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Interpersonal Distance Regulation and Approach-Avoidance Reactions Are Altered in Psychopathy

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Abstract

In this study, we examined the impact of psychopathy on approach-avoidance reactions and interpersonal distance (IPD) in response to social cues. We selected a student sample and measured psychopathy via self-report. Participants were immersed in a virtual environment in which a virtual person displayed either angry or happy facial expressions. In the first experiment, participants had to walk toward the virtual person until a comfortable IPD had been reached. In the second experiment, participants had to push or pull a joystick in response to the facial expression of the virtual person. Our results suggest that psychopathy does not change average IPD but does impair its regulation. That is, the facial expression of the avatar no longer modulated IPD in participants with psychopathic traits to the extent that it did in participants with fewer psychopathic traits. The speed of the approach and avoidance reactions is altered in psychopathy when confronted with social cues.

Keywords
approach-avoidance, interpersonal distance, virtual reality, psychopathy, emotion

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In a scenario in which someone approaches a stranger to ask for directions, numerous factors influence the interpersonal distance (IPD) people consider to be appropriate. People want to be near enough to be noticed and far enough away to appear polite and respectful. Among other things, the facial expression of the approached person signals how comfortable he or she is with the approach and has long been recognized as fundamental for social interaction and survival (e.g., Darwin, 1872/1956). Social threat communicated by an angry face elicits fear and arousal and is processed in a preferred manner (Alpers, Adolph, & Pauli, 2011; Schupp, Junghöfer, Weike, & Hamm, 2004). Thus, expressions of anger promote faster avoidance than approach reactions (Marsh, Ambady, & Kleck, 2005). Such forces of approach and avoidance also regulate the distance people maintain between themselves and others (Argyle & Dean, 1965; Bailenson, Blascovich, Beall, & Loomis, 2001). People assume a greater distance from a person with an angry facial expression than a person displaying a happy facial expression (Ruggiero et al., 2017; Welsch, Hecht, & von Castell, 2018).

IPD has been assumed to be rather persistent and related to personality traits that shape humans' perception of the environment (Lewin, 1935; Welsch, von Castell, & Hecht, 2019). For example, positive emotionality and extraversion may strengthen the approach reaction, whereas traits such as neuroticism and negative emotionality may strengthen the avoidance reaction (Elliot & Thrash, 2002). People would thus predict noticeable changes in distance behavior as a function of extreme personality traits, such as psychopathy.

Recent findings regarding psychopathy give rise to a conceptualization of psychopathy that does not limit the concept to forensic or clinical populations but includes subclinical and "successful" psychopaths (e.g., Patrick & Drislane, 2015). Thus, psychopathy can be studied in community samples, as well (Boll & Gamer, 2016; Edens, Marcus, Lilienfeld, & Poythress, 2006; Guay, Ruscio,

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Knight, & Hare, 2007; López, Poy, Patrick, & Moltó, 2013; Patrick, Edens, Poythress, Lilienfeld, & Benning, 2006; Welsch et al., 2018). Psychopathy can be characterized by persistent deviant social behavior and interpersonal and emotional deficiencies (e.g., see Hare, 2006), including the tendency to cause harm by undermining social norms. Indeed, clinical reports suggest that psychopathic subjects violate personal space (i.e., choose uncomfortably close IPDs in social interactions; Quayle, 2008; Rimé, Bouvy, Leborgne, & Rouillon, 1978). Experimental studies suggest that this may be limited to situations of social threat (Welsch et al., 2018) or social dominance (Lobbestael, Arntz, Voncken, & Potegal, 2018; Welsch et al., 2018). Thus, interpersonal distance per se is not necessarily diminished in psychopathy, but the appropriate regulation of IPD in response to social cues is (Welsch et al., 2018). We would consider this diminished IPD regulation to be due to a reduced avoidance motivation when confronted with social threat. Consistent with this notion, von Borries et al. (2012) reported a diminished avoidance reaction toward angry faces in psychopathy. However, it is not yet known to what extent the degree of avoidance relates to IPD regulation and which facets of psychopathy affect the approach-avoidance reaction.

Hence, we sought to compare the speed of the approach-avoidance reaction with preferred IPD by manipulating the facial expression of a virtual person in three virtual-reality (VR) experiments. Thus, we examined the effects of different psychopathy traits on preferred IPD and on the speed of the avoidance reaction.

IPD

The IPD that people maintain spans a more or less concentric personal space around the individual, and when someone intrudes into this space, arousal and/or discomfort ensue (Hayduk, 1978). Vieira and Marsh (2014) investigated the effect of psychopathic traits on the perception of IPD in a student sample using 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 particular subscale.

The just-mentioned studies used real persons as stimuli, who may have slightly changed their facial expression or posture during the experiment. Measuring IPD in VR allows for the experimental control of many such confounding variables while maintaining external validity (Blascovich et al., 2002). In the case of psychopathy, this might be particularly important. For example, Welsch et al. (2018) showed that when controlling for reactivity in the facial expression of the confederate through usage of a virtual person, the direct effects of psychopathy traits on IPD might disappear. Participants, regardless of their tendencies toward psychopathy, kept a larger IPD toward socially threatening avatars with an angry facial expression compared with avatars with a happy facial expression. No overall preference for shorter distances was found in psychopathy, although distance regulation appeared reduced.

Approach-avoidance task

Solarz (1960) first studied the approach and avoidance reaction using a reaction time (RT) task. He presented participants with words of either positive valence (e.g., "happy") or negative valence (e.g., "stupid"). Participants then reacted as quickly as possible with a previously learned set of arm movements. In compatible trials, participants reacted with a push of a lever to words of negative valence, which constituted an avoidance reaction, and with a pull of a lever to positive words (approach reaction). In incompatible trials, the mapping of valence and reaction direction was reversed (push–positive, pull–negative). The results of this experiment showed that compatible trials were facilitated and produced faster RTs than incompatible trials. Chen and Bargh (1999) conceptually replicated this experiment and instructed participants to push a lever in reaction to a set of positive and negative words and then react with a pull of the lever to the same set of words in a second block. Although the evaluation of the presented words was no longer necessary for response selection, effects of compatibility persisted: Pull–positive and push–negative trials elicited faster reactions than push–positive and pull–negative trials.

Rinck and Becker (2007) developed the approach-avoidance task (AAT). They added a zooming feature to Solarz's (1960) lever task that increased the size of the stimulus picture presented on a computer monitor when the participant pulled a joystick and decreased the size when pushing the joystick. First, they found that spider-phobic individuals showed a more pronounced avoidance reaction toward spider pictures than did healthy control participants. Second, compatible with Chen and Bargh (1999), these effects still emerged when the response cue was stimulus-irrelevant; for instance, when reacting to the format of the picture (landscape vs. portrait). Third, the sizes of the RT asymmetries between approach and avoidance were correlated with walking speed when approaching a real spider, which indicates that that the relative speed of the reaction is linked to distance behavior.

Variants of the AAT have been developed and extensively implemented in clinical psychological research, likely for the diagnostic potential associated with the strength of the compatibility effect. Specifically, variations in the compatibility effect can be observed in reference to clinically relevant stimuli, such as drugs (Cousijn, Goudriaan, & Wiers, 2011; C. E. Wiers et al., 2013; R. W. Wiers, Rinck, Dictus, & Van Den Wildenberg, 2009; Zhou et al., 2012), aversive stimuli relevant for phobias (Heuer, Rinck, & Becker, 2007; Reinecke, Becker, & Rinck, 2010; Rinck & Becker, 2007), and social stimuli in depression (Radke, Guths, Andre, Muller, & de Bruijn, 2014; Struijs et al., 2018). Psychopaths have been found to show weaker compatibility effects in response to social threat (von Borries et al., 2012). Participants were instructed to pull or push a joystick dependent on the picture content, which produced a zoom-in or a zoom-out effect. Control participants pushed angry faces faster than they pulled them. This avoidance facilitation was reduced in individuals with psychopathic traits. The authors related this finding to the interpersonal emotional deficiencies observed in psychopathy.

Aim of our study

The goal of our study was to investigate if IPD behavior is similarly compromised in psychopathy. To do so, we examined RTs of approach and avoidance reactions toward happy- and angry-looking avatars, as well as preferred IPD in a virtual environment. In Experiment 1, we aimed to replicate findings concerning the diminished IPD regulation associated with psychopathic traits, especially exploring whether the impulsive facet of psychopathy and coldheartedness would predict IPD regulation (Welsch et al., 2018). In Experiment 2, the strength of the approach and avoidance reactions toward angry and happy avatars was measured by RT in a virtual-reality AAT (VR-AAT). Because the feeling of depth and three-dimensional (3-D) layout is crucial for the compatibility effects in the AAT (Rougier et al., 2018), it is surprising that the AAT has not yet been implemented in a 3-D virtual environment. We hypothesized that angry faces elicit faster avoidance reactions than approach reactions, whereas happy faces elicit faster approach reactions than avoidance reactions. In addition, following von Borries et al. (2012), the avoidance reaction should be diminished in psychopathy. In Experiment 3, we implemented a VR-AAT in which we followed Chen and Bargh (1999) and Rinck and Becker (2007) and instructed the participants to react to a stimulus-irrelevant cue.

Previous studies have mainly examined approach-avoidance behavior and IPD in relation to the overall psychopathy score (Hammer & Marsh, 2015; López et al., 2013; von Borries et al., 2012; Welsch et al., 2018), which may be problematic because psychopathy is not a unitary construct (e.g., Patrick, Fowles, & Krueger, 2009). The overall PPI-R score does not have much incremental predictive value beyond the PPI-R facets. This is because facets of the PPI-R are sometimes correlated in opposing directions with external measures, which results in decreased correlation regarding the overall score (Miller & Lynam, 2012). Thus, we mainly analyze and interpret the psychopathy facets and their associations with the experimental measures, which allows for fine-grained interpretations of our results that can be integrated into current models of psychopathy. We merely provide an analysis of the overall psychopathy score for reasons of comparability with previous findings and replication.

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, 2015). 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; Hastings, Tangney, & Stuewig, 2008), we have chosen to contrast only angry and happy facial expressions. Although the spatial and temporal components to approach and avoidance behavior may be intertwined (Argyle & Dean, 1965; Bailenson et al., 2001; Lewin, 1935), their relation has not been thoroughly studied. Therefore, another goal was to directly compare approach- and avoidance-related behavior in RT and IPD estimates within participants.

Experiment 1: Replicating Effects of Psychopathy on IPD Regulation

In Welsch et al. (2018), IPD was regulated as a function of facial expression. Participants preferred greater IPD from angry-looking avatars in comparison with happy-looking avatars. This effect was modulated by psychopathy; that is, self-centered impulsivity and coldheartedness were associated with diminished IPD regulation. These findings should be replicated.

Method

Participants. Eighty-seven volunteers took part in the study, 11 of whom we excluded: 6 because of technical problems, 4 because of excessive error rates in Experiments 2 and 3, and 1 because of missing questionnaires. This left 76 participants (51 female) ages 19 to 38 years

(*M* = 24.51, *SD* = 4.36) who completed all three experiments and the questionnaires in return for partial course credit or monetary compensation. Participants had, on average, been enrolled for 6.75 semesters (*SD* = 5.50). Seventy-four of the 76 participants (97.36%) studied psychology, 22 (29.73%) at the postgraduate level. After Experiment 1, all participants subsequently completed Experiments 2 and 3. 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 experiment. Forty-nine participants (64.5%) had normal vision and 27 (35.5%) had 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 s of arc. The criterion for participation was that at least six of the nine trials had been answered correctly. Participants rated whether they were experienced with VR setups, VR programs, and 3-D games from 1 (*a lot)* to 5 (*little*). They had, on average, very little experience with VR setups and programs (*M* = 4.30, *SD* = 0.93). Participation in the whole study took about 60 min.

PPI-R-40. We used the short version of the PPI-R, the PPI-R-40 (Eisenbarth, Lilienfeld, & Yarkoni, 2015), to measure psychopathy. It has proven to be comparably reliable and valid with regard to the PPI-R long form, with sufficient psychometric properties in both student and forensic samples (Ruchensky, Edens, Donnellan, & Witt, 2017).

The PPI-R-40 can be merged into two higher-order factors: self-centered impulsivity and fearless dominance. The subscale coldheartedness 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 and antisocial personality traits associated with psychopathy (Patrick et al., 2009). The PPI-R-40 was scored from 1 (*false*) to 4 (*true*).

Apparatus and stimuli. Participants saw stereoscopic full-scale simulations on a large rear-projection screen (2.60 m wide × 1.95 m high). We used a 3-D projector (projectiondesign F10 AS3D; Barco, Kortrijk, Belgium) with 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-XP; XPANDVISION USA, Beaverton, OR 97008) synchronized via an infrared emitter, such that each eye received 60 frames per second. Participants' individual interpupillary distance was measured by a pupil-distance meter and taken into account when computing the stereoscopic disparity of the VR environment. Measured from a distance of 2.35 m from the screen, the geometric 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. 1a). The participants' movement was tracked with a sampling frequency of 30Hz using an infrared sensor (Kinect; Microsoft Corp., Redmond, WA).

Stimuli were presented using the VR software Vizard 5 (Worldviz, Santa Barbara, CA). Avatars were designed in Makehuman, and facial expression was modulated in 3ds Max (Autodesk, San Rafael, CA) to resemble Ekman pictures (Ekman & Friesen, 1977). Four different (two female, two male) White avatars were used to present a variety of social stimuli. Three of the four avatars had been previously used in Welsch et al. (2018). Each of the four avatars was presented with both happy and angry facial expressions. All avatars wore gray shirts and black pants. The virtual position of the avatars was 15 cm behind the projection screen throughout all trials. Because body height can influence IPD (Caplan & Goldman, 1981), body heights of the 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 bridge of the observer's nose. The participant was positioned in front of the avatar, facing it directly. Both the avatar and the participant stood on platforms. Initial distance was set at 250 cm from the avatar (235 cm from the projection screen). The realistic appearance of the avatars was judged as being good to medium (*M* = 2.82, *SD* = 0.84), as rated on a 5-point scale from 1 (*very good*) to 5 (*bad*).

Design and procedure. We varied two experimental factors within participants: avatar sex (two male, two female) and emotional expression (happy, angry). Each factor combination was presented five times, resulting in 40 trials. Trials were presented in random order. Before the experiment, every participant completed eight training trials with all avatars showing neutral facial expressions, two trials for each avatar. The participants were told to walk toward the avatar until a comfortable distance for conversation had been reached for a situation in which the participant would have to ask a stranger for

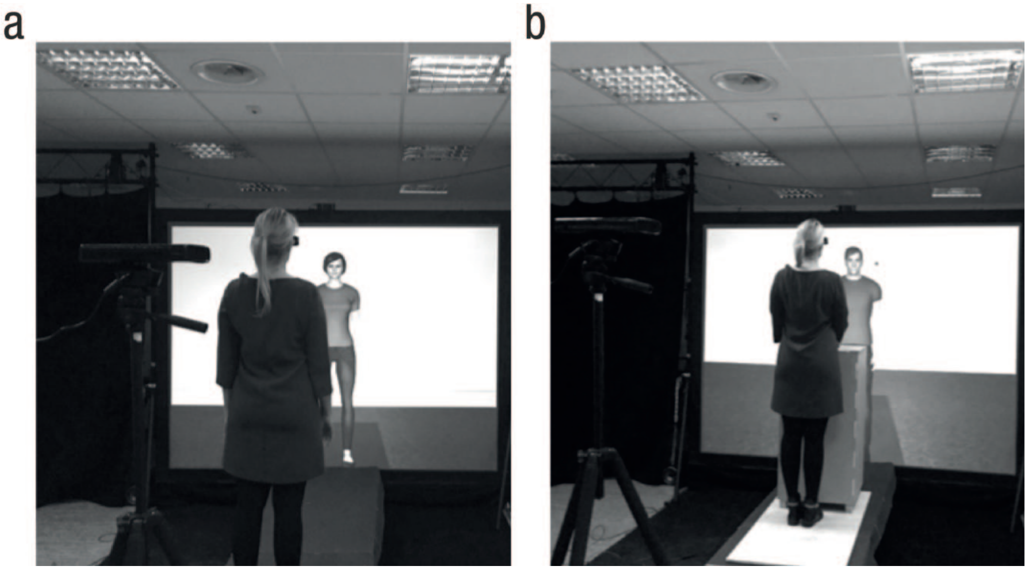

Fig. 1. Apparatus used in Experiment 1 (a) and Experiments 2 and 3 (b). The rear-projection screen displayed the avatars in Experiments 1 through 3. The joystick mount and platform were used only in Experiments 2 and 3.

directions. The participant then confirmed the position and the IPD was logged. After each trial, a black screen appeared and the participant went back to the starting position. No time limit was given. Participants were instructed in both written and verbal form.

Results and discussion

Data were analyzed on the basis of the outlier-corrected individual distances for each factor combination. Outliers were corrected in two steps. First, of the 3,040 distances measured, one value exceeded the starting distance of 2.5 m and was discarded (< 0.01%). Second, using the Tukey criterion, trials with distances more than 3 times the interquartile range lower than the first or higher than the third quartile for each factor level combination for every participant were classified as outliers. This affected 1.15% (35 of 3,039) of the cases. Furthermore, on the questionnaires, 6 out of 3,040 questionnaire responses (0.20%) were missing. They were replaced with the individually predicted value based on the participant's responses in the respective higher-order factor. Cronbach's α was acceptable for the sum score of the PPI-R-40 ($M = 85.74$, $SD = 10.78$; $\alpha = .778$) and for the subscales fearless dominance ($M = 37.64$, $SD = 6.62$; $\alpha = .792$) and self-centered impulsivity ($M = 38.50$, $SD = 6.65$; $\alpha = .726$) but was relatively low for coldheartedness ($M = 9.61$, $SD = 2.12$; $\alpha = .500$).

For statistical inference, following a Bayesian approach, we relied on the posterior median p value ($p_{\tilde{b}}$). This metric was computed by calculating the relative proportion of posterior samples being zero or opposite to the median (for a well-written and accessible introduction, see Kruschke, 2013). For an illustration of parameter distributions, see Figure 2c. Thus, we quantified the proportion of probability that the effect is zero or opposite given the data observed. Note that this is the reverse of the classical approach to inferential statistics, where one measures the probability of the data given the null hypothesis. Still, $p_{\tilde{b}}$ should have properties similar to those of the classical p value (see Berkhof, van Michelen, & Hoijtink, 2000; but see also Gelman et al., 2013). Effects were considered to be meaningful when there was a particularly low probability ($p_{\tilde{b}} \leq 5\%$) that the effect could be zero or opposite. This threshold was chosen to resemble an α level of 5%, normally used in classical statistical inference. In cases in which there was a fairly low probability ($5\% \leq p_{\tilde{b}} \leq 10\%$), we mention a trend but state that more data are needed before drawing definite conclusions. In addition to the median of the parameter, we calculated high-density posterior intervals (HDI) at 95% of the posterior distribution for all parameters, which indicate the possible range of effects given the data.[1]

Coldheartedness did not correlate with fearless dominance, $r = -.04$ (95% HDI = [–25, .19]), $p_{\tilde{b}} = 37.3\%$, or self-centered impulsivity, $r = -.07$ (95% HDI = [–.17, .27]), $p_{\tilde{b}} = 26.5\%$. Self-centered impulsivity was weakly related to fearless dominance, $r = .26$ (95% HDI = [.05, .48]), $p_{\tilde{b}} = 1.58\%$. Note that these scales were abbreviated using a genetic algorithm aimed at decreasing

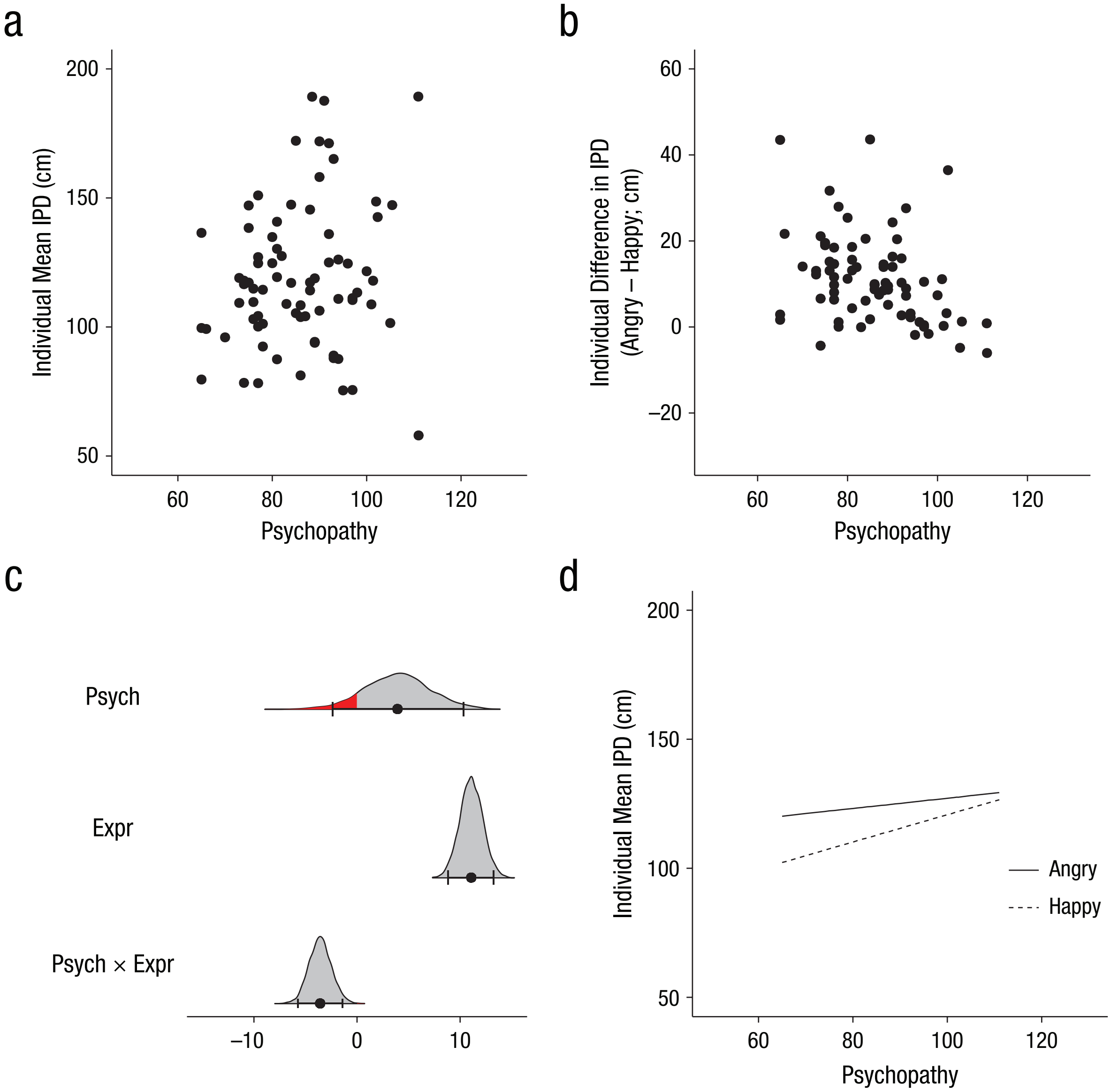

Fig. 2. Results from Experiment 1. The scatterplots at the top of the figure show the relationship between psychopathy scores (sum score of the Psychopathic Personality Inventory–Revised-40) and (a) individual mean interpersonal distance (IPD) and (b) the mean difference in IPD (IPD for happy faces subtracted from IPD for angry faces). The posterior density plots in (c) show the estimated effects of facial expression (Expr) and psychopathy (Psych) on IPD in Experiment 1. The dots represent the median of the respective posterior distribution, and error bars indicate 95% high-density intervals. The red/black-area indicates the proportion of posterior samples opposite the median and is thus a visual representation of the posterior median *p* value. The graph in (d) shows individual mean IPD as a function of psychopathy, separately for the two facial expressions of the avatar, as predicted by the Bayesian linear mixed model.

redundancy, thus decreasing correlations between items and factors (see Eisenbarth et al., 2015).

To visualize the association of psychopathy and 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 each participant (see Fig. 2a). There seems to be no direct link between psychopathy and IPD. Furthermore, we plotted the difference between the mean IPD for happy-looking and angry-looking avatars (averaged across avatar sex and repetitions, respectively) against psychopathy for every participant to visualize the potential Facial Expression × Psychopathy interaction in the sample (see Fig. 2b). We found a medium correlation between this difference and the psychopathy score, $r = -.34$ (95% HDI = [−.53, −.11]), $p_{\tilde{b}} = 0.0\%$, which indicates that the effect of facial expression on IPD is reduced in psychopathy.

We used the statistical package *brms* (Bürkner, 2017), a wrapper for the STAN sampler (Carpenter et al., 2017) for the R software environment (R Core Team, 2018) to calculate a Bayesian linear mixed model (BLMM).[2] We standardized psychopathy scores and used effect coding on categorical variables (Happy = .5, Angry = –.5). We calculated the effect measure δ_t, which can be interpreted quite similarly to Cohen's *d* (Hedges, 2007; Judd, Westfall, & Kenny, 2017).

In the BLMM, we estimated a varying intercept for every stimulus and a varying intercept for every participant with varying slopes for facial expression to account for the repeated measures structure of the experiment. We also added varying slopes for every participant regarding the sex of the avatar to control for individual sex effects in IPD preference (Uzzell & Horne, 2006). The population-level effects, facial expression of the avatar and psychopathy (PPIR-40 score), were fully crossed in the model (Baayen, Davidson, & Bates, 2008).

In total, this model explained $\tilde{R}^2 = 89.11\%$ (95% HDI = [88.81, 89.39]) of the variance in the data. The intercept (mean IPD to the avatar across all participants and experimental manipulations) was 118.75 cm (95% HDI = [111.97, 126.98]).

We now take a closer look at the population-level effects. Psychopathy did not affect overall IPD, $\tilde{b} = 3.93$ cm (95% HDI = [–2.36, 10.33]), $p_{\tilde{b}} = 10.5\%$, $\delta_t = 0.12$ (95% HDI = [–0.08, 0.32]).[3] As can be seen in Figure 2c, there was a substantial probability of this effect being zero. In contrast to the findings of Vieira and Marsh (2014) with reference to the median value, there was no indication of a negative relation between psychopathy and overall IPD. Consistent with the findings of Ruggiero et al. (2017) and Welsch et al. (2018), facial expression strongly affected IPD, $\tilde{b} = 11.08$ cm (95% HDI = [8.83, 13.25]), $p_{\tilde{b}} = 0.0\%$, $\delta_t = 0.35$ (95% HDI = [0.26, 0.43]). Participants preferred closer IPDs from happy avatars (*M* = 113.29 cm, *SD* = 25.96) than from angry avatars (*M* = 124.38 cm, *SD* = 30.48). This effect differed across individuals as a function of psychopathy, $\tilde{b} = -3.58$ cm (95% HDI = [–5.72, –1.42]), $p_{\tilde{b}} = 1.3\%$, $\delta_t = -0.11$ (95% HDI = [–0.18, –0.05]). One standard deviation above the sample mean in the psychopathy score corresponded to a reduction of about 4 cm in IPD regulation (see Fig. 2c and 2d). Note that these effects closely resemble our previous findings (Welsch et al., 2018).

Which dimensions of psychopathy are associated with IPD regulation? Having established that the effects of facial expression are present when controlling for effects of sex of avatar and other experimental control variables, we opted to investigate the relation of the psychopathy subscales to the averaged IPD data. We correlated the mean IPD (as well as the difference between the mean IPD for happy-looking and angry-looking avatars) with each subscale of the PPI-R-40. Contrary to the results of Vieira and Marsh (2014) but in line with those of Welsch et al. (2018), coldheartedness was not associated with a general preference for shorter IPD, $r = -.02$ (95% HDI = [–.20, .24]), $p_{\tilde{b}} = 43.3\%$. Likewise, there was no association with the facet fearless dominance, $r = -.05$ (95% HDI = [–.17, –.26]), $p_{\tilde{b}} = 33.5\%$. Surprisingly, there was some indication of an increase in overall IPD with self-centered impulsivity, $r = -.19$ (95% HDI = [–.01, .40]), $p_{\tilde{b}} = 4.0\%$. Note that this correlation was rather small in size. Fearless dominance, $r = -.30$ (95% HDI = [–.49, –.09]), $p_{\tilde{b}} = 0.5\%$, as well as self-centered impulsivity, $r = -.21$ (95% HDI = [–.42, .00]), $p_{\tilde{b}} = 3.1\%$, moderated the effect of facial expression on IPD. Note that self-centered impulsivity was more weakly correlated with IPD regulation than was fearless dominance. There was no substantial correlation of coldheartedness and IPD regulation, $r = -.13$ (95% HDI = [–.34, .09]), $p_{\tilde{b}} = 12.7\%$.

Experiment 2: Is the Approach-Avoidance Reaction Affected by Psychopathy?

To examine the influence of different psychopathy traits on the speed of the approach and avoidance reaction, we applied an AAT to the virtual environment of Experiment 1 and presented the stimuli to the same participants. They reacted with a push or pull of a joystick in response to the facial expression of the avatar. In one block, a compatible (push–angry face, pull–happy face) reaction was requested, and in the other an incompatible (pull–angry face, push–happy face) reaction was requested. Von Borries et al. (2012) used simple photographs with angry and happy faces. We hypothesized that the reduced compatibility effects they found in psychopaths would be as strong or even stronger in a VR setup if pictures were indeed indicative of a real-world effect.

Method

Apparatus and stimuli. We used the same experimental setup as in Experiment 1. Again, avatars were positioned 15 cm behind the projection screen in virtual space, looking straight at the participant. The observer was positioned at a distance of 1.35 m from the projection screen, such that the avatar was presented at a distance of 1.50 m from the observer. The virtual FOV matched the geometric FOV (horizontal: 71°; vertical: 61°). A joystick (Thrustmaster T16000M; Guillemot Corporation, La Gacilly, France) was mounted on a desk in front of the participant at a height of about 90 cm (see Fig. 1b). With a 16-bit precision and a dead zone of 1% (the range of joystick positions not signaling movement) of the maximum joystick displacement, it was sufficiently accurate for the purposes of our experiment.

In every trial, the task was to move the avatar via the joystick. A pull of the joystick initiated an 80 cm movement of the avatar toward the participant and a push of the joystick moved the avatar 80 cm away from the participant. The speed of the avatar's movement was adjusted to the amount of joystick displacement. We analyzed the RT from the appearance of the avatar until maximum joystick displacement with a precision of 1 ms.

Design and procedure. We used the same four avatars as in Experiment 1 (2 female, 2 male). Again, all avatars were presented with either happy or angry facial expressions. Each of these stimuli was to be pushed and pulled 10 times in response to the respective facial expression. In the compatible block, participants avoided the angry-faced avatar by pushing the joystick and approached the happy-faced avatar by pulling the joystick; in the incompatible block, this mapping was reversed. In total, the experiment consisted of 160 trials. Participants were instructed to react as quickly and correctly as possible with a push or pull until the joystick was fully displaced and the avatar disappeared. Half of the participants first completed the compatible block followed by the incompatible block; the order was reversed for the other half. Participants completed eight randomly selected training trials before every block.

The task was self-paced. The participant started a trial by pressing a button on the left side of the joystick mount. The avatar appeared immediately, and the participant reacted with movement of the joystick. After the joystick had been fully displaced, the avatar disappeared and the participant released the grip of the joystick and pressed a button on the right side of the joystick mount. A black screen appeared, and the next trial could be started.

Data analysis. Outliers were individually corrected in three sequential steps. First, RTs under 300 ms and above 2,500 ms were classified as outliers (1.43%; 174 of 12,160) and discarded. Second, using the Tukey criterion, trials with RTs more than three times the interquartile range lower than the first quartile or higher than the third quartile for each factor-level combination were classified as outliers for every participant. This affected 1.49% (178 of 11,986) of the remaining cases. In the final step, we deleted trials with an incorrect reaction, 2.42% (290 of 11,808). Overall, 642 (5.28%) of the 12,160 trials were discarded.

Results and discussion

We first present the descriptive data (Fig. 3, left) and then discuss and visualize the predictions of our statistical model (Fig. 4). The left panel of Figure 3 displays the respective approach and avoidance bias (mean RT in approach trials – mean RT in avoidance trials) as a function of the overall psychopathy-score (split on the median) and facial expression. One can see a facilitated approach reaction toward happy faces and a facilitated avoidance reaction toward angry faces. This facilitation effect seems reduced in participants with psychopathic traits. Note that we are well aware of information loss when transforming a continuous variable into a binary variable and that this was only done for illustrative purposes. All statistical inference is based on a continuous measurement of psychopathy.

We calculated a BLMM on the $\log_2$ transformed RTs. As in Experiment 1, a varying intercept for every stimulus and a varying intercept for every subject was estimated with fully crossed varying slopes and population-level effects for joystick direction (approach = 0.5 vs. avoidance movement = –0.5) and facial expression of the avatar. We also added psychopathy to the fully crossed population-level effects term.

This model could account for $\tilde{R}^2 = 43.29\%$ (95% HDI = [42.23, 44.28]) variation in the data, intercept = 9.72 (95% HDI = [9.67, 9.77]). Angry-looking avatars, $M = 861$ ms, $SD = 149$, were processed marginally faster than happy-looking avatars, $M = 876$ ms, $SD = 136$; $\tilde{b} = 0.02$ (95% HDI = [0.01, 0.04]), $p_{\tilde{b}} = 0.1\%$, $\delta_t = 0.05$ (95% HDI = [0.02, 0.09]). Note also that the avoidance reaction was slightly faster, $M = 861$ ms, $SD = 127$, than the approach reaction, $M = 876$ ms, $SD = 139$, $\tilde{b} = -0.02$ (95% HDI = [–0.04, –0.01]), $p_{\tilde{b}} = 0.3\%$, $\delta_t = -0.05$ (95% HDI = [–0.08, –0.01]. As expected, the Joystick Direction × Facial Expression parameter affected RT, $\tilde{b} = 0.13$ (95% HDI = [0.06, 0.19]), $p_{\tilde{b}} < 0.01\%$, $\delta_t = 0.29$ (95% HDI = [0.15, 0.44]). Joystick movement was facilitated in compatible trials ($M = 848$ ms, $SD = 130$) compared with incompatible trials ($M = 891$ ms, $SD = 149$). The magnitude of this effect varied across participants as a function of psychopathy, $\tilde{b} = -0.06$ (95% HDI = [–0.12, 0.01]), $p_{\tilde{b}} = 4.53\%$, $\delta_t = -0.13$ (95% HDI = [–0.28, 0.02]). Figure 4, right, shows that the relative facilitation of motor reaction in compatible trials (approach–happy; avoid–angry) in contrast to incompatible trials (avoid–happy; approach–angry) decreases with psychopathic traits. Note that there was a particularly small and thus negligible association of psychopathic traits and the general speed of the avoidance response, $\tilde{b} = 0.01$ (95% HDI = [0.00, 0.03]), $p_{\tilde{b}} = 4.97\%$, $\delta_t = 0.03$ (95% HDI = [–0.01, 0.06]). Psychopathic traits were related to a slight decrease in the speed of the avoidance response (see

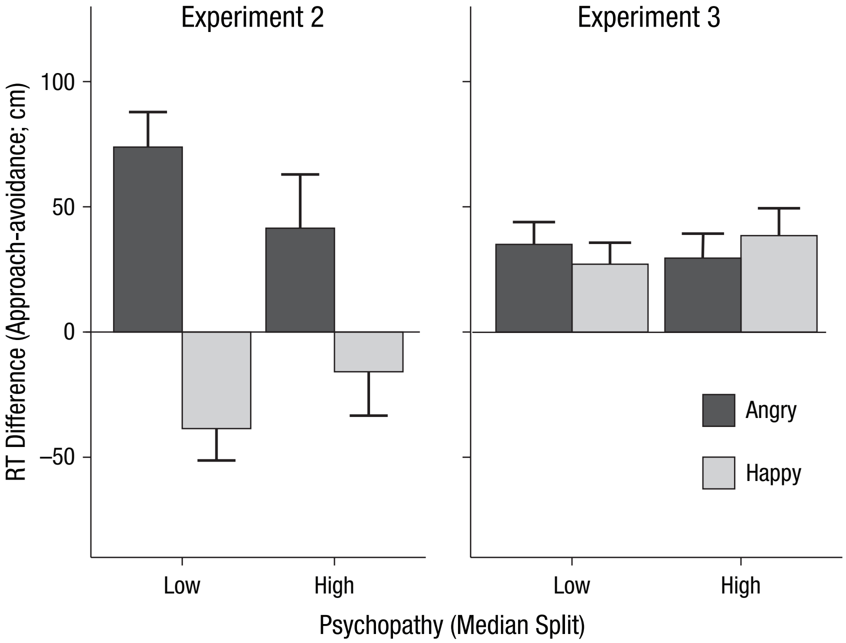

Fig. 3. Results from Experiments 2 and 3. The mean response-time (RT) difference is shown as a function of psychopathy (split on the median), separately for happy and angry faces. The mean RT difference was calculated as avoidance minus approach.

Fig. 4, right). All remaining effects were small and not distinguishable from zero, $p_{\tilde{b}} \geq 17.0\%$.

Next, we investigated whether the variability in the compatibility effect corresponded to individual variability in the subscales of the PPI-R-40. We computed the RT difference between incompatible and compatible trials and divided this difference by the individual standard deviation of the overall RT (Greenwald, Nosek, & Banaji, 2003). This RT score was substantially correlated with self-centered impulsivity, $r = -.27$ (95% HDI = [−.47, −.06]), $p_{\tilde{b}} = 0.7\%$, but not with coldheartedness, $r = -.08$ (95% HDI = [−.29, .14]), $p_{\tilde{b}} = 25.4\%$, or fearless dominance, $r = -.09$ (95% HDI = [−.31, .13]), $p_{\tilde{b}} = 21.7\%$. We can conclude that the impulsive facet of psychopathy promotes the tendency to approach angry-looking avatars instead of avoiding them, and thus may motivate potentially harmful or violent social interactions.

Furthermore, the RT score and the mean difference in IPD from avatars with happy facial expressions versus angry facial expressions were weakly correlated, $r = .23$ (95% HDI = [.00, .42]), $p_{\tilde{b}} = 2.83\%$. The stronger the compatibility effect in Experiment 2, the more participants regulated IPD in Experiment 1. Next, we investigated whether these scores could predict fearless dominance and self-centered impulsivity in two separate linear models (all variables standardized). IPD regulation, $\tilde{b} = -0.30$ (95% HDI = [−0.53, −0.08]), $p_{\tilde{b}} = 0.4\%$, but not RT, $\tilde{b} = 0.03$ (95% HDI = [−0.20, 0.26]), $p_{\tilde{b}} = 41.5\%$, could predict fearless dominance. In contrast, self-centered impulsivity could be better predicted by RT, $\tilde{b} = 0.25$ (95% HDI = [0.02, 0.48]), $p_{\tilde{b}} = 1.9\%$, than by IPD regulation, $\tilde{b} = -.16$ (95% HDI = [−0.39, 0.06]), $p_{\tilde{b}} = 7.6\%$. Thus, although IPD regulation and RT both predicted psychopathy, IPD appeared to be the better predictor for fearless dominance, and RT was more predictive for self-centered impulsivity.

Experiment 3: AAT With Response to a Stimulus-Irrelevant Cue

As demonstrated by Chen and Bargh (1999) and Rinck and Becker (2007), AAT compatibility effects may be found even when stimulus features are not relevant for the selection of the motor response. Especially in forensic contexts, faking of diagnostic outcomes and socially desirable responding are a prime concern. Indirect latency-based measures may circumvent these limitations by obscuring the contingency between independent and dependent variables of the experimental design (Schmidt, Banse, & Imhof, 2015). Therefore, we adapted the procedure of Experiment 2 and used a stimulus-irrelevant cue to instruct a motor response, comparable with the method of Rinck and Becker (2007).

Method

Participants were instructed to react according to the position of a small sphere next to the head of the avatar

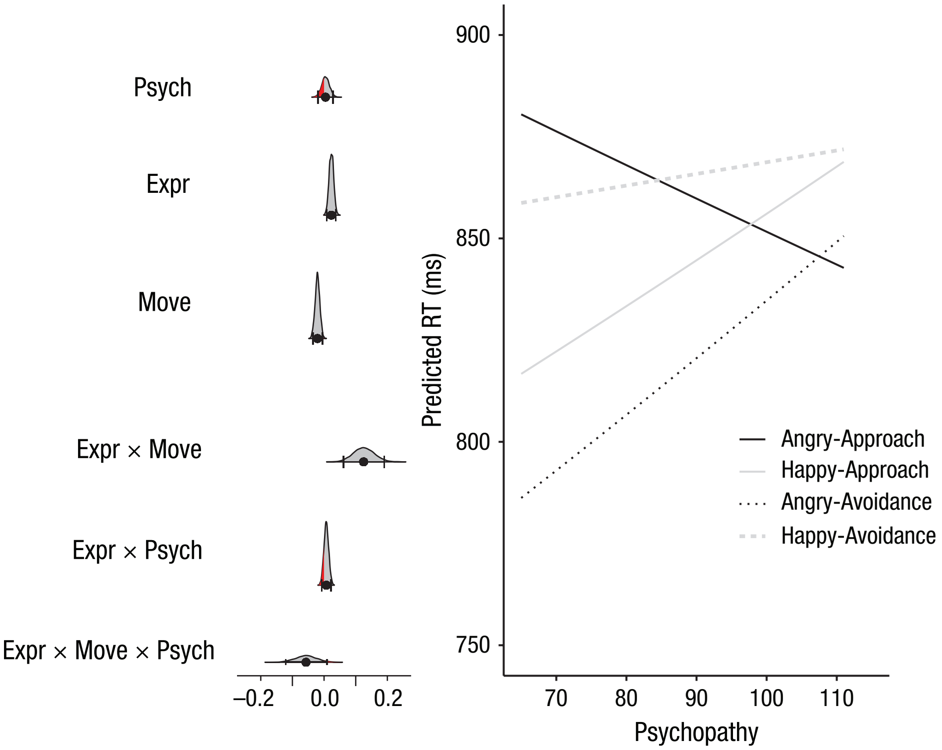

Fig. 4. Results from Experiment 2. The posterior density plots (left) show, for all population-level parameters in the model, the estimated effects of facial expression (Expr), joystick direction (Move), and psychopathy (Psych) on reaction time (RT). The dots represent the median of the respective posterior distribution, and error bars indicate 95% high-density intervals. The red/black-area indicates the proportion of posterior samples opposite the median and is thus a visual representation of the posterior median *p* value. The graph on the right shows RT as a function of psychopathy, separately for two joystick directions and two facial expressions of the avatar, as predicted by the final linear mixed regression model

(see Fig. 1b). Half of the participants pushed the joystick when the sphere was shown on the right side and pulled the joystick when the sphere was presented on the left side; the other half of the participants were instructed to do the opposite. In contrast to Experiment 2, reversing the instruction in a second block was unnecessary; therefore, all trials were presented in a fully randomized order within one block. The number of experimental trials was the same as in Experiment 2. Again, every participant completed eight training trials in which all avatars showed neutral facial expressions. In a stepwise analysis (see Experiment 2), outliers (2.42%; 305 of 12,160) and incorrect trials (0.8%; 95 of the remaining 11,855 trials) were discarded.

Results and discussion

Our data revealed neither facilitation of the approach reaction as a result of happy-faced avatars nor facilitation of the avoidance reaction as a result of angry-faced avatars (see Fig. 3, right). In addition, the RTs were, on average, about 150 ms faster than in Experiment 2. Nonetheless, we fitted a BLMM to the data, resembling the analysis of Experiment 2 but without psychopathy as a predictor, $\widetilde{R}^2$ = 52.9% (95% HDI = [52.0, 53.7]), intercept = 9.39 (95% HDI = [9.34, 9.44]). Again, the joystick direction modulated the RT, $\widetilde{b} = -0.06$ (95% HDI = [−0.08, −0.03]), $p_{\widetilde{b}} = 0.0\%$, $\delta_t = -0.16$ (95% HDI = [−0.23, −0.10]). Avoidance movements, *M* = 671 ms, *SD* = 113 ms, were faster than approach movements, *M* = 706 ms, *SD* = 137 ms. As in Experiment 2, angry-looking avatars, *M* = 686 ms, *SD* = 120 ms, were processed somewhat faster than happy-looking avatars, *M* = 691 ms, *SD* = 127 ms; $\widetilde{b} = 0.01$ (95% HDI = [0.00, 0.02]), $p_{\widetilde{b}} = 5.9\%$, δ_t = 0.02 (95% HDI = [−0.01, 0.05]).

In contrast to Experiment 2, we did not observe a facilitation effect for compatible trials compared with incompatible trials. The Joystick Direction × Facial Expression interaction term was perfectly centered at zero, $\widetilde{b} = 0.00$ (95% HDI = [−0.02, 0.02]), $p_{\widetilde{b}} = 49.1\%$, $\delta_t = 0.00$ (95% HDI = [−0.02, 0.02]). Thus, in this experiment, in which stimulus features were irrelevant for response selection, reaction speed remained largely unaffected by facial expression. In Experiment 2, in contrast, facial expression did instruct the participant to either pull or push the joystick. Therefore, we conclude that the emotional quality of the stimulus has to be relevant to the action to exert an effect via the AAT.

General Discussion

Both IPD regulation (Experiment 1) and the speed of the approach and avoidance reaction (Experiment 2) in response to social cues varied as a function of different psychopathic traits. We studied both effects in the same relatively large sample, thus allowing for direct comparison. We used Bayesian parameter estimation to account for the uncertainty in estimating the size of the effects. The main finding of this study is that certain psychopathic traits have more pervasive effects than previously thought. They are related to the reaction speed concerning approach and avoidance in virtual environments, and they are associated with the regulation of IPD in participants confronted with happy and angry avatars. Experiment 1 replicated the effect of diminished IPD regulation in response to social threat (Welsch et al., 2018). This strengthens the hypothesis that psychopathic traits, in particular self-centered impulsivity and fearless dominance, cause a lack in the integration of social cues (Hamilton, Hiatt Racer, & Newman, 2015). In addition, Experiment 2 showed that the compatibility effect (facilitation of the approach response toward happy avatars and of the avoidance response toward angry avatars) declines with increasing self-centered impulsivity, as indicated by a reduced RT when approaching angry-looking avatars (see Fig. 4). We interpret these results in light of equilibrium theory. That is, psychopathic traits, such as self-centered impulsivity, interfere with the normal equilibrium between approach and avoidance, which people seek. Stronger approach tendencies toward angry-looking people may result in violations of personal space requirements. Note that when correlating mean AAT scores and preferred IPD, we found a weak link between the two aggregates, suggesting that IPD is regulated by approach and avoidance forces (Argyle & Dean, 1965; Bailenson et al., 2001).

Why could the compatibility effect found in Experiment 2 not be replicated in Experiment 3? Be reminded that in Experiment 2, participants had to react in direct response to the facial expression of the avatar, whereas in Experiment 3, participants had to react to a socially irrelevant stimulus presented simultaneously with the avatar. Embodied accounts of approach-avoidance effects posit that arm flexion is facilitated in response to positive stimuli and arm extension is facilitated in response to negative stimuli (Chen & Bargh, 1999), irrespective of the level of stimulus processing. However, the validity of these effects has been challenged by meta-analyses (Laham, Kashima, Dix, & Wheeler, 2015; Phaf, Mohr, Rotteveel, & Wicherts, 2014) and by direct replication attempts (Rotteveel et al., 2015; Seibt, Neumann, Nussinson, & Strack, 2008).

Moreover, rigorous experimentation could show that the position of the self as a reference for approach and avoidance, as well as the anticipated outcome (perceived increase or decrease of stimulus distance), are crucial for the compatibility effect (Markman & Brendl, 2005). Note that when the instruction for motor response was carried by a stimulus-irrelevant cue in the VR-AAT of Experiment 3, the interaction effect of facial expression and joystick direction disappeared. Thus, when stimulus features could be ignored in response selection, they no longer affected approach or avoidance reaction speed. This finding is consistent with recent challenges (see Phaf et al., 2014; Rotteveel et al., 2015) to the findings of Chen and Bargh (1999) and thus favors distance-change accounts of the AAT effect (Laham et al., 2015), which state that the change of distance in the stimulus affects RT. One could also consider the idea that task order may have influenced our results. A habituation to the stimuli could have produced a decline in effect size from Experiment 1 to Experiment 3, but previous studies have not found habituation effects in AAT-related tasks using pictures (see Krieglmeyer & Deutsch, 2010; Rougier et al., 2018). Note also that the compatibility effect obtained in Experiment 2 was comparable in size (Marsh et al., 2005) or even slightly larger (Phaf et al., 2014) than effects found in previous studies that did not use avatars or a virtual environment. Having said this, we cannot fully dismiss a possible effect of habituation, as we did not control for task order, but the reduction in effect size would be small and could not serve as an explanation for the complete lack of an effect in Experiment 3.

IPD violations in psychopathy in light of equilibrium theory

Deficits in the processing of emotional expression may prevent individuals with psychopathic traits 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 diminished or absent (see Experiment 2) and thus cannot serve as regulatory forces. And this lack of regulatory forces translates into a diminished spatial reaction toward (or away from) the other person as a function of their facial expression.

The diminished reactivity toward social threat, as indicated by the correlation of fearless dominance and IPD regulation, may be interpreted as an adaptive strategy. Rather dominant and bold people may attempt to dominate threatening social encounters by closer interpersonal distances. Note, however, that we did not find this link in our previous study (Welsch et al., 2018). Thus, this hypothesis deserves to be further investigated. We also found an effect of self-centered impulsivity on the regulation of interpersonal distance consistent with the findings of Welsch et al. (2018). 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). This is also supported by our findings in Experiment 2, that mainly self-centered impulsivity affected the approach-avoidance reaction. When fast integration of social cues into distance behavior is needed, self-centered and impulsive individuals may fail to do so.

Transferability to clinical samples

The present study has shown that regulation of distance toward facial expression can be reliably assessed using a virtual environment. This was the case for the stop-distance task as well as for the AAT, as demonstrated with a subclinical student sample. The results suggest that this VR paradigm including socially threatening scenarios can be extended to spatial behavior in severe psychopathy. Thus, the measurement of IPD regulation and approach-avoidance behavior in VR may be a starting point in the development of a diagnostic toolset in the study of psychopaths' deviant social behavior. In the present study, fearless dominance could be better predicted by IPD regulation, and self-centered impulsivity was best predicted by differences in reaction speed between compatible and incompatible trials. Consequently, IPD, as well as the VR-AAT, may be used as complementary tools to study different facets of psychopathy. Whereas the stop-distance task may capture evaluative social-distance behavior, the AAT may measure more automatic and impulsive aspects of social-distance behavior, but note that people are not well aware of their IPD (Hall, 1966; Leibman, 1970).

Although IPD-regulation deficiencies in individuals with psychopathic traits were relatively small in our student sample, one would expect stronger effects in highly psychopathic samples. Note that we merely sampled a general student population. We presented explicit and rather strong facial expressions. Considering psychopaths' deficit in recognizing subtle facial expressions (Hastings et al., 2008), weaker social cues may produce yet more pronounced failure to regulate IPD.

Transferability to real-world scenarios

An underestimation of distances in virtual environments has been reported, but this effect seems to disappear when rendering and level of detail are of sufficient quality (Loyola, 2017; Mohler, Creem-Regehr, Thompson, & Bülthoff, 2010). Because we are interested in the effects of manipulated social cues on perceived IPD, the absolute level of the estimates, even if distorted in VR, is rather irrelevant as long as the direction and the slope of the effects remain unaffected by the virtual environment, which seems likely in the present experiments (for a discussion, see von Castell, Hecht, & Oberfeld, 2018). A recent real-world study by Lobbestael et al. (2018) lends credibility to our findings. In their experiment, the difference in size of personal space between approaches of a dominant confederate and a nondominant confederate was related to psychopathic self-centered impulsivity. Thus, dominance of the approaching confederate did regulate IPD to a relatively smaller degree in self-centered individuals than in less self-centered individuals. We interpret these real-life data as converging evidence to the VR scenario applied in Experiment 1, which does substantiate the ecological validity of our task. Furthermore, when comparing effects in a stop-distance task in reality and VR, there seem to be no systematic differences (Hecht, Welsch, Viehoff, & Longo, 2019; Iachini et al., 2016), IPD appears to be as functional in VR as it is in reality.

Conclusion

In sum, our findings show that psychopathy affects the regulation of IPD in response to social cues. Individuals with psychopathic traits fail to regulate interpersonal distance in tune with emotions expressed by the other person. This failure is consistent with a reduced response to social cues in approach and avoidance reactions. A virtual environment is suitable to study such effects.

Action Editor

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

Author Contributions

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

authors approved the final version of the manuscript for submission.

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Agnes Münch programmed the tasks and created the virtual environment and the avatars. Martin Rettenberger gave valuable advice on diagnostic instruments. We thank Lea Thomas, Lisa Gölz, and Chiara Oftring for assistance with data collection. This study was approved by a local ethics committee of the Johannes Gutenberg-Universität Mainz (protocol number: 2016-JGU-psychEK-021; Title: “Personal Space and Emotion; Why Psychopaths Do Not Stand Back”).

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.

Notes

1. For all analyses we tested different weakly informative priors, which did not alter our inferences. This is not surprising, as Bayesian parameter estimation is not heavily influenced by prior choice.

2. We applied normally distributed priors ($M = 0$, $SD = 1$) to all population-level effects, with Cholesky priors on the (residual) correlation ($\eta = 1$) and a *t*-distributed prior, to allow for thicker tails ($df = 3$, $M = 0$, $SD = 1$) on the centered intercept and the variance parameters. Then, prior *SD*s were scaled to the *SD* of the response distribution. These priors are only very weakly informative and mostly help in the regularization of the posterior distributions. We computed four Hamilton-Monte-Carlo chains with 2,000 iterations each and 50% warm-up samples. Trace plots of the Markov-chain Monte-Carlo permutations were inspected for divergent transitions. All Rubin-Gelman statistics (Gelman & Rubin, 1992) were well below 1.1.

3. $\tilde{b}$ values represent the median as a point estimate of the b-parameter posterior distribution.

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