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Psychopathy and the Regulation of Interpersonal Distance

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Abstract

Psychopathic traits are often associated with interpersonal and affective deficits. This study examined the impact of psychopathy on judgments of comfortable egocentric interpersonal distance (Experiment 1) and exocentric interpersonal distance (Experiment 2). We selected a student sample and measured psychopathy via self-report. To study spatial behavior under highly controlled conditions, these participants were immersed in a virtual environment. In Experiment 1, they approached a virtual person with angry or happy facial expression until a comfortable distance for conversation was reached. In Experiment 2, participants adjusted a comfortable distance between two avatars. Our results suggest that psychopathy alters the regulation of interpersonal distance with respect to facial expression of the approached as well as between avatars of mixed sex.

Keywords

interpersonal distance, psychopathy, emotion, virtual reality, stop-distance task

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Personal space can be defined as a more or less concentric area around a person, into which intrusion causes arousal or discomfort (Hayduk, 1978). Preferred interpersonal distance (IPD) is the distance a person keeps from another to prevent intrusion of her or his personal space. Aside from obvious situational factors (e.g., the context of a crowded bus vs. an open field), personal space is strongly influenced by social cues (Ruggiero et al., 2017), social norms, and values (Iachini, Pagliaro, & Ruggiero, 2015; Leibman, 1970). Consequently, personality traits or disorders that change the perception or evaluation of such norms should also affect personal space regulation. We explored the effect of psychopathy in this context. It is characterized by persistent deviant social behavior and interpersonal-emotional deficiencies (see, e.g., Hare, 2006). Not only do psychopaths tend to exploit others, they may also cause harm by undermining social norms. Recent discussions regarding psychopathy give rise to a conceptualization of psychopathy that does not limit the concept to clinical populations but includes subclinical and "successful" psychopaths (Patrick & Drislane, 2015). Thus, psychopathy is not limited to forensic samples, but can be studied in community samples as well (Boll & Gamer, 2016; Edens, Marcus, Lilienfeld, & Poythress, 2006; Guay, Ruscio, Knight, & Hare, 2007; López, Poy, Patrick, & Moltó, 2013; Patrick, Edens, Poythress, Lilienfeld, & Benning, 2006).

Even though some publications state that psychopathic individuals are prone to invade others' personal space (Quayle, 2008; Rimé, Bouvy, Leborgne, & Rouillon, 1978), we could find merely one experimental study that has investigated this relationship: Vieira and Marsh (2014) investigated the effect of psychopathic traits on IPD in a student sample by means of a stop-distance paradigm. Participants were instructed to approach another person and stop when a comfortable IPD had been reached. Those who scored high on the Coldheartedness scale (psychopathic lack of empathy) of the Psychopathic Personality Inventory–Revised (PPI-R; Lilienfeld & Widows, 2005) maintained a lower overall IPD compared with participants who scored low on this subscale. However, it remains unclear why psychopathic individuals might prefer shorter IPDs. Do they have a fundamentally different understanding of appropriate

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IPD? Or do they not react appropriately to nonverbal social cues?

In everyday life, nonverbal cues such as facial expression play an important role when it comes to the distance we keep from others. In this context, reacting appropriately to facial expression is hypothesized to be fundamental for social interaction and survival (Darwin, 1956). Social threat communicated by angry faces elicits fear and arousal and is processed in a preferred manner (Alpers, Adolph, & Pauli, 2011; Schupp, Junghöfer, Weike, & Hamm, 2004). Moreover, expressions of anger promote faster avoidance than approach reactions (Marsh, Ambady, & Kleck, 2005). Ruggiero et al. (2017) have tested spatial behavior in a virtual reality (VR) setting while varying the facial expression of virtual persons (avatars). Participants kept a larger distance toward socially threatening avatars with an angry facial expression as compared with avatars with a happy or neutral facial expression. In general, reaction to and recognition of threat is impaired in psychopathic individuals (Fowles, 1980; Hastings, Tangney, & Stuewig, 2008; von Borries et al., 2012). Thus, we hypothesized that psychopathic individuals should keep closer distances or fail to regulate their IPD as a function of emotional expression.

Measuring IPD in VR

The influential review of determinants of personal space compiled by Hayduk (1983) paints a heterogeneous picture, probably because the stimulus has rarely been controlled within experiments that have employed real human beings. Advances in VR technology now offer the chance 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).

In an innovative experiment by Bailenson, Blascovich, Beall, and Loomis (2003), participants had to move through a virtual space to report a letter on an avatar's shirt while the minimum IPD was recorded without the participant's awareness. According to the authors, this method offers an unobtrusive and highly naturalistic measure of personal space in a controlled environment. However, it is very time-consuming, as participants were allowed to walk freely through the room. Moreover, this indirect measure of preferred IPD is affected by the size of the target, the choice of font, and resolution limits of the display monitors of the head-mounted display. Therefore, this minimum distance may not correspond to the edges of personal space.

The stop-distance paradigm, which is widely used for other purposes in VR settings, could circumvent some of the above mentioned limitations. For example, Iachini, Pagliaro, et al. (2015) manipulated perceived morality of an avatar by pairing it with moral, neutral, or amoral descriptions. Participants produced largest IPDs in trials with amoral descriptions, intermediate distances for neutral descriptions, and closest distances when moral descriptions were given. Furthermore, sex, age (Iachini et al., 2016), personality (Iachini, Ruggiero, Ruotolo, Schiano di Cola, & Senese, 2015), and facial expression (Ruggiero et al., 2017) affected preferred IPD in VR.

Aims of the Present Study

In two experiments, we sought to conceptually replicate and extend the findings of Vieira and Marsh (2014), namely that Coldheartedness is related to shorter IPD, and to examine why psychopathic individuals violate personal space requirements (Rimé et al., 1978). Is interpersonal spatial behavior in relation to display of emotion altered in psychopathic individuals? In Experiment 1, participants adjusted the distance to an avatar by walking toward the avatar until comfortable conversation was deemed possible. Psychopathic traits, such as Coldheartedness, should be associated with a smaller IPD between participant and avatar (Vieira & Marsh, 2014). Equilibrium theory suggests that personal space size is regulated by approach and avoidance forces until a social equilibrium is reached (Bailenson, Blascovich, Beall, & Loomis, 2001). Approach reactions are fostered by happy facial expressions and avoidance reactions are most reliably elicited by angry facial expressions (see Phaf, Mohr, Rotteveel, & Wicherts, 2014). Thus, in line with equilibrium theory, we manipulated the avatars' facial expression to either show a happy or an angry facial expression to foster such reactions. Note that when contrasting happy and angry facial expressions with other expressions, such as sad or fearful expressions that share similar evaluative connotations, the latter can trigger both approach and avoidance-related behavior depending on the contrast (Paulus & Wentura, 2016). Thus, although psychopathy is related to deficits in recognition of other facial expressions such as fear (Marsh & Blair, 2008) or sadness (for a meta-analysis, see Dawel, O'Kearney, McKone, & Palermo, 2012; e.g., Hastings et al., 2008), we have chosen to contrast only angry with happy facial expressions.

We expected to replicate the findings of Ruggiero et al. (2017) in normal participants, that is, shorter distances in response to happy avatars compared with angry avatars. This regulatory process may be altered in psychopathic individuals who lack the proper avoidance reaction to social threat (von Borries et al., 2012). Following this consideration, psychopathy should be related to diminished spatial reactions toward facial expression.

Does psychopathy also impact the understanding of the concept of personal space in others? In Experiment 2, participants adjusted the IPD between two avatars to a distance that should be appropriate for these avatars (exocentric IPD). Thus, they adjusted a comfortable IPD without direct personal involvement in the particular social situation. In light of psychopathic traits being linked to decreased empathy (Almeida et al., 2015; Soderstrom, 2003) and social norm violations (Hare, 2006), we hypothesized that psychopathic individuals adjust shorter preferred exocentric IPDs in comparison to less psychopathic individuals. All participants completed both experiments in a single session of 75 to 90 min. Half of the participants started with Experiment 1 and the other half with Experiment 2.

Experiment 1: Regulating IPD as a Function of Facial Expression

The first experiment was designed to study the regulation of IPD. Participants had to approach an avatar and stop when their preferred IPD for conversation with a stranger was reached. We additionally varied the facial expression (happy vs. angry) of the avatar to test spatial behavior in threatening and nonthreatening social encounters.

Method

Participants. Forty volunteers (25 female, 15 male), primarily White, ages 18 to 40 years (M = 23.80, SD = 4.92), took part in the experiments in return for partial course credit. Participants were recruited via advertisements on the campus of the University of Mainz and associated online communities. In accordance with the Declaration of Helsinki, participants gave written informed consent and were debriefed after the experiments. All participants had normal or corrected to normal vision. Visual acuity was tested using the Freiburg Visual Acuity Test (Bach, 1996). Visual acuity of all participants was 1.00 (Snellen fraction 6/6) or better. Stereoscopic acuity was tested using a digital version of the Titmus Test (Bennett & Rabbetts, 1998) with stereoscopic disparities of 800, 400, 200, 140, 100, 80, 60, 50, and 40 seconds of arc. The criterion for participation was that at least six of the nine trials had been answered correctly.

PPI-R-40. Ever since the very first clinical description of a psychopath by Cleckley (1941), the greatest advancement in the assessment of psychopathy has been made by the introduction of the psychopathy checklist developed for offenders by Hare (1980). This diagnostic instrument, which is based on interview and record analysis in offenders, has structured the field and allowed research on psychopathy to prosper. However, taxometric analysis indicates a dimensional structure of psychopathy, thus it can be studied in community samples as well (Edens et al., 2006; Guay et al., 2007). For example, Boll and Gamer (2016) have applied the PPI-R to assess psychopathic traits in a community sample. They studied the facial exploration in pictures of angry, neutral, and happy faces and found self-reported psychopathy to be related to a reduction in facial exploration and a reduced bias to shift one's gaze toward the eye region, irrespective of the facial expression.

We used the short version of the PPI-R, the PPI-R-40 (Eisenbarth, Lilienfeld, & Yarkoni, 2015), to measure psychopathy. It has shown to be a reliable and valid measure with sufficient psychometric properties in both student and forensic samples (Ruchensky, Edens, Donnellan, & Witt, 2017). Moreover, in a forensic sample, it showed convergent validity with Hare's Psychopathy Checklist–Revised.

The PPI-R-40 can be merged into two higher-order factors, Self-Centered Impulsivity and Fearless Dominance. The Coldheartedness subscale does not load on any of these higher-order factors. It represents low empathy and not caring about the feelings of others. Although often neglected, Coldheartedness is of special importance as it may reflect some core deficiencies of psychopathy (Berg, Hecht, Latzman, & Lilienfeld, 2015). Fearless dominance covers emotional and interpersonal deficiencies of psychopaths (low arousal, low fear, high dominance) but is also related to charming and deceiving behavior. Self-centered impulsivity covers deviant antisocial personality traits associated with psychopathy (Patrick, Fowles, & Krueger, 2009).

Apparatus and stimuli. Participants saw stereoscopic full-scale simulations on a large rear-projection screen (2.60 m wide × 1.95 m high). The 3D projector (projectiondesign F10 AS3D) had a color resolution of 8 bits per channel, a display resolution of 1,400 × 1,050 (horizontal × vertical) pixels, and a refresh rate of 120 Hz. Participants wore LCD shutter glasses (XPAND X102) synchronized via an infrared emitter, such that each eye received 60 pictures per second. Participants' individual interpupillary distance was taken into account when computing the stereoscopic disparity of the VR environment. Measured from a distance of 2.35 m from the screen, the physical field of view (FOV) was 58° horizontally and 45° vertically. The virtual FOV corresponded to the geometric FOV. The VR environment resembled the surrounding laboratory (see Fig. 1, left). The participants' movement was tracked with a sampling frequency 30 Hz using an infrared sensor (Microsoft Kinect), and the projection was rendered according to the observer's position. The reference for this position was the participant's spine.

Stimuli were presented using the VR software Vizard 5 (Worldviz, 2016). Avatars were designed in MakeHuman 1.1.0 Nightly Build (MakeHuman Team, 2016), and facial

Fig. 1. Left: Apparatus used in Experiment 1 with rear projection screen displaying the avatar, platforms, and Microsoft Kinect motion tracker. Right: Setup of Experiment 2 with rear-projection screen showing the avatars, platforms, and desk in front of the subject.

expression was modulated to resemble Ekman pictures (Ekman & Friesen, 1977) in 3ds Max (Autodesk, San Rafael, CA). Four different (two female, two male) White avatars were used to present a variety of social stimuli to match participant ethnicity with the avatars. Each of these four avatars was presented with both happy and angry facial expression. All avatars wore a gray shirt and black pants. The virtual position of the avatars was 15 cm behind the projection screen throughout all trials. As body height can influence IPD (Caplan & Goldman, 1981), body height of participant and avatar were matched in all experiments by scaling the avatar. To control for effects of gaze direction (Argyle & Dean, 1965; Bailenson et al., 2001), the avatar's eyes were dynamically adjusted so that they looked directly onto the observer's bridge of the nose. The participant was positioned in front of the avatar, facing it directly. Both the avatar and the participant were standing on platforms. We used two starting positions, one at 2.20 m and the other at 2.50 m from the avatar, to prevent perfectly predictable and repetitive walking strategies. Note that both starting distances were well beyond IPD typically found in stop-distance tasks (Hayduk, 1983). Participants were told to align their body center with the respective starting position. IPD was calculated as the distance between the participant's and the avatar's spine with a precision of 1 cm.

After the experiments, all stimuli were rated on a 9-point version of the SAM (Self-Assessment Manikin) scales (Bradley & Lang, 1994) and on a 10-point scale for attractiveness, ranging from 1 (*not attractive*) to 10 (*very attractive*). The manipulation of emotional valence was successful, as indicated by a significant difference of mean valence ratings of facial expression, $t(39) = 10.47$, $p < .001$, Cohen's (1988) $d_z = 1.65$. Happy avatars created a more positively valenced emotion ($M = 3.18$, $SD = 0.82$) than did angry avatars ($M = 5.96$, $SD = 1.46$). Mean attractiveness ratings of avatars were not significantly related with IPD ($-.06 < r < .26$). Overall realism of the avatars was judged as good to medium ($M = 2.73$, $SD = 0.75$), as rated on a 5-point scale, ranging from 1 (*very good*) to 5 (*bad*).

Design and procedure. We varied three experimental factors within participants: avatar (two male, two female), emotional expression (happy, angry), and starting position (2.20 m, 2.50 m). Each factor combination was presented three times, resulting in 48 trials. Trials were presented in random orders. Before the experiment, every participant completed eight training trials with all avatars showing neutral facial expressions, one for each starting position and avatar. The participants were told to walk toward the avatar until a comfortable distance for conversation had been reached for a situation where the participant would have to ask a stranger for directions. After each trial, a black screen appeared and the participant went back to the next starting position. No time limit was given. Participants were instructed in both written and verbal forms.

Data analysis. Data were analyzed on the basis of the outlier-corrected individual distances for each combination of the experimental factors of starting distance and facial expression of avatar. Outliers were corrected in two steps. First, distances exceeding the initial distances of 2.20 m or 2.50 m (0.3%; 5 of 1,920) were classified as outliers and discarded. These outliers can be attributed to glitches of the thermal camera of the Microsoft Kinect.

Second, using the Tukey criterion, trials with distances more than 1.5 times the interquartile range, lower than the first or higher than the third quartile for each factor level combination, were classified as outliers. This affected 4.6% (88 of 1,915) of the cases. Furthermore, in the questionnaires, 2 out of 1,600 (< 0.01%) responses were missing for two participants. They were replaced with the individually predicted value based on the participant's responses in the respective higher-order factor. Cronbach's alpha was high for the sum score of the PPI-R-40 (α = .80) and the Fearless Dominance subscale (α = .72), but relatively low for the Self-Centered Impulsivity (α = .58) and Coldheartedness (α = .67) subscales. Note, however, that these scales were abbreviated using a genetic algorithm that aimed at decreasing redundancy, thus decreasing correlation between items (for details, see Eisenbarth et al., 2015).

The alpha level was 5% in all analyses. We analyzed effects of the experimental manipulations on the IPD with a linear mixed model (LMM) using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in R (R Development Core Team, 2010) on the basis of individual trials (Baayen, Davidson, & Bates, 2008). Model selection prior to analysis was based on likelihood ratio tests comparing the fit (maximum likelihood) of the concurrent models. To estimate significance of fixed effects, models were refitted on the basis of restricted maximum likelihood estimates and degrees of freedom were approximated using the Kenward-Roger method for Wald *t* test and *F* test type III. This procedure may be preferable in small sample sizes (Luke, 2017). Estimates of R^2 are based on the MuMIn package by Barton (2013).

Results and discussion

To visualize the absolute effect of psychopathy on IPD in the empirical data, we plotted psychopathy (as the sum score of the PPI-R-40) against mean IPD aggregated over all experimental manipulations for every participant (see Fig. 2a), $r(38) = -.12$, $p = .46$. Furthermore, we calculated the difference between the mean IPD for happy-looking avatars and the mean IPD for angry-looking avatars, averaged across the levels of sex of avatar and starting position. This difference was plotted against psychopathy for every participant to visualize the potential Facial Expression × Psychopathy interaction in the sample (see Fig. 2b, middle), $r(38) = -.32$, $p = .04$.

In the LMM, we estimated a random intercept for every participant and avatar to account for the repeated-measures structure of the experiment. We also added random slopes for every participant regarding the sex of the avatar to control for individual sex effects (Uzzell & Horne, 2006). All fixed factors were fully crossed in every step of the modeling process. Subsequently, we added the fixed factors in three steps and tested the increase of the goodness of fit using likelihood-ratio tests, comparing the model fit to the previous step: In Step 1, we added facial expression of avatar, $\chi^2(3) = 180.15$, $p < .001$; in Step 2, we added the PPI-R-40 score (measuring psychopathy), $\chi^2(2) = 21.26$, $p < .001$; and,

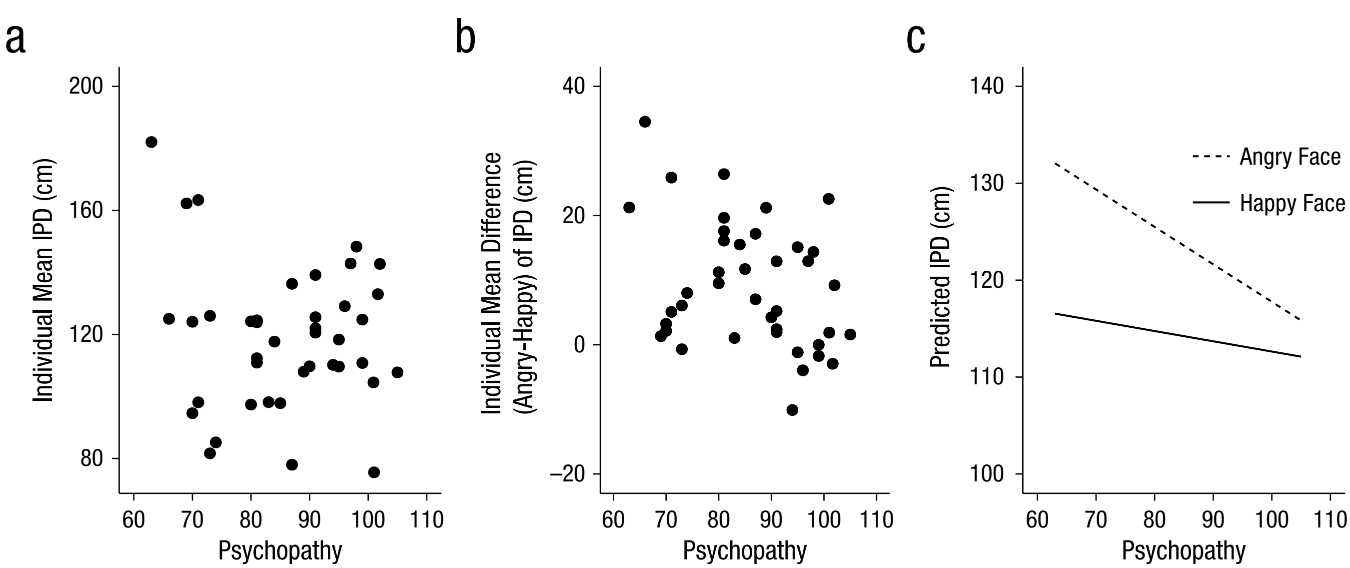

Fig. 2. (a) Mean egocentric interpersonal distance (IPD) in centimeters as a function of psychopathy score (sum score of PPI-R-40). (b) Mean difference in egocentric interpersonal distance, happy subtracted from angry as a function of psychopathy. (c) Predicted IPD as a function of psychopathy and facial expression of the avatar from the linear mixed regression model.

Table 1. Coefficients of the Linear Mixed Regression Analysis for Egocentric IPD as a Function of Facial Expression and Psychopathy Subscales of the Psychopathic Personality Inventory–Revised–40

	Egocentric preferred interpersonal distance	
Variable	*b* (*SE*)	β (*SE*)
Intercept	131.52*** (30.04)	
Facial expression	32.14*** (5.53)	0.58 (0.10)
Coldheartedness	1.24 (1.75)	0.11 (0.16)
Facial Expression × Coldheartedness	–1.36*** (0.32)	0.25 (0.06)
Self-centered impulsivity	–0.62 (0.74)	–0.12 (0.14)
Facial Expression × Self-Centered impulsivity	–0.39** (0.14)	–0.26 (0.09)
Fearless dominance	–0.19 (0.70)	–0.04 (0.16)
Facial Expression × Fearless Dominance	0.10 (0.13)	–0.07 (0.09)

Note: Facial expression: 0 = *happy*, 1 = *angry*.
**$p < .01$. ***$p < .001$ for Wald *t*.

in Step 3, we added sex of avatar and sex of participant to the model, $\chi^2(11) = 8.83$, $p = .63$. The model fit did not significantly increase from Step 2 to Step 3.

Only the random intercept structure and the fixed effects of the model from Step 2 are reported. In total, this model explained $R^2 = 72.00\%$ of the variance in the empirical data. The intercept of the model was $b = 123.21$ cm, $SE = 28.53$ cm. Variance of random effects based on participants, $\chi^2(2) = 29.07$, $p = .010$ and stimuli, $\chi^2(1) = 6.56$, $p = .010$, was significantly different from 0, which validates the random-intercept structure of the model.

There was no overall effect of psychopathy, $F(1, 38.00) = 0.56$, $p = .458$; psychopathy $b = –0.11$, $SE = 0.33$. In contrast, facial expression modulated IPD substantially, $F(1, 1743.85) = 38.56$, $p < .001$; angry $b = 33.18$, $SE = 5.34$. Participants preferred closer IPDs toward happy avatars ($M = 114.04$ cm, $SE = 3.52$ cm) as compared with angry avatars ($M = 123.18$ cm, $SE = 3.89$ cm). Note that these results are consistent with the findings of Ruggiero et al. (2017).

Does psychopathy influence the regulation of IPD? In the LMM, the Facial Expression × Psychopathy interaction reached significance, $F(1, 1743.74) = 20.76$, $p < .001$; Angry × Psychopathy $b = –0.28$, $SE = 0.06$. As depicted in Figure 2c, facial expression had a smaller effect in participants with higher psychopathy scores, as compared with participants with low psychopathy scores, supporting the lack of avoidance hypothesis proposed by von Borries et al. (2012).

Which dimension of psychopathy constitutes this effect? Again we modeled IPD as a function of facial expression with each subscale of the PPI-R-40 (see Table 1). This increased the goodness of fit in comparison to the previous model, $\chi^2(4) = 14.52$, $p = .006$, $R^2 = 72.70\%$. Contrary to Vieira and Marsh (2014), Coldheartedness was not associated with a preference for shorter IPD. Similarly, there was no direct effect of the facets Fearless Dominance or Self-Centered Impulsivity on IPD. However, the Coldheartedness and Self-Centered Impulsivity subscales equally predicted a diminished effect of facial expression on IPD (see the β weights in Table 1).

Experiment 2: IPD Between Two Avatars

In Experiment 1, we had expected to find a general preference for shorter IPD in psychopathy, especially in Coldheartedness (Vieira & Marsh, 2014). However, we rather found a reduced regulation of IPD as a result of the facial expression of the avatar, instead of a reduced IPD per se in psychopathy. In Experiment 2, we investigated whether this impaired regulation is the result of a fundamentally different understanding of social norms. If so, the regulation difficulties should not be limited to the own personal space but persist even when self-involvement is not necessary for judging the appropriateness of IPD. Thus, in Experiment 2, participants had to adjust the IPD between two avatars, one approaching the other, until the IPD was presumed pleasant for conversation between them.

Method

Apparatus and stimuli. The same experimental setup was used as in Experiment 1. However, instead of presenting one avatar frontally as in Experiment 1, two avatars were shown in side view on a virtual frontoparallel plane. Again, avatars were standing 15 cm behind the projection screen in virtual space, looking straight at each other. The virtual plane of avatar motion was at a distance of 1.50 m from the observer. The observer was positioned at a distance of 1.35 m to the projection screen, such that the virtual FOV matched the geometric FOV. Only one of the avatars could be moved in a given trial via a joystick. A small black mark on the shirt indicated which avatar was moveable. A joystick (Thrustmaster T16000M) was mounted on a desk in front of the participant at a height of about 90 cm. With 16-bit precision and a dead zone of 1% (the range of joystick positions not signaling movement), it was sufficiently accurate for the purposes of our experiment. Pushing the joystick sideways moved the avatar in the same direction with a speed of 33 cm per second. We formed 12 pairs using the four avatars from Experiment 1 and had every avatar approach all others. The interspine distance between the two avatars was measured with a precision of 0.1 cm.

Design and procedure. We presented 24 experimental conditions: Each avatar of the pairs was once moved from the right side of the virtual room to the left, and once in the opposite direction (see Fig. 1, right). All experimental conditions were repeated once resulting in 48 trials, presented in random orders. Instructions were similar to those in Experiment 1: Participants were told to move one avatar toward the other avatar until a comfortable distance for conversation had been reached, for a situation where the approaching avatar would have to ask the other (a stranger) for directions. After the participant had verbally confirmed the preferred distance, the avatar positions were recorded, a black screen appeared, and the experimenter advanced to the next trial. Prior to Experiment 2, participants completed four training trials, randomly selected from the 48 trials.

Data analysis. Estimates were corrected for outliers according to the individual distances for each combination of avatar pair (female pairs, mixed pairs, male pairs). Using the Tukey criterion, we identified 4.42% (85 of 1,920) trials as outliers. As in Experiment 1, we conducted a LMM on the basis of the individual trials using the same specifications regarding tests of model fit and effects as in Experiment 1.

Results and discussion

In the model, again, participant was entered as a random factor. Subsequently, we added the fixed factors. First, we added avatar pair, second, psychopathy, and last, sex of the participant. Avatar pair, $\chi^2(2) = 174.95$, $p < .001$, and psychopathy, $\chi^2(3) = 19.49$, $p < .001$, did significantly improve the goodness of fit of the model; in contrast, sex of participant did not significantly contribute to the model, $\chi^2(6) = 7.08$, $p = .31$. Therefore, only psychopathy and avatar pair were included as fixed factors in the model. We first analyzed the random intercept structure and then the fixed effects. The model explained $R^2 = 82.26\%$ of the variance. Variance between participants differed significantly from zero, $\chi^2(1) = 2848.50$, $p < .001$, indicating that participants varied substantially in their estimates of exocentric IPD.

Replicating our results from Experiment 1, we did not find a main effect of psychopathy on exocentric IPD estimates, $F(1, 38.19) = 0.01$, $p = .98$; psychopathy $b = 0.08$, $SE = 0.20$. However, the Avatar Pair × Psychopathy interaction was significant (mixed pairs as baseline), $F(2, 1791.03) = 9.76$, $p < .001$; Females × Psychopathy $b = 0.11$, $SE = 0.04$, $t(1791.00) = 2.87$, $p = .004$; Males × Psychopathy $b = 0.15$, $SE = 0.04$, $t(1791.00) = 3.86$, $p < .001$. For mixed pairs, exocentric IPD decreased with psychopathy, but not so for all female or all male pairs (see Fig. 3). Moreover, we found a significant effect of avatar pair, $F(2, 1791.03) = 9.76$, $p < .001$. Female pairs were positioned closest, $M = 60.43$ cm, $SE = 2.21$ cm; females $b = -13.42$, $SE = 3.27$, $t(1791.00) = -4.10$, $p < .001$, followed by trials with mixed avatar pairs, $M = 64.62$ cm, $SE = 2.32$ cm (as baseline), and male pairs, $M = 67.92$ cm, $SE = 2.31$ cm; males $b = -9.56$, $SE = 3.38$, $t(1791.00) = -2.83$, $p = .005$. This result is consistent with sex effects typically found in egocentric IPD (Iachini et al., 2016; Sussman & Rosenfeld, 1982; Uzzell & Horne, 2006).

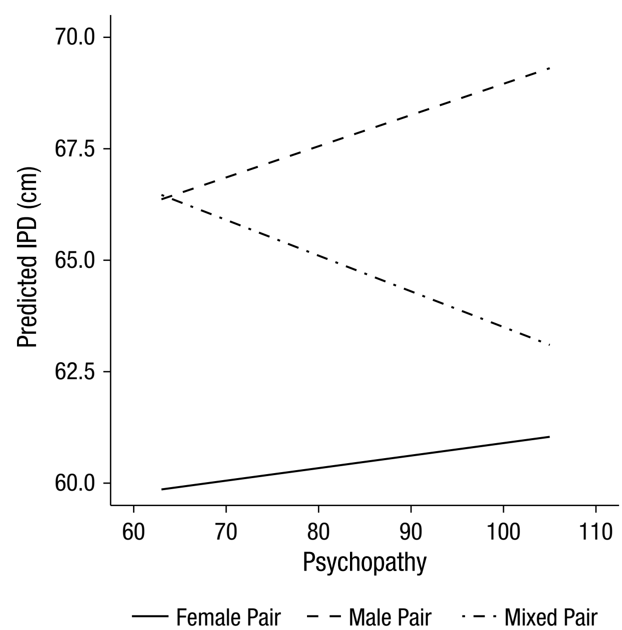

Fig. 3. Mean predicted exocentric interpersonal distance (IPD) in centimeters as a function of psychopathy, separated by gender of avatar pairing.

Again we examined the effects of psychopathy on exocentric distance judgments in more detail by specifying interactions for the higher-order factors and the Coldheartedness subscale of the PPI-R-40. This increased the goodness of fit of the model, $\chi^2(6) = 20.94$, $p = .002$, $R^2 = 83.17\%$. The main effect of avatar pair resembled the previous analysis, $F(2, 1787.03) = 10.47$, $p < .001$, and no direct effect of the psychopathy subscales on exocentric IPD emerged, all *p*s > .34. However, the Avatar Pair × Self-Centered Impulsivity interaction was significant, $F(2, 1787.01) = 14.58$, $p < .001$, which indicates that the effect of Self-Centered Impulsivity differed across avatar pairs. We found a nonsignificant tendency for shorter exocentric distances with increasing Self-Centered Impulsivity, $b = -0.43$, $SE = 0.45$, $t(36.16) = -0.95$, $p = .35$, in female pairs, Females × Self-Centered Impulsivity $b = 0.10$, $SE = 0.08$, $t(1787.01) = 1.15$, $p = .25$, and mixed pairs (baseline). In contrast, Self-Centered Impulsivity did virtually not affect exocentric IPD in male pairs, Males × Self-Centered Impulsivity $b = 0.46$, $SE = 0.08$, $t(1787.01) = 5.40$, $p < .001$. All remaining effects were not significant (*p*s > .07).

As a post hoc analysis, we correlated the mean exocentric IPD estimates with the mean egocentric distance judgments, $r(38) = 71$, $p < .001$. Participants who prefer closer egocentric IPD to an avatar also adjust closer exocentric IPD in pairs of avatars. Besides that, mean preferred exocentric IPD between avatars ($M = 64.47$ cm, $SD = 14.30$ cm) was considerably smaller than preferred egocentric IPD ($M = 118.65$ cm, $SD = 22.90$ cm), $t(39) = -21.02$, $p < .001$, Cohen's $d_z = 3.36$. Note that egocentric distance estimates in VR settings could suffer more from compression effects (e.g., Thompson et al., 2004; von Castell, Oberfeld, & Hecht, 2014) than could exocentric distance judgments. Thus, compression cannot be the culprit for the discrepancy between egocentric and exocentric IPD. Rather, IPD may be experienced differently when one's own personal space is not affected. Note that Nandrino, Ducro, Iachini, and Coello (2017) also found smaller distances for exocentric IPD than egocentric distance when judging preferred IPD on the basis of video scenes.

General Discussion

We have conducted two experiments to examine why psychopaths may not stand back as others do. In Experiment 1, we simulated a positive and a negative social situation by manipulating the facial expression of avatars. We did not find an overall effect of psychopathy on IPD but a diminished regulation of IPD in accordance with facial expression in high-psychopathy participants. In contrast, low-psychopathy participants did regulate distance in accordance with facial expression, which agrees with the findings of Ruggiero et al. (2017). Thus, participants scoring higher in psychopathy did not generally prefer closer distances but rather exhibited reduced regulation of IPD toward social threat as conveyed by facial expression. To further investigate this effect, in Experiment 2 we examined whether this diminished regulation is the result of a fundamentally different understanding of IPD. Controlling for effects of personal involvement, one avatar was moved toward another until the respective distance between them was deemed appropriate for conversation. Indeed, psychopathy was associated with smaller distance estimates in mixed pairings but not when avatars were of the same sex. These two approaches to spatial behavior could be especially useful in understanding personal space and regulation of personal space in general, as well as in psychopathology patients.

IPD violations in psychopathy in the light of equilibrium theory

In light of our results, equilibrium theory provides a good framework to understand regulatory deficiencies in psychopathic individuals. Theories that conceive personal space as a body buffer zone protecting the individual from psychological or physical harm (Dosey & Meisels, 1969) or as a function of arousal (Nesbitt & Steven, 1974) would have predicted main effects of psychopathy on IPD, in the light of psychopaths' low fear (Fowles, 1980; López et al., 2013) and low arousal levels (Benning, Patrick, & Iacono, 2005). This is not what we found. Consequently, we favor equilibrium theory over competing theories of personal space. Deficits in the processing of emotional expression may prevent psychopathic individuals from experiencing the emotional state of others. More precisely, the approach and avoidance tendencies elicited by an empathic experience of the emotions of others are absent and, thus, cannot serve as regulatory forces (von Borries et al., 2012). And this lack of regulatory forces translates into a diminished spatial reaction toward (or away from) the other person as a function of the person's facial expression. If this is the case, the link between motivational tendencies and IPD deserves to be further investigated.

The link of Coldheartedness and diminished spatial regulation in response to social threat may be understood as a lack of empathy. Coldhearted individuals do not feel the emotions of the counterpart and, thus, do not act accordingly. Certainly, this finding of a diminished regulation in IPD provides further evidence for the theory of psychopathy being a disorder of emotional empathy (Soderstrom, 2003). The other connection of

Self-Centered Impulsivity and distance regulation had not previously been found. Participants with more Self-Centered Impulsivity, and thus antisocial tendencies, regulated distance less according to facial expression. This could reflect a tendency to not integrate peripheral information of social cues into one's own behavior when engaging in goal-directed behavior, as proposed by the response modulation hypothesis of psychopathy (Smith & Lilienfeld, 2015).

Alternatively, one could entertain that the diminished reactivity toward social threat may be an adaptive strategy in threatening social encounters, for example, to dominate the situation or reduce distress in close social threatening encounters. However, this is at odds with the effects concerning the subscales of the PPI-R-40 in our first experiment. The dimension of Fearless Dominance, in contrast to Coldheartedness and Self-Centered Impulsivity, did not predict IPD regulation. Still, the PPI-R-40 subscale of Fearless Dominance can measure only quite explicit aspects of the bold behavioral tendencies in psychopathy; thus, the reduced reactivity to social threat as indicated by IPD may still be an adaptive mechanism in psychopathy unrelated to traits of social dominance.

Considering that participants who preferred smaller egocentric distances also tended to adjust smaller distances between pairs of avatars, there might be an individual norm influencing spatial behavior. In other words, the comfortable IPD we ascribe to strangers is related to our own preferred distance. This is consistent with Hayduk's (1983) observation that IPD is mutual; that is, the approaching person and the person being approached are typically in agreement over the appropriate distance between them.

Experiment 2 highlights that high-psychopathy individuals may differ from low-psychopathy individuals in their understanding of certain social norms. Low-psychopathy individuals had the same concept of personal space for mixed sex and male pairs. However, mixed pairs were adjusted more like female pairs by participants with higher scores in psychopathy. For avatar pairs of mixed sex, psychopathy was associated with a decrease in IPD estimates. In contrast, there was a trend toward a slight increase in IPD for male avatar pairs associated with psychopathy (see Fig. 3), which is consistent with personal space intrusions by males eliciting a more pronounced emotional response in violent offenders (as compared with female faces), as indicated by increased amygdala activity (Schienle, Wabnegger, Leitner, & Leutgeb, 2016).

With an increase of psychopathy, gender effects seem to strengthen, especially when female avatars are involved. However, this was moderated by antisocial tendencies of psychopathy as indicated by the Avatar Sex × Self-Centered Impulsivity interaction. Consequently, these effects may be conceived of as an altered gender-specific spatial norm related to psychopathy, antisocial traits, and beliefs. In detail, encounters of mixed pairs could be viewed as less threatening. The potential physical dominance of the male may not be fully integrated in the spatial adjustment of mixed pairs. Adjusting an appropriate IPD between two avatars is a relatively complex task because it requires a consideration of the potential physical dominance of one avatar over the other. This may be rather difficult for psychopathic individuals. In mixed and female pairs, which might be ambiguous regarding the dominance of the social interactants, self-centered individuals prefer closer IPD. In contrast, this is not the case in male pairs, where there might be less room for interpretation regarding physical dominance. Note that this tendency for bold social behavior in complex situations is consistent with theories of impaired cue integration in psychopathy (Hamilton, Hiatt Racer, & Newman, 2015; Smith & Lilienfeld, 2015). However, considering the comparably small sample size and the fact that we did not predict these effects, further research would be required to substantiate this interpretation.

Studying personal space violations in VR

The findings of the present study point out the advantages of studying social behavior in VR. With the use of avatars, we can be certain that all social cues were identical for all participants, thus making their psychopathy scores a powerful indicator. In a naturalistic task, even skilled actors might have shown signs of distress or other social cues as a function of the participants' looks, facial expressions, and so on. This could potentially explain why we failed to replicate the effect of Coldheartedness on IPD reported by (Vieira & Marsh, 2014). One could of course explicitly test this hypothesis by comparing effects in VR with effects found in a stop-distance task with a real confederate.

Our results suggest that the application of a VR paradigm in a forensic sample would provide valuable insights into spatial behavior in severe psychopathy without having to endanger a confederate. The present study has shown that regulation of distance toward facial expression can be reliably assessed in a stop-distance task. Thus, the measurement of IPD in VR may be a powerful diagnostic tool in the study of psychopaths' deviant social behavior and lack of empathy. Although regulation deficiencies in psychopathic individuals were relatively small (in the range of a few centimeters) in our sample, one would expect stronger effects in highly psychopathic offenders. Note that we merely sampled a general student population. In addition, we presented explicit and rather strong facial expressions. Considering psychopaths' deficit in recognizing subtle facial expressions (Hastings et al., 2008), weaker social cues may result in even more pronounced personal space violations as compared with controls.

One might argue that behavior in virtual environments does not translate to behavior in the real world when it comes to distance underestimation. However, we were interested in the effects of manipulations of social cues on the perceived IPD; thus the absolute level of the estimates, even if distorted in VR, should be rather irrelevant as long as the direction and the slope of the effects remain unaffected by the virtual environment. When comparing effects in a stop-distance task in reality and VR, there seem to be no systematic differences (Iachini et al., 2016); IPD appears to be as functional in VR as it is in reality. For example, effects of sex, gender, and gaze direction on IPD can be found in online games (Yee, Bailenson, Urbanek, Chang, & Merget, 2007) as well as in reality (Argyle & Dean, 1965; Uzzell & Horne, 2006).

Implications and limitations

Our results harbor some insights for practitioners. Social cues, such as facial expression, are not fully integrated in psychopaths' spatial behavior. Therefore, the training of personal space regulation in accordance with social cues may be of special importance in patient care units or in correctional facilities exposed to psychopathy. Following this consideration, a virtual social skills training using our avatar tasks in a safe environment may become a viable part of psychotherapy. Most importantly, spatial norm violations may be valuable behavioral indicators of psychopathy, which could be exploited for its diagnosis. We recommend to research IPD regulation effects using a sample of psychopathic offenders. The experimental setup and student sample of the present study cannot represent the heterogeneity within the psychopathic population. In the light of psychopaths' low anxiety, low arousal, and deficient aversive conditioning leading to deficient socialization (Hamilton et al., 2015), shorter IPDs in egocentric tasks may be found after all when contrasting controls and highly psychopathic offenders.

The diminished regulation of IPD in psychopathy may not be limited to expressions of anger. Psychopathic individuals exhibit a pronounced deficit in the recognition of fearful facial expressions (cf. Marsh & Blair, 2008), also relevant in threatening social situations. We had chosen not to include fear stimuli because their effect on IPD is hard to predict. Fear stimuli can signal threat within the environment and at the same time foster approach reactions (Marsh et al., 2005). Thus, without further qualification, fear signals do not permit a clear prediction of approach versus avoidance. Their specific influence on IPD, however, deserves to be investigated in the future. Moreover, one could present high- and low-psychopathic participants with moral, neutral, and amoral descriptions of virtual persons as in Iachini, Pagliaro, et al. (2015).

As measures of egocentric IPD and exocentric IPD are highly correlated, functional magnetic resonance imaging studies regarding IPD and psychopathy may benefit from adopting the exocentric-distance approach, rather than relying on frontal face stimuli to estimate IPD. Moreover, the activation of the amygdala may serve as an indicator of distress and perceived threat resulting from intrusion of personal space (Schienle et al., 2016) in tasks involving exocentric IPD judgments.

It is also conceivable that our task is not the best suited to assess psychopathic proneness to invade the personal space of others. In the stop-distance task, participants were explicitly asked to adjust the preferred IPD to another person. However, in the light of psychopaths' impaired integration of social cues (Hamilton et al., 2015), personal space may be violated in many other ways when psychopathic individuals engage in social actions that do not affect or are correlated with comfortable IPD.

Conclusion

In sum, our findings show that psychopathy is not associated with an altered perception of appropriate interpersonal distance per se. Instead, psychopathy is related to the regulation of IPD with respect to social cues. Psychopathic individuals do not regulate distance in tune with emotions expressed by another person. Differences in IPD regulation may also arise from differences in the understanding of the concept of personal space.

Action Editor

Scott O. Lilienfeld served as action editor for this article.

Author Contributions

R. Welsch, H. Hecht, and C. von Castell contributed to the design and implementation of the research. R. Welsch wrote the manuscript with support from C. von Castell and H. Hecht. R. Welsch collected the data and performed the analysis, but all authors discussed the results. H. Hecht supervised the study. All the authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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