few individual points is sufficient for the perception of emotions in individual subjects, but also in dyadic interactions (Krüger et al., 2018; Kaletsch et al., 2014a; Kaletsch et al., 2014b; Lorey et al., 2012; Jansson et al., 1994). It has been shown that basic emotions can be perceived from body kinetics (Atkinson et al., 2004; Clarke et al., 2005). This became an essential aspect of the present work.

Assessment of the Interpersonal Distance

The interpersonal distance is assessed by measuring real distances or by asking the test persons to symbolically (re) establish a distance. Real distance methods relate to measuring the distance between people in real or comparable situations in the laboratory. Videos can be recorded and analyzed, or other observation techniques can be used. Both real-world interactions and situations in which a person interacts with an actor are used. In addition to these free field methods, experimental methods are used. The stop-distance method describes the situation in which a stimulus person approaches the proband. The proband is asked to indicate the distance at which they are less comfortable.

The (re-) production of interpersonal distance requires the imagination of social situations. The subjects are asked to place figures on a field. One of the figures represents the test person himself (Duke & Nowicki, 1972; Pedersen, 1973). Critics have been concerned about the reliability of this method (Hayduk, 1983). However, there are no systematic studies that check the validity of the various measures.

Real life observations are often not reliable enough because the stimuli are less controllable. In the laboratory, many factors of social interaction cannot be sufficiently experimentally manipulated, especially when trying to study an isolated characteristic of social interaction as body movements. If one is interested in the effects of body kinetics on social interaction, it would be beneficial if factors such as attractiveness, likeability, gender, hairstyle, body shape, and many other factors could be experimentally controlled, or even better, masked out entirely. This can be achieved through an *immersive virtual environment* (IVE).

Immersive Virtual Environments

Translating the characteristics of a real acting person into a fully controlled virtual environment in real time is a promising method for studying behavior, including social interaction. The idea of creating digital realizations of immersive virtual environments (IVE) has been discussed intensely since the 1960s. Immersion in virtual reality describes the perception of being physically present in a non-physical world. This perception is created by surrounding the real person with sensory information that provides an attractive overall environment.

Virtual environments are already and increasingly being used for psychological research. The social interaction with virtual subjects was examined (Wieser et al.

(2010); Yaremych & Persky, 2019; Garau et al., 2005; Bailenson et al., 2001, 2003). The results showed the occurrence of compensatory behavior (e.g. averted gaze or increased interpersonal distance) and showed that the test subjects normally made no distinction between real and virtual test subjects during the interaction. Yaremych and Persky (2019) summarize that interpersonal distance is the most common application of position tracking data in virtual reality. Interpersonal distance metrics have been defined in a number of ways, including minimum distance, average distance, or point of smallest face-to-face distance between the interacting partners, or more complex metrics, including analysis of the walking trace. Rinck et al. (2010) investigated interpersonal distance as an indicator of avoidance behavior in women with social anxiety using virtual reality technology (head mounted display). The task was to approach a virtual interactant in a virtual supermarket and read some information from the chest and back. The social interaction was manipulated by the head movements of the virtual interactant and the simulation of the direct gaze in order to create a more or less threatening situation. The subjects were able to move freely within 8×4 m. A sound simulation was implemented to make the simulation more realistic. Several evaluated distance metrics were strongly correlated. A significant positive correlation between distance and social anxiety scores (LSAS) was reported. Wieser et al. (2010) examined gaze, sex, interpersonal distance, and social anxiety. A male or female virtual character (observed with a head-mounted display while the subject remained in a static position) approached up to a distance of 1.5 m or 0.5 m. The virtual interactant held either direct or averted gaze. Regardless of the distance (near / far), the very anxious female test subjects showed avoidance behavior when male avatars approached with a direct look. Several recent studies have shown the correspondence between acting in the real world and virtual reality/virtual environments in relation to social distancing behavior. Iachini, et al. (2016) examined the relationship between interpersonal comfort distance and peripersonal reachability distance, both distances being moderated by age and gender. Peters et al. (2018) used mixed reality environments to measure comfortable social distances between humans, virtual humans, and virtual robots. The participants walked onto a comfortable distance from the virtual character. The virtual character was a male or female human or a virtual humanoid robot. It was concluded that the social interactions between humans, virtual humans and virtual robots are very similar in virtual reality. Simões et al., 2020, compared social distance behavior in a real and virtual environment using the stop distance paradigm

in a group of participants with and without an ASD. Both groups showed high correlations in interpersonal distance metrics between real and virtual environments. However, a larger slope was observed in the control group, which likely indicates that reduced perceptual details in VE affected participants without ASD, but not participants with ASD. Riem, et al. (2019) found that oxytocin reduces the virtual interpersonal distance between different emotional states.

Despite the commonly reported consistency of behavior in VR and IRL, the question of the extent of transferability in either direction remains open. Harris et al. (2019) address this question in relation to VR. In general, they argue that less binocular depth cues and conflicting depth information (resulting in a skewed estimate of distance) or limited haptic feedback can alter the way the brain converts vision into action. Feldstein et al. (2020) compared distance estimates in real and virtual environment based on a literature review and an experiment. As a result, no significant difference was found between egocentric distance estimates in real and virtual environments. However, the question arises as to how relevant this might be for the regulation of interpersonal distancing in the VE, or more concretely for comparing social distancing for different conditions (e.g. perceived emotional value of a social interaction partner), where thus relative distance differences and not absolute distances are of interest.

The interpersonal distance is continuously and automatically adjusted in order to feel comfortable and safe. The social distance regulation influences the interaction behavior. As summarized above, the role of body kinetics in interpersonal distance behavior, apart from facial expressions, gazes, gestures, or other non-verbal cues, has not previously been studied. This is surprising insofar as the distance regulation often takes place at a time when the person opposite is not yet close enough to be able to perceive the facial expression, for example. The aim of the current study was to investigate the effects of pure body kinetics, which is made possible through the use of an immersive virtual environment. The virtual characters were created by body movements of real people, but all properties except body kinetics have been masked out, similar to the point light display technology. This made it possible to study the influence of body kinetics on interpersonal distance behavior, completely independent of other factors such as facial expression, sympathy, attractiveness, appearance, sex or others. First, the influence of the emotional expression of the virtual interaction partner on social distance behavior was examined (3.1). Then the effects of relevant psychological factors of the perceiver on the distance behavior and in particular the interaction with the emotional valence of the interaction partner were examined (3.2).

Methods

Three experimental test runs were carried out with different samples. This study was not designed at the drawing board, but was slowly developed from the ground up due to the lack of comparable studies. From run 1 to 2, some technical parameters of the VE were slightly adjusted and the functionality of the agent was slightly expanded. In runs 2 and 3, the psychological test battery was expanded to include clinical aspects and an electroencephalogram (EEG) was recorded to add a biological aspect to the question. In the third run, the motion detection (XBox®) had to be replaced by an improved model for technical reasons (defective), which required some changes. In the following we report all relevant technical and experimental settings with the exception of the data from the EEG.

Building the Immersive Virtual Environment (IVE)

A virtual environment based on KINECT® was developed. In Experiment 1 and 2, Kinect for Windows v1 (XBox 360®) was used. In Experiment 3 it was changed to Kinect v2 (XBox ONE®), which mainly included an improved camera that resulted in better resolution and an enlarged field of view. From experiment 1 to 2 the engine for the graphics output was changed from Microsoft XNA * 1 to the open source graphics rendering engine OGRE * 2 (https://www.ogre3d.org). Both engines use DirectX® as a graphical API (Application Programming Interface). The appearance of the IVE was maintained by adjusting the coordinates so that no difference could be seen.

The immersive virtual environment (IVE) consisted of a base that represents a 2.60×2.80 m (3.15 m Kinect v2) rectangle in the real world. In addition to other parameters, the perspective axis could be adjusted. The base was designed as a grid pattern to give the impression of the depth of the room. Other objects in the area were two squares on the floor that marked the starting point and the end point for the participants' required action. At the top of the screen was a text object that gave the participants brief instructions. Two characters have been activated in the IVE. The avatar, which is a graphic representation of the participant or their character. Agents are understood as elements that show a behavior that makes them appear as independent intelligence and thus alive. Agents are likely to get the most attention and interaction from the participant. In this sense, the characters of the social interaction partners in this study are referred to as agents. Objects could also be displayed in the IVE instead of agents.

Technical Design of Avatars, Agents and Objects

For *agents*, the body movements of an actor and an actress were pre-recorded using KINECT® technology. 20 points, mainly joints and the head were captured at a frame rate of 30fps. The raw data were post-processed using smoothing to minimize recording artifacts. Each agent was saved as a 3D data set. 15 joints were used to indicate an agent in the IVE. The computer had full control over the appearance (e.g. height, orientation, line width, point size), behavior (rotation, movement, speed) and positioning of an agent. Avatars were generated by capturing the participants' movements in real time with a smoothing filter optimized for short latencies. Again 20 points were recorded (26 in Experiment 3) and 15 points displayed. The delay between real movements and avatar actions was around 100 ms. While walking, the participants could observe their avatar on a 2.80×1.40 m (exp 3: 2.45×1.73) m large projection screen that was mounted in front of them. The screen resolution was 1024×768 (exp 3: 1280×720). To induce distance control behavior, an agent or an object was placed between the start and finish. In the IVE, both the avatar and the agent were shown as stick figures, the avatar in gray (RGB 211/211/211), the agent and objects in yellow (RGB 255/215/0). The color could change due to lighting characteristics and shades. While in Experiment 1 the agents were moved as recorded, in Experiment 2 the interactivity was increased. The agent turned so that the normal of the shoulder axis was continuously aligned with the center of the avatar's body. This reinforced the impression that the agent was facing the avatar. All dynamic data of every scene, consisting of avatar and agent or object, was saved to enable a complete reconstruction. An example of the visual appearance of the IVE is shown in Fig. 1a. Objects were generated with Blender (https://www.blender.org; GNU GPL Version 3). All programming of the IVE was developed in our laboratory. The programs consisted of three modules (1) for real-time recording, (2) for processing the sensor data in order to display them in the virtual environment, and (3) for drawing and controlling the virtual environment.

Content Design of Agents and Objects

Before the main study, 83 video sequences were examined using an online survey (LimeSurvey®). Each video sequence with an acting stick figure was presented once. Below the video eight questions had to be answered by checking one of several check boxes related to the character's perceived emotional expression (angry, afraid, happy, surprised, disgusted, sad; Ekman, 1982; Ekman & Rosenberg, 1997), intensity of emotion expression (7-point rating scale), valence of the emotion (positive, neutral, negative), and the sex of the stick

Fig. 1 Appearance and measures: (**a**) Visual appearance of the immersive virtual environment. Upper line shows an example of avatar – agent interaction, lower line shows the avatar passing by an object. (**b**) Sketch of a walking trace. Both the avatar and the agent position is represented by the hip center or spine base. Distance was computed frame by frame between the avatar position and the centroid of the agents position during the trial. The length of trace (LoT) is calculated as Euclidian distance between start and finish. (**c**) show the framewise distances across time (black). This time series was resampled to 1000 pts (grey). The Point of closest approach PoCA was defined as the minimum of the timeseries. PoCAt indicated point in time of PoCA. Distance values were averaged within each block to get DISTblock
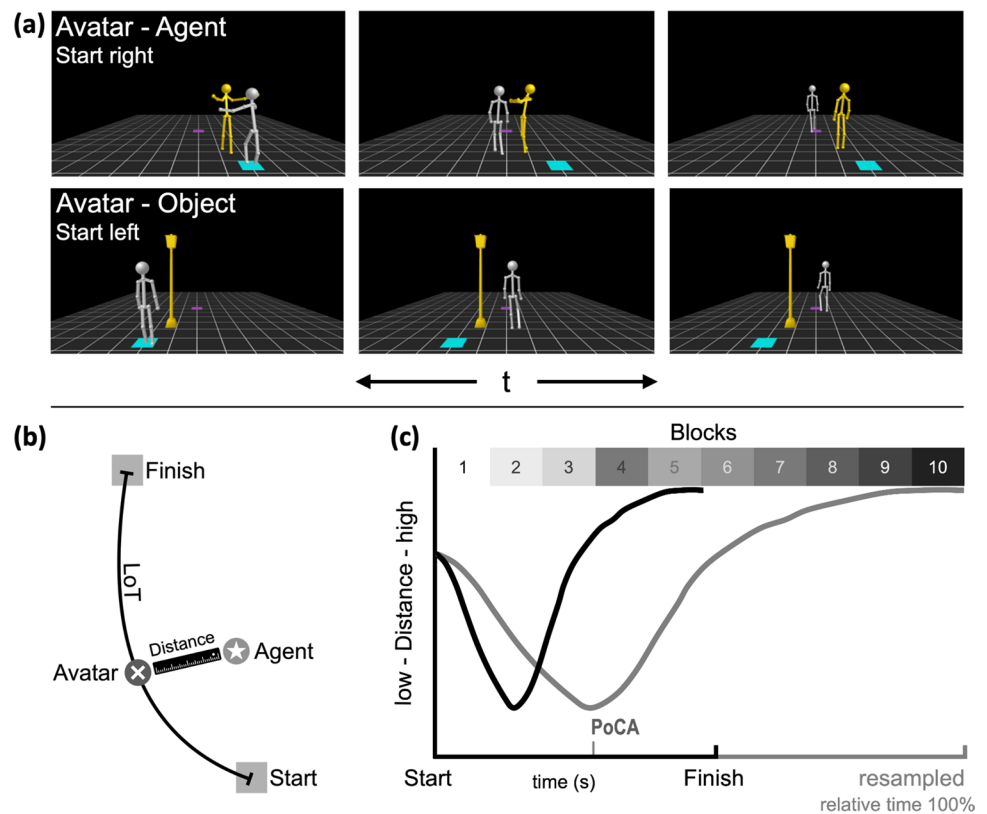

figure. In addition, questions were asked about the emotional impression on the perceiving person (again angry, fearful, happy, surprised, disgusted, sad), the intensity of this emotion (7-point rating scale), how far you would distance yourself from this figure (close, medium, distant) and whether the body expression was addressed to the perceiving person or to another person. All participants were asked to indicate their age, gender and level of education. The time required to complete the survey was 40–60 min.

The survey was available online for three weeks. 318 people took part in the survey (f = 192; m = 67; not stated = 59). 47 participants (age between 18 and 73 years, M = 29.78, SD = 12.06) carried out the survey, 129 participants answered fewer than three questions, 152 participants did not answer all questions. Only completed surveys are displayed as results here. However, the inclusion of incomplete data sets did not change the results for the items of interest. Those elements were selected that showed clear ratings for both the emotional expression and the impression of the kinetics of the stick figures. Ambiguous elements that received half positive and half negative valence ratings were used in Experiment 1 and 2, but were not included in the analysis for the current study. Table 1 shows the properties of the selected elements, Fig. 2 shows the average profiles of the item categories.

In some trials, objects were shown in the IVE instead of agents. In the first experiment, only one object was used, a cylindrical column. Their height was adjusted on average to that of the agents, the width to ((shoulder left—right) + (hip left—right) / 2). The number of different objects in Experiment 2 was increased to 5 (flower, street lamp, garbage can, street bollard, chair) and in Experiment 3 to 7 (additional suitcase, dynamite bundle) (see Table 1). The street lamp was about twice the average agent's height, the chair and dustbin were about the agent's chest height, and the width was shoulder-width. Flowers and bollards were the smallest objects, about the height of the average agent's waist.

The idea behind the use of different objects was to be able to later compare the effect of a perceived emotional valence of the form on the social distance control – presumably limited here. For the current study, however, traces of "object" runs were pooled within each subject, assuming any valence effects would cancel out.

Subjects

169 healthy community volunteers took part in the study (f = 86; m = 83; age = 28.77, sd = 8.8; range = 18–62 years). The subsamples for the three experiments were very similar in terms of age and gender (Experiment 1: f = 26; m = 26; age$_f$ = 32.1, sd$_f$ = 11.5; age$_m$ = 30.5, sd$_m$ = 10.2, range$_{f\&m}$ = 18—57 yrs; Experiment 2: f = 31; m = 32; age$_f$ = 27.1, sd$_f$ = 8.6; age$_m$ = 29.8,

Table 1 Perceived emotions from kinetics of those stick figures that were selected for the experiment. Intensity ratings are corresponding with a seven-step rating scale

Item	Experiment	Valence	Perceived Intensity	Experienced Intensity	Scene
1	1,2,3	positive	4.89	4.28	fanning out arms
2	1,2,3		5.60	4.13	prancing
3	1,2,3		4.19	3.60	fanning out arms
4	1,2,3		4.98	3.38	cheering
5	2,3		4.19	3.19	prancing
6	3		6.45	4.94	cheering
7	3		6.47	4.62	cheering
8	1,2,3	neutral	3.15	2.13	scratching one's head
9	1,2,3		2.53	1.89	raising one arm, saying 'Hi'
10	1,2,3		2.17	1.74	bending forward
11	1,2,3		2.26	1.74	typing on mobile phone
12	2,3		3.77	2.77	hand kiss
13	3		3.15	2.26	combing hair
14	3		2.00	1.70	tapping on a smartphone
15	1,2,3	negative	5.45	3.57	backing off
16	1,2,3		3.36	3.15	sneezing
17	1,2,3		4.57	3.38	slumping
18	1,2,3		5.62	4.83	shaking a fist
19	1,2,3		4.02	2.98	arm akimbo, feet stamped down
20	3		4.55	3.74	pushing
21	3		3.89	2.62	sighing
22	1,2	ambiguous	4.49	3.62	beckoning
23	1,2		3.64	3.21	waving
24	1		3.66	2.79	folding arms
25	2		3.26	2.51	stomping
26	2		4.26	2.96	rising hand
27	2		4.00	2.85	tapping the forehead
28	1	object			pillar
29	2,3				flower
30	2,3				latern
31	2,3				garbage can
32	2,3				bollard
33	2,3				chair
34	3				dynamite bundle
35	3				suitcase

$sd_m = 5.8$; $range_{f\&m} = 18$—62 yrs; Experiment 3: f = 29; m = 25; $age_f = 26.3$, $sd_f = 8.1$; $age_m = 27.2$, $sd_m = 7.6$; $range_{f\&m} = 19$—58 yrs).

The subjects were recruited through an announcement on the laboratory's website, the distribution of flyers and a call to participate via open mailing lists. The expense allowance was paid at EUR 8 / h or a course credit was issued. All participants were informed about the procedure and gave their written consent. All experimental procedures followed the Helsinki Declaration. The study complies with the ethical standards of the APA.

The initial a priori estimate of the sample size was based on the incorrect use of G*Power (Fail, Erdfelder, Lang & Buchner, 2009), a problem recently pointed out by Giner-Sorolla et al. (2020). This underestimated the sample size. Since we had increased the sample size anyway to anticipate the exclusion of cases due to technical problems, this mistake had no effect. The sample size ultimately met the requirement. The corrected estimate of the sample size with G*Power recommended a total sample size of 153 participants (repeated measurements within-between interaction (ANOVA): effect size $f = 0.252645$, $\alpha = 0.05$, output = 0.99, repeated measurements = 4, number of groups 3).
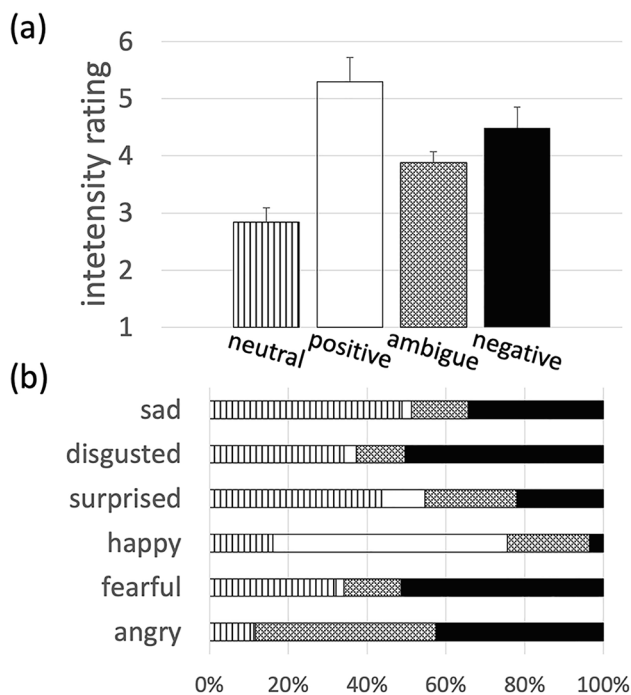
(a)

(b)

Fig. 2 **a** shows the mean intensity rating for each valence category. **b** shows the percentage of ratings for the six basic emotion categories. All error bars indicate CI95%

Task

Each session started with a process to familiarize the participant with the virtual environment. A few short strips of tape on the floor marked the cover of the KINECT® sensors. The first exercise was walking to alternate, highlighted squares in the IVE. The second step in training was to go from square to square again. However, an agent or object was added to the IVE for the participant to walk past. For the main study, participants were instructed to navigate their avatar by walking from start to finish in the real world and asked to walk past other people or objects they encounter. First, the participant entered the starting point, which was marked in the IVE by a blue square. If the starting point has been entered correctly, the square will glow light blue. The agent or object appeared at the same time and immediately began moving (not the objects). After a short delay, a beep sound indicated that the participants should walk past the agent / object to the endpoint. If the participant correctly reached the endpoint marked in pink, the square changed its brightness. "OK" was written at the top of the screen, followed by the instruction to return to the starting point. The end point was always in the middle (left–right) in the background of the IVE level. To avoid the avatar obstructing the participant's view of the agent / object, the starting point was either left or right. Each

agent or object was therefore approached once from the right and once from the left (see Fig. 1a). The test run consisted of 48 (exp 1: 10 neg, 8 new, 8 pos, 6 amb, 8 obj) / 50 (exp 2: 10 of each category) / 56 (exp 3: 14 of each category) trials. The sequence of trials was organized in blocks that included interactants from each category. The order of the blocks was randomized. The duration of the experimental part in each experiment was about 15 to 20 min. Finally, the participants completed the test battery. The total time for a session was approximately 90 min.

Test Battery

A test battery has been compiled to examine the influence of psychological factors on distance regulation. (1) The *Social Interaction Anxiety Scale* (SIAS; Mattick and Clarke (1998); German version by Stangier et al., 1999) is a self-assessment method for assessing anxiety states during social interactions. (2) The *Social Phobia Inventory* (SPIN; Connor, et al. (2000); German version by Sosic et al., 2008) is a self-assessment scale for evaluating the symptoms (fear, avoidance, physiological correlates) of phobias of social problems. (3) The *Stait-Trait-Anxiety-Inventory* (STAI; Spielberger et al. 1970) asks about characteristics and state anxiety (self-assessment). (4) The *Big Five Inventory* (BFI-K, Rammstedt & John, 2005) was added to assess aspects of personality. The BFI-K records agree with the big five personality factors theory by Costa and McCrae (1992). It deals with the dimensions of extraversion, openness to experience, agreeableness, conscientiousness, and neuroticism. (5) A modified version of the *Self-consciousness Scale* by Fenigstein et al. (1975) is the Questionnaire for the assessment of dispositional self-attention ("Fragebogen zur Erfassung dispositionaler Selbstaufmerksamkeit; SAM; Filipp and Freudenberg, 1989). This questionnaire is particularly interesting because aspects of private (feelings, attitudes, goals, body sensations) and public (appearance, social behavior, expected appraisal by others) are discriminated against. (6) The Emotion Regulation Scale (ERQ) by Gross and John (2003) measures emotion regulation in terms of suppression and reappraisal. This has become a highly valued approach in emotion regulation research. (7) The German attachment questionnaire (ABQ) by Grau (1999) contains two dimensions of attachment insecurity in close relationships fear and avoidance. It has been suggested that attachment behavior is related to social cognition and anxiety. (8) The imagination of how great a distance that is perceived as pleasant from another person should be can be recorded with the Comfortable Interpersonal Distance Scale (CID; Duke & Nowicki, 1972). In this paper and pencil test, subjects are asked to indicate the most comfortable distance between themselves (stick figure in the middle) and another figure within a circle. This process is repeated for different relationships (close

friend, boss, stranger, colleague, partner, parent, relative or sibling). (9) The Beck Depression Inventory (BDI) is a widely used self-report inventory that assesses characteristic attitudes and symptoms of depression (Beck et al., 1996; German Version by Hautzinger, Keller, & Kühner). Descriptions of the test results are shown in Table (2).

Data Preprocessing

A single tracking point (TP) was used for all calculations. In experiments 1 and 2 this was the *hip center*, in experiment 3, for technical reasons, the point was changed to the *spine base*, which is very close to the center of the hip.

The distances were calculated between the TPs of the avatar and the agent (Fig. 1b). While the agents moved a little, the centroid of the TP-trace marked the agent's position. The position was a fixed point for objects. The agent's body kinetics could interact with the emotional valence. In order to check the equivalence of movements under all emotional valence conditions, the variability of the agent movements was calculated by averaging all absolute differences between the centroid and all other positions of the agent. Univariate analysis of variance showed that there were no differences between the conditions ($F(3,26) = 0.80$, $p = 0.50$; mean/sd: neutral = 0.03/0.03, positive = 0.10/0.13, negative = 0.07/0.07, (ambiguous = 0.10/0.12), object = 0/0 was not included in the model).

All computations used the TP projection in x–y (2D). Artifacts caused by sensor errors or undesired behavior of the avatars (e.g. missing the finish point) have been corrected by depeaking and linear interpolation. Only 0.36 percent of all trials contained an artifact.

The simplest measure for the distance behavior (1) was the length of the route from start to finish (LoT) as a Euclidean distance (Fig. 1b). The basis for all other measures was a time series of differences that was calculated frame by frame from the start point to the end point as the Euclidean distance between the avatar and the agent (Fig. 1c). The resulting time series was used to compute a new time series by resampling for 1000 points to compensate for the different duration of each walk (Fig. 1c). This time series was used to (2) calculate the smallest distance (PoCA) between avatar and agent of each walk and its point in time ($PoCA_t$). (3) The time series belonging to the same valence of the interactant (positive, negative, neutral, object) were averaged for each subject (median). These averaged time series were divided into 10 blocks of equal length, each block representing 10% of the length of the trace. The arithmetic means for each block ($DIST_{block}$) were used for statistical analysis. (4) Differences *negative* minus *positive* trials were calculated for the average of blocks 3 and 4 ($DIST_D$), (5) and for LoT (LoT_D). All calculations were performed using Matlab (The MathWorks Inc., Natick, Massachusetts).

Table 2 Descriptives for the results of the test battery and age: The Beck Depression Inventory (BDI), German attachment questionnaire (ABQ), Comfortable Interpersonal Distance Scale (CID), Emotion Regulation Scale (ERQ), Questionnaire for the assessment of dispositional self-attention (SAM), Social Interaction Anxiety Scale (SIAS), Social Phobia Inventory (SPIN)—Anxiety and Avoidance, Big Five Inventory (BFI-K) with sub scales Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness, age

Descriptives of the Test Battery

	BDI	ABQ	CID	ERQ	SAM	SIAS	SPIN-Anx	SPIN-Avo	STAI-S	STAI-T	BFI-K-E	BFI-K-A	BFI-K-C	BFI-K-N	BFI-K-O	age
N	117	166	114	113	113	113	113	113	113	112	167	167	167	167	167	168
Missing	52	3	55	56	56	56	56	56	56	57	2	2	2	2	2	1
Mean	7.01	3.25	7.26	4.07	79.9	22.9	5.68	7.14	35.1	39.9	3.37	3.15	3.52	2.95	3.88	28.8
Median	6.00	3.25	6.75	4.10	80.0	20.0	5.00	6.00	32.0	37.5	3.50	3.25	3.50	3.00	4.00	26.7
Minimum	-0.30	1.35	1.13	1.60	28.0	1.00	0.00	0.00	21.0	22.0	1.50	1.25	1.50	1.00	1.00	18.0
Maximum	23.00	5.85	16.10	6.00	114	72.0	23.0	24.0	75.0	78.0	5.00	5.00	5.00	5.00	5.00	62.6
Skewness	0.78	-0.03	0.59	-0.25	-0.15	0.96	1.31	1.11	1.56	0.96	-0.20	-0.22	-0.34	82	-0.75	1.82
Std. error skewness	0.22	0.19	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.19	0.19	0.19	0.19	0.19	0.19
Kurtosis	-0.10	0.13	-0.23	-0.04	-0.20	1.39	2.75	1.65	3.22	0.76	-0.99	-0.46	-0.06	-0.48	0.28	3.13
Std. error kurtosis	0.44	0.37	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.37	0.37	0.37	0.37	0.37	0.37
Shapiro–Wilk W	0.93	0.99	0.96	0.99	0.98	0.95	0.91	0.93	0.88	0.93	0.96	0.98	0.97	0.98	0.94	0.80
Shapiro–Wilk p	<.001	0.274	0.002	0.696	0.281	<.001	<.001	<.001	<.001	<.001	<.001	0.009	0.003	0.027	<.001	<.001

Statistical Analysis

The effect of the emotion expressed by the agent (*valence*) was investigated using separate rmANOVAs for LoT, DIST$_{block}$, PoCA and PoCA$_t$. Within factors were *valence* (object, neutral, positive, negative). For DIST$_{block}$ analysis, the within factor *time* (blocks 1–10) has been added. In a second step, the (sub) test-scores of the psychological questionnaires (median split) were included as between factor to the model.

For the pairwise correlation with questionnaires, LoT$_D$ and DIST$_D$ were standardized for each experimental session in order to compensate for global differences. Due to the lack of normality tested with the Shapiro–Wilk-test in some of the questionnaire data (Table 2), Spearman's rho correlations were calculated.

Statistics were computed with Jamovi (The jamovi project (2020). jamovi (Version 1.2) [Computer Software]. Retrieved from https://www.jamovi.org) and Jasp (JASP Team (2020). JASP (Version 0.13.1)[Computer software]).

Results

Effects of the Emotional Valence of Agent Body Movements or Stationary Objects on Distance Behavior

Length of the Walking Trace (LoT)

The distance behavior was estimated by measuring the length of the route from start to finish (LoT) as a Euclidean distance. Because the agent or objects were blocking the direct path between the start and end points for the avatar, increasing the distance to the obstacle should result in longer traces.

The results of a repeated measurement ANOVA that included length of trace (LoT) clearly showed a main effect for *valence* (object, neutral, positive, negative; F(3,498) = 35.6, p < 0.001 η^2_p = 0.18, ω^2 = 0.07). The main factor *experiment* (F(2,166) = 41.57, p < 0.001, η^2_p = 0.33, ω^2 = 0.32) showed that LoT is different for each experiment. LoT was different between all three experiments (p$_{Holm}$ < 0.001), and increased from experiment 1 to experiment 3. No interaction effect *valence x experiment* was observed (F(6,498) = 1.13, p = 0.34, η^2_p = 0.01, ω^2 = 0.0). Holm post hoc tests for *valence* showed that all differences were significant at p$_{holm}$ < 0.001, with the exception of the difference between *neutral* and *positive*. As a result, the length of trace was shortest for *objects*, followed by *positive* and *neutral* valence condition and longest in the *negative* condition (Fig. 3).
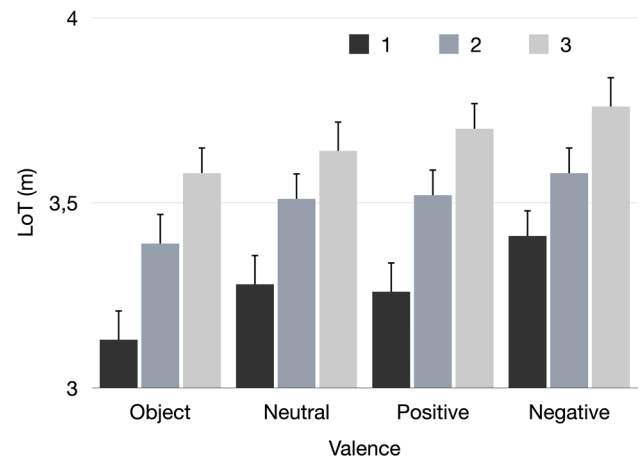

Fig. 3 Length of walking trace (LoT) averaged (3 valences) for trials with objects and agents. Mean values are displayed for each experiment (1 = black, 2 = dark gray, 3 = light gray). Error bars represent the CI95%

Point of Closest Approach (PoCA)

While LoT provided an overall measure of distance behavior, the point of closest approach provided information about the average shortest distance reached between avatar and agent/object during the walks.

In the rmANOVA including the factors *valence* and *experiment*, the interaction *experiment* x *valence* (F$_{Greenhouse-Geisser}$ (4.9,407.8) = 14.6, p < 0.001, η^2_p = 0.15, ω^2 = 0.03) showed that the PoCA-valence patterns were different between the three experiments. Analysis of the sub-designs for each experiment revealed that in Experiment 1 under condition *negative*, the PoCA was greater than under all other valence conditions and objects (which did not differ) ((F(3,153) = 16.3, p < 0.001, η^2_p = 0.24, ω^2 = 0.06; post hoc p$_{Holm}$ < 0.001). In Experiment 2 the PoCA for objects was lower than all other valence conditions ((F$_{Greenhouse-Geisser}$ (1.9,118.2) = 39.6, p < 0.001, η^2_p = 0.39, ω^2 = 0.10), and the PoCA for negative agents was greater than all other conditions (both post-hoc comparisons p$_{Holm}$ < 0.001). In contrast to this, in experiment 3 no valence effect was found in experiment 3 ((F$_{Greenhouse-Geisser}$ (1.8,94.5) = 1.3, p = 0.274, η^2_p = 0.02, ω^2 = 0.001). The results are shown in Fig. (4a).

Figure 4b shows the mean values for PoCA$_t$. The interaction *valence* x *experiment* ((F$_{Greenhouse-Geisser}$ (4.6,382.5) = 20.5, p < 0.001, η^2_p = 0.2, ω^2 = 0.04) indicated differences between the experiments that further were evaluated using separate rmANOVAs. In experiment 1 (*valence*: F (3,153) = 19.2, p < 0.001, η^2_p = 0.27, ω^2 = 0.11) objects were approximated later (p$_{Holm}$ < 0.001) than agents (all conditions). In experiment 2 (*valence*: F$_{Greenhouse-Geisser}$ (2.25,139.38) = 21.95, p < 0.001, η^2_p = 0.26, ω^2 = 0.08) objects and the *negative* agents were approached later (both p$_{Holm}$ < 0.001) than the agent of

positive and *neutral* conditions. In Experiment 3 (*valence*: $F_{Greenhouse-Geisser}$ (1.84,97.62) = 6.92, $p = 0.002$, $\eta^2_p = 0.12$, $\omega^2 = 0.02$), the PoCA was reached later in the *neutral* condition (p_{Holm} neutral -: object = 0.02, positive < 0.001, negative = 0.009) compared to the other three conditions.

Distance (DIST_block) between Avatar and Agent

The time series (positive, negative, neutral, object) belonging to the same valence condition were pooled as the median for each subject. These averaged time series were divided into 10 blocks of equal length, each block representing 10% of the length of the trace. While PoCA neglects timing information, it is preserved in the DISTblock measures and thus represents another aspect of distance control behavior. Only blocks 3, 4 and 5 were selected for the analysis, since the mean PoCA for the conditions was between 36.6% and 52.5% of the total distance (see Fig. 4b).

RmANOVA was computed. The main factors were *experiment* (1, 2, 3), *valence* (neutral, positive, negative; object was omitted here because the effects of emotional valence were to be investigated), and *block* (3, 4, 5) which represent 30–40, 40–50, and 50–60 percent of the total distance walked. With exception of the main factor *experiment* all within-subject effects showed an effect ($p < 0.001$, $0.42 \leq \eta^2_p \leq 0.86$, $0.05 \leq \omega^2$ 0.57). Because of the 3-way interactions in which *experiment* was involved, a separate analysis was computed for each experiment. The data are shown in Fig. 5a, the results are shown in Table 3. For experiment 1, the results show that in all three blocks the distance in the negative valence condition was greater than in both

other conditions, positive and neutral (all $p_{Holm} < 0.001$). In experiment 2, the results show that in blocks 3 and 4 the distance in the negative valence condition was greater than in the two other conditions (each $p_{Holm} < 0.001$). No valence effect could be seen in block 5. As in experiment 1, experiment 3 showed that in all three blocks the distance in the negative valence condition was greater than in positive and neutral conditions (block 3 and 4: $p_{Holm} < 0.001$; block 5: $p_{Holm: positive–negative} = 0.007$, $p_{Holm: neutral-negative} = 0.045$).

Analogously, DIST_block for objects was compared to that of the emotionally neutral condition (Fig. 5b). Experiment 1 showed that in block 3 and block 4 the distance to objects was greater than in the neutral condition (block 3 and 4: $p_{Holm} < 0.001$; block 5: $p_{Holm: object-neutral} = 0.21$). Experiment 2 showed that in all three block the distance to objects was greater than in the neutral condition (block 3: $p_{Holm} < 0.04$; block 4, and 5: $p_{Holm} < 0.001$). Experiment 3 showed that in all three blocks the distance to objects was greater than in the neutral condition (block 3: $p_{Holm} = 0.03$; block 4: $p_{Holm} = 0.02$, and 5: $p_{Holm} = 0.04$).

Effects of Psychological Factors of the Perceiver on Distance Behavior

Effects of Psychological Factors of the Perceiver on the Distance (DIST_block) between Avatar and Agent

The previous analysis of the effects of emotional valence on distance behavior showed no interactions for the negative

Fig. 4 Point of closest approach PoCA for each condition and experiment. The top line shows the PoCAs, the bottom line shows when PoCA occurred during the walk. Error bars represent the CI95%
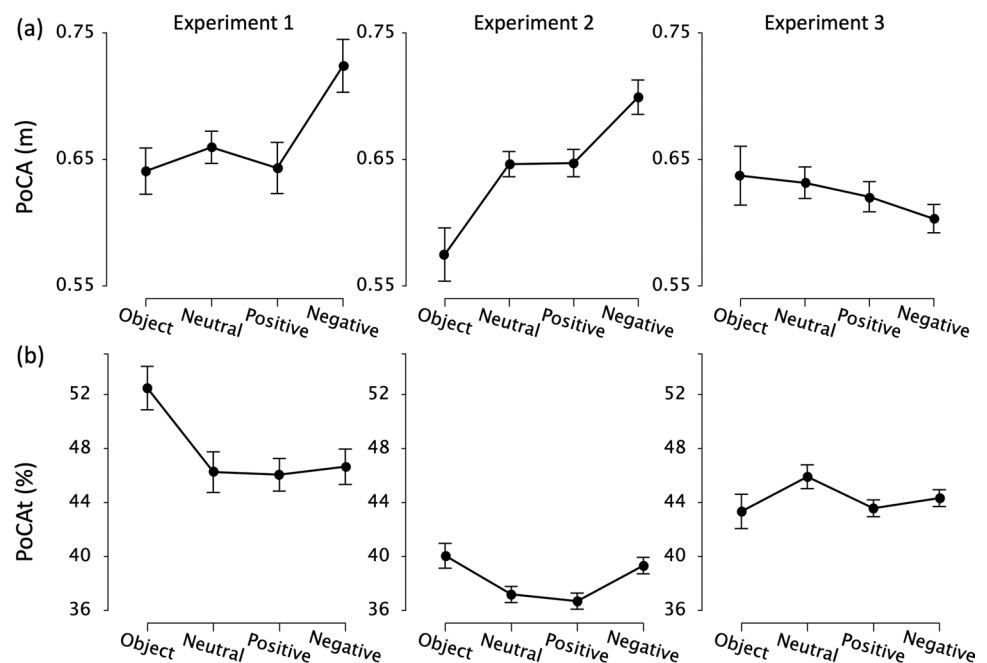
Table 3 Results of the repeated measurement ANOVAs for each experiment. Within-factors are *valence* and *block*. It can be seen that the p-values can easily survive a Bonferroni correction

	valence (neutral, positive, negative) block 3,4,5					valence (neutral, object) block 3,4,5				
Experiment 1										
source	Df_{corr}	F	p	η^2_p	ω^2	Df_{corr}	F	p	η^2_p	ω^2
valence	1.8,93.2	167.6	<.001	.77	.41	1,51	53.1	<.001	.51	.09
block	1.2,62.3	111.4	<.001	.69	.36	1.4,69.5	252.8	<.001	.83	.39
valence x block	1.5,75.6	22.37	<.001	.31	.08	1.2,59.7	137.7	<.001	.73	.09
Experiment 2										
valence	1.6,97.2	1035.1	<.001	.94	.69	1,62	47.3	<.001	.43	.11
block	1.2,75.9	367.0	<.001	.86	.61	1.3,80.8	92.6	<.001	.59	.26
valence x block	1.6,98.5	674.5	<.001	.92	.65	1.2,76.8	24.3	<.001	.28	.03
Experiment 3										
valence	1.4,73.3	262.1	<.001	.83	.58	1,53	11.1	.002	.17	.03
block	1.5,78.1	299.4	<.001	.85	.68	1.4,75.0	108.8	<.001	.67	.33
valence x block	1.3,70.6	192.9	<.001	.78	.53	1.3,69.1	.13	.79	.002	.00

df Greenhouse–Geisser corrected if required

and positive valence with blocks 3 and 4. Therefore blocks 3 and 4 were averaged ($DIST_{block30\%-40\%}$) and were used as dependent variable in mixed models. The Questionnaire data were dichotomized (*low, high*) using a median split method. The medians are shown in Table 2. Valence (positive, negative) and dichotomous scores (low, high) from the questionaries were introduced as fixed effects. Since there were only main effects of *experiment* (all p < 0.001) but no interaction effects, *experiment* was treated as a random factor. Gender and age (except for the ERQ; see Table 4) did not explain the variance significantly (all p > 0.3), and were therefore not included in the final model. For the model examining the ERQ, age was included as a covariate. Separate models were computed for each questionnaire.

Main Effects of Psychological Factors All tests showed a main effect of *valence* (p < 0.001), one analysis showed an main effect of CID (F(1,112) = 8.48, p = 0.004). CDI_{low} (estimated mean = 0.83, CI95%[0.80:0.86]) showed a smaller distance than CID_{high} (estimated mean = 0.89, CI95%[0.86:0.92]) (Fig. 6a).

Interaction Effects with Psychological Factors For the BDI and the ERQ, an interaction effect between *valence* x *psychological factors* was found. In the negative valence condition, there was a difference between high and low BDI and high and low ERQ. The BDI_{high} and the ERQ_{high} groups came closer to the negative stimulus figure than the

Fig. 5 Average distance for blocks 3 to 5. Top row: neutral (solid gray line), positive (dashed black line) and negative condition (solid black line). In the lower line, the neutral condition (solid gray line) is compared with the object condition (solid black line, empty markings). Error bars represent the CI95%
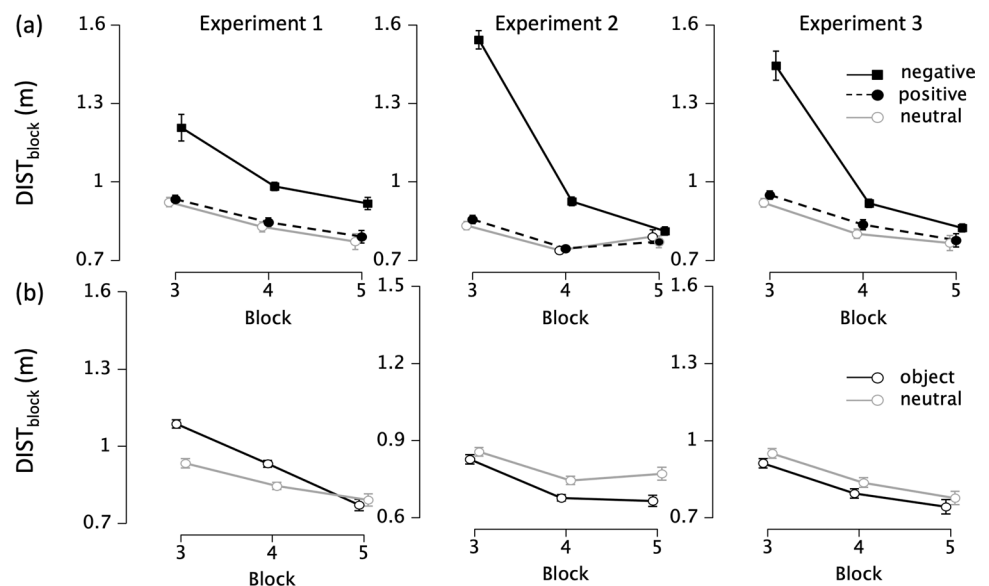
Table 4 Correlation matrix for the difference between the positive and negative valence condition for the average of blocks 3 and 4 ($DIST_D$), LoT_D and the psychological factors. The significance level of the p-values is indicated by asterisks

Correlation Matrix

	LoT_D	$DIST_D$	age	BDI	ABQ	CID	ERQ	SAM	SIAS Anx	SPIN Avo	SPIN	STAI-S	STAI-T	BFI-K-E	BFI-K-O	BFI-K-A	BFI-K-C
LoT_D																	
$DIST_D$	0.447***																
age	-0.033	-0.042															
BDI	-0.349***	-0.365***	0.006														
ABQ	-0.111	-0.129	-0.001	0.279**													
CID	0.103	-0.012	0.085	-0.124	0.305**												
ERQ	0.070	-0.165	0.232*	-0.016	0.005	0.077											
SAM	0.149	0.076	-0.033	-0.040	0.097	0.321***	-0.007										
SIAS	-0.248**	-0.165	-0.101	0.252*	0.527***	0.238*	-0.066	-0.007									
SPIN-Anx	-0.171	-0.082	-0.145	0.241	0.327***	0.051	-0.084	-0.130	0.711***								
SPIN-Avo	-0.191*	-0.096	-0.036	0.284*	0.416***	0.151	-0.109	-0.016	0.700***	0.765***							
STAI-S	-0.165	-0.130	-0.005	0.332**	0.439***	0.237*	-0.009	0.157	0.515***	0.368***	0.416***						
STAI-T	-0.251**	-0.138	-0.087	0.600***	0.462***	0.106	-0.312***	-0.019	0.622***	0.486***	0.553***	0.651***					
BFI-K-E	0.074	-0.050	-0.135	-0.202*	-0.226**	-0.101	0.160	-0.035	-0.265**	-0.143	-0.326***	-0.229*	-0.342***				
BFI-K-O	0.096	0.047	-0.020	-0.163	-0.012	0.052	0.264**	0.121	-0.110	-0.020	-0.063	-0.084	-0.183	-0.045			
BFI-K-A	-0.007	-0.023	-0.056	-0.317***	-0.312***	-0.182	-0.079	-0.019	-0.050	0.100	0.024	-0.166	-0.146	0.162*	-0.007		
BFI-K-C	0.184*	0.023	0.061	-0.256**	-0.066	0.069	0.200*	0.117	-0.062	-0.019	-0.097	-0.095	-0.241*	0.372***	-0.065	0.015	
BFI-K-N	-0.052	-0.006	-0.076	0.160	0.218**	0.070	-0.397***	0.080	0.344***	0.260**	0.237*	0.410***	0.482***	-0.237***	-0.012	-0.117	-0.085

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

respective low groups (BDI x *valence*: $F(1,61) = 12.69$, $p < 0.001$, estimate $= 0.035$, CI95%[0.02:0.06]; ERQ x *valence*: $F(1,111) = 5.9$, $p = 0.016$, estimate $= -0.033$, CI95%[-0.06:0.006]; covariate age $F(1,110), = 3.8$, $p = 0.05$) (Figs. 6b and c).

The only questionnaire that showed no correlation with the BDI was the SAM. Therefore, both questionnaires were added to the linear model as fixed effects. For the averaged blocks 3 and 4 the two-way interaction BDI(low, high) x SAM_private (low, high) ($F(1,118) = 9.4$, $p = 0.003$, $\eta^2_p \leq 0.07$, $0.07 \leq \omega^2 0.06$) showed that subjects with higher BDI scores together with higher private self-attention showed a smaller distance to the agent of positive and negative valnece than the other factor combinations (Fig. 6d). All other questionnaires showed neither a main effect nor an interaction with the valence.

Correlation of the Differences LoT_D and $DIST_D$ between Emotionally Negative and Positive Expression of the Agent with Psychological Factors of the Perceiver

As a final hypothesis of this study, it was tested whether the extent of the difference in distance between emotionally negative and positive expression of the agents is modulated by psychological factors of the perceiver.

The difference between the positive and negative valence condition for the average of blocks 3 and 4, $DIST_D$ and LoT_D was chosen to correlate with the psychological factors. The correlation matrix is shown in Table 4.

Only one correlation with BDI was found for $DIST_D$. The negative sign indicates that higher levels of depression were associated with a smaller difference between negative and positive trials. For LoT_D, a correlation was also found with BDI but also with the personality factor conscientiousness, higher fearfulness in social interaction, social phobia related avoidance, and trait anxiety. With the exception of conscientiousness (higher conscientiousness – larger LoT_D), all correlations were signed negatively. Higher levels of depression, fearfulness in social interaction, social phobia related avoidance, and trait anxiety were associated with a lower LoT_D.

Discussion

The role of body kinetics in regulating interpersonal distance has been neglected in previous research. In real life, facial expressions are often imperceptible when approaching another person because there is insufficient light, clothing hides a face, or because the distance is too great. However, it appears that individuals are able to control their interpersonal distance using information other than face.
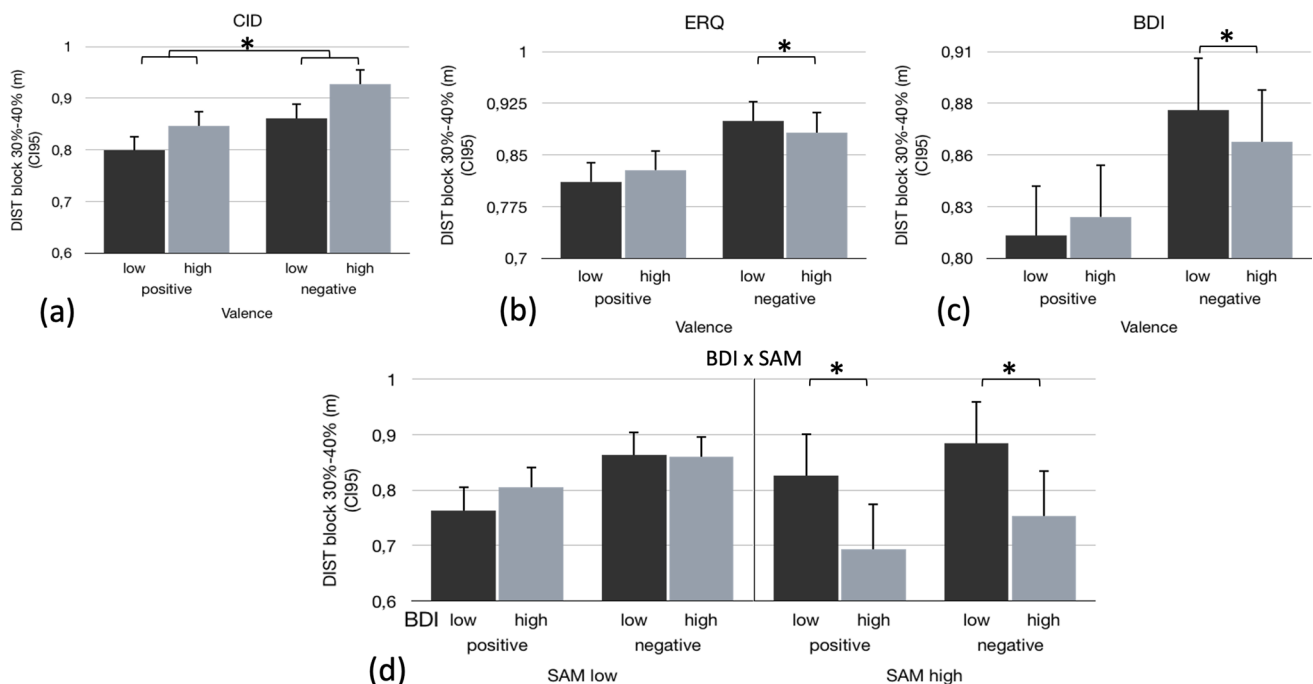

Fig. 6 Results for the analysis of the interaction between valence and psychological factors. Test result groups were generated by median split (low: high). The results are shown for (**a**) the CID, (**b**) the ERQ and (**c**) the BDI. (**d**) shows the 3-way interaction *valence* x BDI x SAM. Error bars represent the CI95%. Asterisks indicate significant differences

In recent studies, we have focused on examining the influence of body kinetics on emotion perception in healthy volunteers and people with psychiatric illnesses (Kaletsch, Krüger, et al., 2014; Kaletsch, Pilgramm, et al., 2014; Krüger et al., 2018). It could be shown that, similar to facial expressions, the body kinetics are sufficient to assess the emotional status of a subject. This inspired us to use an immersive virtual environment to study the effects of emotional valence based solely on affective information related to body movements on interpersonal distance behavior. To the best of our knowledge, this is the first study that deals with pure body kinetics and distance regulation. So far, research on interpersonal distance has mainly been based on surveys to assess people's subjective impression of their expected behavior, behavioral analyzes based mainly on experimental approaches (e.g. stopping paradigm), video recordings of behavior in the field or in the laboratory or in virtual environments where attempts are made to implement scenes as realistically as possible. In the current study, the opposite was the case here. The idea was to create a very simple space for social interaction. The body kinetics of the interactants, an avatar and a virtual agent, were displayed in the form of point light displays, which were supplemented to become stick figures. All actions could be compared on the same scale. The technique was kept as simple as possible. Kinect, a commercially available, mass-produced product, was selected because it allows programming through an open, documented interface and is very cheap.

A second part of the study consisted of examining the role of the participant's psychological factors in remote regulatory behavior. As explained in the introductory part, the results of numerous studies suggest that interpersonal distance depends on the characteristics of the subjects, including social anxiety, attachment, self-attention and others. So far, however, there has been a lack of systematic studies that relate these perceptual features to specific body kinetics.

Effects of Perceived Body Kinetics of an Moving Agent in an IVE on the Regulation of Distance

The results of the main study showed impressively an influence of the perceived emotional value of the agent on the interpersonal distance behavior. When subjects perceived a figure as an expression of negative emotions through body movements, they did not pass this figure as closely as figures that express neutral or positive body movements. If an agent was perceived as neutral, the distances were comparable to those of positive agents. Regarding the effects, this result was the same for practically all distance measures and all three experiments used. Only in Experiment 3 was the point of closest approach (PoCA) the same for all valence conditions. Since this

missing replication only affected PocA, it can be assumed that this measure probably has a different validity structure, for example by showing a greater susceptibility to parameters of the "Vision to Action" in addition to the aspect of distance control. In the third experiment, the camera perspective was changed slightly, which may have affected navigation. This is significant because the distance estimation of egocentric vision in IVE/VR is modulated by parameters such as gaze, angle of view, camera position, etc. and has been shown to affect at least the absolute distance estimation as a bias (Feldstein et al., 2020). It seems logical that in this study this would likely affect a point distance measure like PocA more than means like DIST. However, what are the most appropriate and valid measures of distance behavior in an IVE could be a topic for further study.

The length of the walk increased from Trial 1 to Trial 3 because we wanted to allow for more variability. However, this has neither modulated nor influenced the distance control.

Adjusting the Distance when Passing a Stationary Object in an IVE

Adding objects was entirely new in the context of social distance control experiments. In terms of distance, objects were passed closer than agents on average. At first glance, one would say that this could be due to stationary objects and moving agents, if there weren't two exceptions. In test 1 with only one column object, the distance was greater than in the neutral or in the positive experimental condition. In the other two experiments, several different types of objects were used. So, this question must remain unsolved.

Regarding the time course of the walk for objects the lowest distance was reached later (Exp 1 and 2) than with interactants, but this could not be replicated in experiment 3. The explanation could be the same as above given for on PocA for agents.

Effects of the Perceiver's Psychological Characteristics on the Regulation of Distance in an IVE

Almost all studies in the literature dealt with various psychological traits of the perceiver of social distancing behavior. Emotion regulation (Evans & Wener, 2007), attachment (Kaitz et al., 2004) or social anxiety (Wieser et al., 2010; Geraets et al., 2018) have been linked to the regulation of interpersonal distance. In contrast to other studies, the evaluation of depressive symptoms was included in the study because of their similarity or overlap with many of the other factors already mentioned. Two approaches to analysis were used. One focused on the absolute distance to the interactant, the other examined the difference between the positive and negative valence of the agents, regardless of how close the distance to the active

substance was overall. For the latter, of all the psychological variables used in this study, the number of depressive symptoms best explained the variance for the difference between positive and negative valence conditions for both the length of the trace and the distance after 30 to 50 percent of the walking distance. While depression was the only psychological factor that correlated with the difference distance measure, several other psychological variables correlated with the length of the trace difference measure. A higher number of symptoms of depression, higher fearfulness in social interaction, a higher level of avoidance related to social phobia, and a higher level of trait anxiety indicated that psychological factors associated with anxiety and avoidance, as well as less conscientiousness, resulted in smaller distance differences.

For the average distance after 30 to 50 percent of the walking distance, a main effect of emotion regulation (ERQ) and depression (BDI) was found. For both psychological factors, the distance to agents who express negative emotions was lower with higher emotion regulation (suppression, reassessment) and a higher number of depressive symptoms. This is interesting because ERQ and BDI did not correlate. Shorter distances with a higher number of depression symptoms could also be found in people with higher self-attention. The concept of self-attention includes private and public self-attention. Heightened depression could be absorbed by thinking about yourself, causing less attention to the surroundings. The self-attention measure (SAM) correlated only with the CID, and in the current experiment, the CID was actually linked to the overt behavior of regulating social distance. Participants who indicated that comfort required greater distance generally kept greater distance, and vice versa. The CID is a standard tool for proxemics (also using stick figure drawing), but such a clear relationship to open behavior was not expected.

The results of the current study did not support the influence of personality factors as found in some older studies, as mentioned in the introduction. Neither introversion, nor extraversion, or neuroticism seem to play a role in distance regulation. Only conscientiousness had an impact, possibly in terms of how a participant performed the task. However, the lack of social information due to the blocked facial perception may have reduced the influence of personality factors. A direct comparison was not the aim of this study. However, inter-test correlations showed correlations of personality traits with STAI-trait-anxiety, SIAS social-interaction-anxiety, emotion regulation (ERQ), and social-phobia- avoidance (SPIN) so that, for example, neuroticism has partly contributed to the distance behavior. The same can apply to attachment behavior or other psychological variables, since many of these variables share at least a small proportion of variance. This is inevitable because the underlying concepts of the tests used overlap and their validity is rather not tied to a narrow criterion.

Limitations

Using the full spectrum of a clinical symptom scale is always a problem in studies with healthy volunteers. Furthermore, it cannot be ruled out that the laboratory situation and the associated reactance phenomena may attenuate or modulate the influence of psychological factors on the actual experimental situation.

Other restrictions apply to the technical implementation of the virtual environment. The cover of the sensor used restricted freedom of movement considerably. The subjects had to be careful not to leave the marked area. While this has turned out to be practically no problem, we are working to expand the area covered by the sensor configuration. As always in virtual environments and when recording movements in real time, there is a delay between real and displayed movements. For this study, the delay was about 100 ms. Temporal delays in human performance have been studied in manual tracking tasks or when using control systems coupled to body parts or in driving simulations. It has been shown that a tolerable delay depends crucially on the type of task. Shorter delays (70 ms) were required for pointing tasks than, for example, for driving simulators (170 ms). However, none of the subjects asked for shorter delays, and none of the subjects reported a feeling of motion sickness, as sometimes reported with unreasonable delays in solving tasks in virtual environments.

Conclusion

The immersive virtual environment used in this study was found to be suitable for investigating at least simple types of social behavior. It turned out that hiding realistic characteristics of humans and the environment, with the exception of body kinetics, provided enough information about the affective status of a potential interaction partner to initiate the behavior of regulating interpersonal distance. The result supports the common opinion about the function of interpersonal distance behavior. The interpersonal space protects the individual from possible or acute threats (Evans & Howard, 1973). Body movements of others that are perceived as threatening lead to a person keeping their distance. If the body movements were not potentially threatening, as was the case with emotionally positive and neutrally perceived characters, a closer distance was maintained. The passing of stationary objects showed, at least in part, that this obeys other rules that are not considered here and will be the subject of further investigations. It was found that psychological factors of the perceiver that modulate distance behavior are mainly related to the regulation of anxious, depressive emotions and avoidance behavior. However, this also shows that it is not the Big Five personality factors (openness, conscientiousness,

extraversion, agreeableness, neuroticism) that are associated with social distance regulation in the perception of body kinetics, but rather clinically relevant factors. This opens the approach of this study for further clinical research and applications in the field of emotion regulation or the regulation of impulsive behavior in e.g., borderline personality disorder, attention deficit hyperactivity disorder or alcoholism.

Data Availability The datasets generated during and/or analyzed during the current study are not publicly available due to the lack of consent from the participants but are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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