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Revealed masks: Facial mimicry after oxytocin administration in forensic psychopathic patients

Ronald J.P. Rijnders [a,b,*], Anton van Boxtel [c], Minet de Wied [d], Jack van Honk [e,f,g], Maaike M. Kempes [h,i,1], Peter A. Bos [i,1]

[a] Netherlands Institute for Forensic Psychiatry and Psychology, Forensic Observation Clinic "Pieter Baan Centrum", Carl Barksweg 3, 1336 ZL, Almere, the Netherlands
[b] Utrecht University, Faculty of Social Sciences, Department of Psychology Heidelberglaan 8, 3584 CS, Utrecht, the Netherlands
[c] Tilburg University, Department of Cognitive Neuropsychology, Warandelaan 2, 5000 LE, Tilburg, the Netherlands
[d] Utrecht University, Faculty of Social and Behavioural Sciences, Department of Youth and Family, Heidelberglaan 1, 3584 CS, Utrecht, the Netherlands
[e] Utrecht University, Faculty of Social and Behavioural Sciences, Department of Psychology, Heidelberglaan 8, 3584 CS, Utrecht, the Netherlands
[f] University of Cape Town, Department of Psychiatry and Mental Health, J-Block, Groote Schuur Hospital, Observatory, 7925, Cape Town, South Africa
[g] University of Cape Town, Institute of Infectious Diseases and Molecular Medicine, Anzio Rd, Observatory, 7925, Cape Town, South Africa
[h] Netherlands Institute for Forensic Psychiatry and Psychology, Department of Science and Education, Herman Gorterstraat 5, 3511 EW, Utrecht, the Netherlands
[i] Leiden University, Faculty of Social and Behavioural Sciences, Institute of Education and Child Studies, Wassenaarseweg 52, 2333 AK, Leiden, the Netherlands

A B S T R A C T

Facial mimicry serves as an evolutionarily rooted important interpersonal communication process that touches on the concepts of socialization and empathy. Facial electromyography (EMG) of the corrugator muscle and the zygomaticus muscle was recorded while male forensic psychopathic patients and controls watched morphed angry or happy facial expressions. We tested the hypothesis that psychopathic patients would show weaker short latency facial mimicry (that is, within 600 ms after stimulus onset) than controls. Exclusively in the group of 20 psychopathic patients, we tested in a placebo-controlled crossover within-subject design the hypothesis that oxytocin would enhance short-latency facial mimicry. Compared with placebo, we found no oxytocin-related significant short-latency responses of the corrugator and the zygomaticus. However, compared with 19 normal controls, psychopathic patients in the placebo condition showed significantly weaker short-latency zygomaticus responses to happy faces, while there was a trend toward significantly weaker short-latency corrugator responses to angry faces. These results are consistent with a recent study of facial EMG responses in adolescents with psychopathic traits. We therefore posit a lifetime developmental deficit in psychopathy pertaining short-latency mimicry of emotional facial expressions. Ultimately, this deficit in mimicking angry and happy expressions may hinder the elicitation of empathy, which is known to be impaired in psychopathy.

1. Introduction

With an estimated global prevalence of 0.5%–1.2% in the general population (Hare, 1996; Neumann and Hare, 2008; Sanz-García et al., 2021), psychopathic persons are believed to be involved in 30%–40% of violent crime in the United States (Kiehl and Sinnot-Armstrong, 2013). Psychopathy as a lifelong personality disorder is operationally defined by the Psychopathy Checklist-Revised (PCL-R) (Hare, 2003). Its phenotypic expression is heterogeneous (Brinkley et al., 2004), but some core features are invariably present, like affective empathy deficits (Mullins-Nelson et al., 2006; Rijnders et al., 2021a). Based on the assumption that mimicry is a precursor to the empathy process (Hatfield et al., 1994, 2009; Rijnders et al., 2021a) we investigated mimicry responses to morphed pictures of emotional facial expressions in forensic psychopathic patients. In addition, we investigated whether the neuropeptide oxytocin contributes to enhancing mimicry.

Mimicry includes emotional postures, gestures or facial expressions (Chartrand and van Baaren, 2009) and is part of a highly dynamic interpersonal communicative process (Chartrand et al., 2005). Mimicking another person's emotional facial expression can elicit the same affective resonance and isomorphic emotional states in the observer (Adolphs, 2006; Olszanowski et al., 2019; Söderkvist et al., 2018) partly depending on the observer's social appraisal of the context and the relationship with the sender (Hess and Fischer, 2022). Blocked facial mimicry due to congenital facial paralysis in Moebius patients resulted in lower intensities in the perception of others' facial

* Corresponding author. Netherlands Institute for Forensic Psychiatry and Psychology, Forensic Observation Clinic "Pieter Baan Centrum", Carl Barksweg 3, 1336 ZL, Almere, the Netherlands.
E-mail addresses: r.rijnders@dji.minjus.nl (R.J.P. Rijnders), A.vanBoxtel@tilburguniversity.edu (A. van Boxtel), m.dewied@uu.nl (M. de Wied), jackvanh@gmail.com (J. van Honk), m.kempes@dji.minjus.nl (M.M. Kempes), p.a.bos@fsw.leidenuniv.nl (P.A. Bos).
[1] Both authors contributed equally.

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expressions of sadness, fear, anger and disgust (Schiano Lomoriello et al., 2023). Mimicry of emotional facial expressions is often measured with facial electromyography (EMG), a sensitive technique for inferring subjective mood states or affective responses (van Boxtel, 2010). Watching a happy facial expression elicits zygomaticus major muscle activation and inhibition (i.e., relaxation) of the corrugator supercilii muscle activity (van Boxtel et al., 2022). Looking at an angry facial expression induces an increased activation of the corrugator with simultaneously little or almost null effect on the zygomaticus (Dimberg, 1982).

EMG studies of mimicry responses in adult psychopathic individuals or adolescents with psychopathic traits are scarce and inconsistent. Nonpsychopathic and psychopathic male offenders compared with normal controls showed no significant differences in corrugator responses to both neutral and morphed angry, sad, or happy facial expressions (Künecke et al., 2018). In contrast, weaker corrugator EMG responses to sad facial expressions were found in male adolescents with disruptive behavior disorders (DBD) compared with healthy controls, although no significant difference could be established between DBD adolescents with low or high psychopathic traits (de Wied et al., 2012). A recent study revealed significant group differences in EMG responses to dynamic facial emotional expressions in male DBD adolescents with low vs. high psychopathic traits (van Boxtel et al., 2022). These differences occurred in the 500-ms early rise time of dynamic expressions after stimulus onset, often even at very short latencies of 100 or 200 ms, and not during the 1500-ms phase of maximal expression. Within this 500-ms rise time, high-CU adolescents showed both smaller inhibitory corrugator responses and weaker zygomaticus responses to happy expressions and weaker corrugator responses to angry or sad expressions compared with those with low CU traits and healthy controls. Emotional cues may reach the amygdala through several fast subcortical and cortical pathways (for a comprehensive overview, see: van Boxtel et al., 2022). Starting from the assumption that deficient empathy seen in psychopathic individuals is associated with amygdala dysfunction (Blair, 2005b), the current study examines early mimicry responses (i.e. faster dan 600 ms) to dynamic emotional facial expressions in psychopathic patients.

In addition, this study examines the effect of the neuropeptide oxytocin (OT) on the early zygomaticus and corrugator mimicry responses. OT plays an important role in social understanding and interpersonal behavior (Caldwell, 2017; Domes et al., 2007; Landgraf and Neumann, 2004; Meyer-Lindenberg et al., 2011; Schiller et al., 2023), and empathy (Barchi-Ferreira and Osório, 2021). Moreover, in healthy men, OT resulted in increased mimicry of emotional facial expressions, especially angry children's faces (Korb et al., 2016), although the participants' responses were measured over a longer time and therefore cannot be considered automatic early mimicry responses. However, another study in healthy male participants found no positive effects of OT on facial mimicry (Trilla et al., 2020). Interestingly, in an fMRI study, antisocial personality disordered male violent offenders with psychopathy compared to those without psychopathy failed to appropriately process fearful facial expressions with increasing emotional intensity, but these differences were abolished after administration of 40 IU OT. This result indicates the potential to neurochemically modulate empathic processing of others' distress in psychopathic violent offenders (Tully et al., 2023). However, this study did not examine early facial mimicry responses, in addition to the fact that fMRI responses are not easily linked to early facial mimicry responses. To our knowledge, no studies have examined OT effects on early facial mimicry in people with high levels of psychopathy.

In this study, we examined PCL-R confirmed forensic psychopathic patients admitted to five high-security forensic psychiatric hospitals in the Netherlands, as well as normal controls. The first major objective was to examine early zygomaticus and corrugator mimicry responses (that is, the first 600 ms after stimulus onset) to morphed emotional facial expressions of happiness and anger. Since psychopathic patients are thought to have difficulties processing negative and positive emotions (Blair, 2005a; Dawel et al., 2012), we first hypothesized that compared with normal controls, they would exhibit weaker early corrugator activation to angry facial expressions and less corrugator inhibition to happy facial expressions. Second, we hypothesized that the increase in zygomaticus activity during happy expressions would be smaller in psychopathic patients compared with normal controls (second hypothesis).

Exclusively in the group of psychopathic patients, our second major objective was to investigate the effect of a single intranasal dose of 24 IU OT on the early zygomaticus and corrugator mimicry responses to morphed happy and angry facial expressions. Based on the OT social salience hypothesis (Shamay-Tsoory and Abu-Akel, 2016) and OT-associated increased attention to emotional facial expressions, especially in males (Boyle et al., 2022), we hypothesized that in the OT condition, compared with placebo, happy expressions would elicit a stronger zygomaticus activation as well as a stronger corrugator inhibition (third hypothesis). We also expected stronger corrugator EMG responses in the OT condition, compared with placebo, when looking at angry faces (fourth hypothesis).

2. Methods and materials

2.1. Participants

Psychopathy was diagnosed using Hare's Psychopathy Checklist-Revised PCL-R (Hare, 1991) in which a maximum score of 40 point represents maximum psychopathy (see Table S1 in the Supplementary Information). Compared with a diagnostic cut-off score of 30 in North America, several European studies used lower cut-off scores (e.g., Cooke et al., 2005). Initially, 24 male forensic psychopathic patients and 21 male normal control subjects were included in the present study, which was part of a larger study in this patient group (see Rijnders et al., 2021b). The psychopathic patients were selected if their PCL-R total score was 26 or higher. The normal control subjects were male security guards or nursing staff members recruited from two forensic psychiatric hospitals. Similar inclusion and exclusion criteria were applied to them, except that they could not be diagnosed with the PCL-R because this instrument is not appropriate for a non-forensic group. Instead, to check for psychopathic features, they completed the Psychopathic Personality Inventory-Revised PPI-R (Lilienfeld and Widows, 2005).

Additional requirements for participation were a good physical health, an age between 18 and 60 years, a normal visual acuity, and a total IQ of 80 or above. IQ data were not known for the normal controls. Therefore, we decided to use education attainment as a selection criterion. The lower limits of their educational level corresponded to an IQ of at least 85 or above. Exclusion criteria were color blindness, illiteracy, insufficient knowledge of Dutch language, a current severe psychiatric disorder like a psychotic, a depressive, or a severe anxiety disorder (assessed with the Mini-International Psychiatric Interview (Sheehan et al., 1998), endocrine disorders or brain diseases, or the use of selective serotonin reuptake inhibitors, selective norepinephrine reuptake inhibitors, antipsychotics, or hormonal libido inhibitors.

Of the 24 patients who were enrolled in this OT study, four were eventually excluded from analysis, one because of missing EMG data, and three others due to their co-morbid DSM-IV-TR Pervasive Developmental Disorder Not Otherwise Specified (APA, 2000). In addition, two normal controls were excluded from analysis, one because of a psychopathic tendency according to the PPI-R, and the other as he turned out to be alexithymic (Bagby et al., 1994). The 20 remaining psychopathic patients were tested in two separate sessions with either OT or placebo. The 19 remaining normal controls did not receive either placebo or OT and were therefore tested in a single session. They served as the reference population. Detailed sample characteristics are presented in Table 1.

Participants provided written informed consent prior to their

Table 1
Demographic information.

	Psychopathic patients (N = 20)	Normal controls (N = 19)
Age[1] (years)	39.4 ± 9.5	36.5 ± 9.0
(range)	(23.7–54.9)	(25.1–57.5)
Ethnic-cultural and national origin (all participants currently had the Dutch nationality)	18 Europeans and Mediterraneans (viz 15 Dutch, 1 Belgian and 2 Turks), 1 Surinamese African and 1 Surinamese Chinese-African.	17 Europeans and Mediterraneans (viz 14 Dutch, 2 Moroccans, and 1 Turk), 1 Dutch Antillean, and 1 Surinamese - Hindu
Duration of mandatory treatment (months)	118 ± 84	
PCL-R total score (range)	30.9 ± 2.7 (26–36)	
PCL-R facets	–	
Interpersonal facet (facet 1)	5.6 ± 1.3	
Affective facet (facet 2)	7.4 ± 0.8	
Lifestyle facet (facet 3)	7.8 ± 1.3	
Antisocial facet (facet 4)	8.3 ± 1.4	
Category "Other" (two items)	1.9 ± 1.4	
PPI-R total score (range)		287.0 ± 28.3 (243–336)
T-scores		
PPI-R total		47.5 ± 10.1
PPI-R Factor Fearless Dominance		55.2 ± 8.8
Social potency		54.4 ± 11.5
Fearlessness		52.0 ± 11.7
Stress immunity		58.2 ± 8.7
PPI-R Factor Impulsive Antisociality		41.8 ± 10.6
Machiavellian egocentricity		41.6 ± 10.8
Rebellious nonconformity		48.0 ± 10.9
Blame externalization		43.8 ± 8.1
Carefree nonplanfulness		47.1 ± 11.3
Coldheartedness		51.0 ± 12.0

For all variables the means ± standard deviations are reported. 1 No significant group differences in age ($t_{37} = 0.95$, $p = 0.35$). All patients and normal controls grew up and were educated in the Netherlands from an early age. There were no cultural barriers in either group that could eventually interfere with test instructions or test attitudes.
PCL-R = Psychopathy Checklist-Revised (including four facets and two items that do not load on the four facets, i.e. category "Other"; see also Table S1 in the Supplementary Information).
PPI-R = Psychopathic Personality Inventory-Revised (two factors and eight subscales, including the subscale Coldheartedness that does not load on the two PPI-R factors).

participation. The study was approved by the Medical Research Ethics Committee of the University Medical Centre Utrecht, The Netherlands (protocol number 12/056), and was carried out in accordance with the guidelines of the Declaration of Helsinki (World Medical Association, 2013). The participants received a monetary compensation of 30 Euros.

2.2. Study design

The 20 psychopathic patients followed a within-subject, double-blind, counterbalanced, cross-over design, which was in line with previous studies (e.g. Andari et al., 2010; Guastella et al., 2010; Lischke et al., 2012). In two test sessions they received either a nasal spray containing 24 IU OT or a placebo nasal spray consisting of physiological saline. The mean time interval between the two test days was 11.9 ± 3.1 days. The mean time interval between self-administration of the intranasal spray and the start of the dynamic morphing task on both test days was 57.2 ± 6.5 min and 56.9 ± 5.3 min, respectively. All participants were instructed to refrain from cigarette smoking and caffeine consumption at least 1 h before the start of the test session. The overall test procedure for the normal controls was similar to that of the patient group, except that they were tested on one day only, as they did not apply OT. All participants completed the entire test procedure. PCL-R scores including the PCL-R facet scores, and the mean T-scores of the PPI-R combined scales including the higher order PPI-R dimensions Fearless Dominance and Impulsive Antisociality are presented in Table 1.

2.3. Dynamic morphed facial pictures

The dynamic facial morphing task was programmed in E-Prime version 1.2 (Psychology Software Tools, Sharpsburg, USA) and presented on a 17-inch, 120 Hz TFT monitor. Pictures of four different human faces (two male and two female Caucasians) from two standardized photo sets were used (Ekman and Friesen, 1976; Lundqvist et al., 1998). Participants were instructed to look at a small white cross that appeared on a black computer screen for 1000 ms, which served as baseline period. Then a neutral face appeared that immediately started linearly morphing into either an angry or a happy face (see Fig. 1). In total 32 morphed pictures were presented in a random order: four happy faces and four angry faces, each type of expression being produced by two different females and two different males, and each stimulus being repeated four times. So each protagonist showed both a happy and an angry expression four times.

A baseline period of 1000 ms preceded the start of stimulus onset. Participants were instructed to look at the small white cross during this baseline period. Then a neutral face appeared that immediately started linearly morphing into either a happy or angry face, meaning the faces were presented one at a time at high speed in order from low intensity to high intensity. Emotional expression from 0% to 100% emotional intensity occurred in 40 steps of 40 ms each. The fully morphed emotional face was then statically portrayed for another 2000 ms. Then a black screen appeared for 6000 ms before the start of a new baseline period. The five pictures of the two protagonists shown here represent the total range of emotional expression (From Hermans et al., 2006; Figure used with permission).

2.4. Facial EMG recordings and quantification

Facial EMG activity was recorded from two facial muscles: corrugator supercilii (inducing a frown expression) and zygomaticus major (inducing a smile-like elevation of the mouth corner) (Hermans et al., 2006; Larsen et al., 2003; Sonnby-Borgström, 2002). Before attaching the EMG surface electrodes, the skin was cleansed with 70% isopropyl alcohol swaps. Two FLAT Ag/AgCl Active electrodes (Biosemi) were filled with Elefix Z-401CE paste (Nihon Kohden GmbH, Germany) and then attached to the skin above the left corrugator supercilii. Placement was parallel to the longitudinal direction of the muscle with a distance of about 1 cm between the centers of each sensor. The same procedure was applied to the placement of the two electrodes above the left

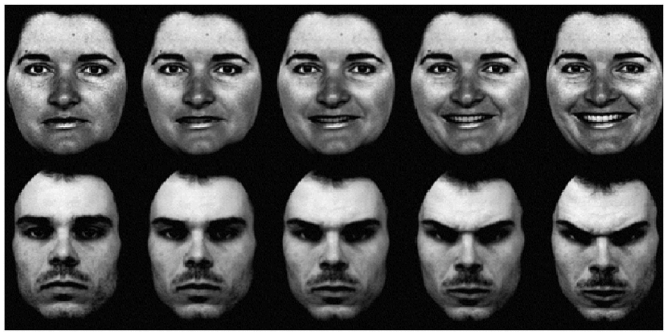

Fig. 1. Visualization of the sequential steps in dynamic facial morphing.

zygomaticus major. Finally, two reference electrodes were placed on the central and right forehead skin with a distance of 6–8 cm between the centers of each sensor.

The raw EMG signals were digitized with an ActiveTwo AD-box amplifier (Biosemi, Amsterdam, 24 bit resolution) at a rate of 2048 Hz (with 24 times oversampling), anti-aliasing filtered at 400 Hz, and stored on a Windows notebook. The EMG signals were then further processed with homemade software. They were 20-Hz digitally high-pass filtered to remove low-frequency artifacts (cf. van Boxtel, 2010). EMG responses were then visually inspected by two authors (AvB, RJPR) for remaining technical artifacts or strong potentials caused by disruptive actions like coughing, sneezing, strong eyeblinks, etc. Responses affected by such actions were removed by consensus. Removing records during this inspection did not affect the analysis design since each stimulus was presented four times. Thus, deleting one or two (in a single case even three) EMG responses did not lead to an incomplete design. In the control group, the removal rate was 4.8%, while in the patient group it was 2.5% in the OT condition and 3.0% in the placebo condition.

For each morphed picture, EMG was recorded during a period of 4600 ms: (1) the 0–1000 ms baseline period before onset of dynamic facial morphing, (2) the 1600-ms linear morphing period, and (3) the 2000-ms period of maximal expression. For analysis purposes the entire 4600-ms period was divided into intervals of 200 ms. The optimal morphing duration for processing happiness and anger expressions is several hundred milliseconds after stimulus onset (van Boxtel et al., 2022; Hoffmann et al., 2010; Sato and Yoshikawa, 2004). These short-latency facial mimicry responses are thought to be automatic, amygdala-processed preconscious responses that are by definition difficult to control voluntarily, and as such might have diagnostic value for psychopathy (van Boxtel et al., 2022). Therefore, we analyzed short-latency EMG responses during a 600-ms period following morphing onset. For each morphed picture, the mean rectified EMG value in the 1000 ms baseline period was calculated and the average EMG value during the 600-ms periods was expressed as a percentage of baseline value.

2.5. Statistical analyses

Statistical analyses were performed using Microsoft Excel 2016 and SPSS version 27. EMG responses after stimulus onset were expressed as a percentage of the 0–1000 ms baseline activity. EMG responses were analyzed during the first 600 ms of the increasing emotional expression after stimulus onset (i.e., 1000–1600 ms). For greater temporal resolution, we also separately analyzed the three consecutive 200 ms periods within this 600-ms early rise time (i.e. 1000–1200 ms, 1200–1400 ms, and 1400–1600 ms).

Comparisons of early corrugator or zygomaticus EMG responses between the normal control group and psychopathic patients in the placebo condition were performed with independent samples *t*-tests (one-tailed), assuming equal or unequal variances. Within the group of psychopathic patients, comparisons between EMG responses obtained during OT and placebo conditions were performed using paired samples *t*-tests (one-tailed). Finally, Pearson's correlations between psychopathy scores and EMG responses during the 600-ms early rise time were performed to further specify the effects regarding the relationship between psychopathic severity and EMG responses.

3. Results

Results are presented in Fig. 2 and Table 2.

3.1. Early rise time EMG responses of psychopathic patients in the placebo condition vs. those of normal controls

In agreement with expectations, psychopathic patients showed a marginally significant weaker corrugator EMG response to angry faces in the 600-ms early rise time than controls ($p = 0.072$). On a more fine-grained scale, a trend towards a significantly weaker response was also found during the first two consecutive 200-ms periods within this 600-ms period ($p = 0.074$ and $p = 0.098$, respectively). In contrast to expectations, corrugator inhibition during happy faces was not significantly different between groups.

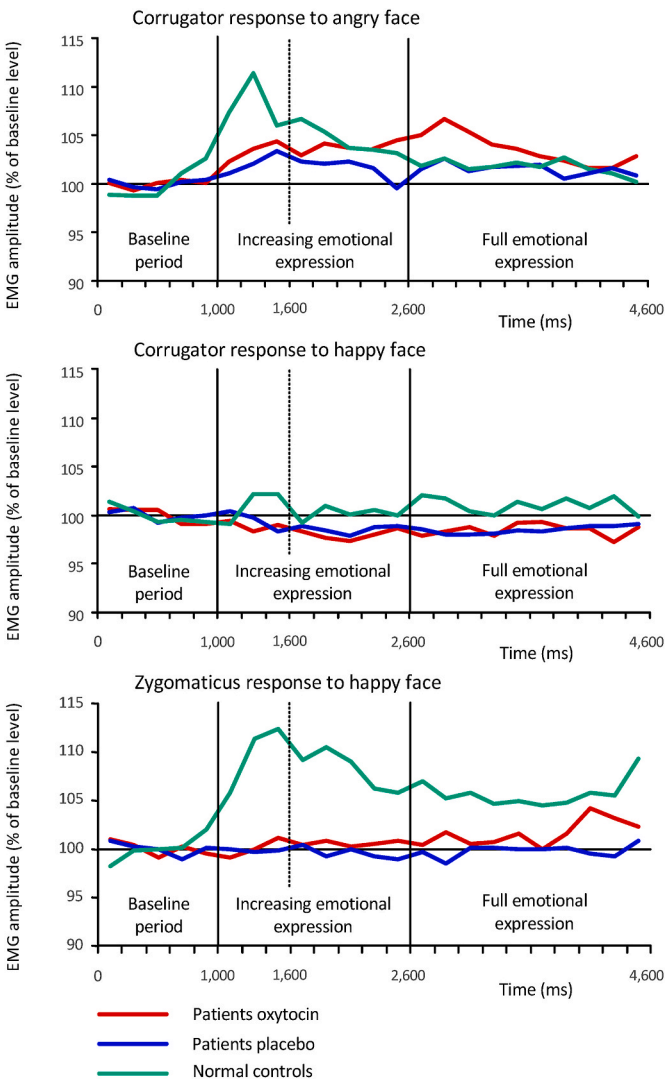

Fig. 2. Facial EMG responses to morphed emotional facial expressions in psychopathic patients and normal control subjects.

Also in agreement with expectations, psychopathic patients showed a significantly weaker zygomaticus 600-ms early EMG response to happy faces than controls. This difference was significant during all three consecutive 200-ms periods (all $ps < 0.05$).

3.2. Early rise time EMG responses of psychopathic patients in OT and placebo conditions

No significant differences between OT and placebo conditions were observed in both corrugator and zygomaticus EMG responses during angry and happy expressions, which contradicted our third hypothesis. However, there was a trend toward a significantly stronger corrugator inhibition in the OT condition when looking at happy faces during the first 200-ms period ($p = 0.074$).

Table 2
Mean EMG responses (SD) during the early dynamic phase of emotional facial expressions.

Time (ms)	1000–1600	1000–1200	1200–1400	1400–1600
Facilitatory corrugator response to angry face				
Patients oxytocin (% baseline)	103.4 (0.12)	102.3 (0.08)	103.6 (0.12)	104.4 (0.16)
Patients placebo (% baseline)	102.2 (0.04)	101.1 (0.03)	102.0 (0.04)	103.4 (0.07)
Normal controls (% baseline)	108.3 (0.17)	107.4 (0.18)	111.4 (0.30)	106.0 (0.12)
Placebo vs. normal controls	$t_{20} = -1.52$; $p = 0.072$ $d = -0.50$	$t_{19} = -1.50$; $p = 0.074$ $d = -0.49$	$t_{19} = -1.34$; $p = 0.098$ $d = -0.44$	$t_{28} = -0.84$ $d = -0.27$
Oxytocin vs. placebo	$t_{19} = 0.47$ $r^2 = 0.010$	$t_{19} = 0.59$ $r^2 = 0.009$	$t_{19} = 0.60$ $r^2 = 0.047$	$t_{19} = 0.27$ $r^2 = 0.021$
Inhibitory corrugator response to happy face				
Patients oxytocin (% baseline)	98.9 (0.03)	99.4 (0.03)	98.4 (0.04)	99.0 (0.04)
Patients placebo (% baseline)	99.5 (0.03)	100.4 (0.03)	99.7 (0.03)	98.4 (0.04)
Normal controls (% baseline)	101.1 (0.14)	99.1 (0.07)	102.2 (0.15)	102.1 (0.19)
Placebo vs. normal controls	$t_{19} = -0.52$ $d = -0.24$	$t_{23} = 0.78$ $d = 0.33$	$t_{20} = -0.70$ $d = -0.21$	$t_{19} = -0.84$ $d = 0.39$
Oxytocin vs. placebo	$t_{19} = -0.86$ $r^2 = 0.150$	$t_{19} = -1.51$; $p = 0.074$ $r^2 = 0.142$	$t_{19} = -1.30$ $r^2 = 0.016$	$t_{19} = 0.62$ $r^2 = 0.136$
Facilitatory zygomaticus response to happy face				
Patients oxytocin (% baseline)	100.0 (0.02)	99.1 (0.02)	99.9 (0.02)	101.1 (0.04)
Patients placebo (% baseline)	99.8 (0.01)	99.9 (0.02)	99.7 (0.03)	99.9 (0.02)
Normal controls (% baseline)	109.8 (0.21)	105.8 (0.13)	111.3 (0.24)	112.4 (0.28)
Placebo vs. normal controls	$t_{18} = -2.04$; $p = 0.028$ $d = -0.66$	$t_{19} = -1.98$; $p = 0.031$ $d = -0.64$	$t_{18} = -2.07$; $p = 0.027$ $d = -0.67$	$t_{18} = -1.98$; $p = 0.032$ $d = -0.64$
Oxytocin vs. placebo	$t_{19} = 0.35$ $r^2 = 0.000$	$t_{19} = -1.80$ $r^2 = 0.274$	$t_{19} = 0.28$ $r^2 = 0.031$	$t_{19} = 1.09$ $r^2 = 0.151$

Effect sizes of between-group differences (placebo vs. normal controls) are indicated by Cohen's *d*. Effect sizes of within-group differences (oxytocin vs. placebo) are indicated by the squared Pearsons' correlation coefficient r^2.

3.3. Psychopathy scores and early rise time EMG responses

Analyses in the psychopathic patients revealed no significant correlations between the PCL-R total scores and corrugator or zygomaticus responses in the 600-ms early rise time (all $ps > 0.424$). The same was true in the normal controls for correlations between PPI-R total scores and all EMG responses in the early rise time (all $ps > 0.391$).

4. Discussion

In the current study, we examined short-latency (that is, within 600 ms after stimulus onset) facial EMG responses to morphed angry and happy facial expressions in forensic psychopathic patients and normal controls. Psychopathic patients in the placebo condition showed significantly weaker short-latency zygomaticus responses to happy faces and a trend to significantly weaker short-latency corrugator responses to angry faces relative to normal controls. These results are consistent with a recent study of facial EMG responses in male DBD adolescents with high CU traits (van Boxtel et al., 2022). In that study, weaker short-latency responses to positive and negative dynamic emotional facial expressions were demonstrated in adolescents with high CU traits compared to those with low CU traits and normal controls, with the latter two groups not showing significantly different responses among themselves.

Our hypotheses that OT in psychopathic patients enhances facial mimicry compared with placebo proved incorrect. The corrugator responses to angry faces (third hypothesis) did not differ between OT and placebo conditions. Similarly, OT did not induce a stronger corrugator inhibition (i.e., relaxation) to happy expressions, except for a trend during the first 200 ms within the early rise time. The zygomaticus response to happy faces (fourth hypothesis) did not differ either between OT and placebo conditions.

Psychopathic patients are impaired in their short-latency mimicry responses of emotional expressions. Both our study in adult male psychopathic patients and the above study by Van Boxtel et al. (2022) in male adolescents with psychopathic traits together demonstrate short-latency mimicry deficits, which are believed to be automatic and unconscious. We therefore posit a lifetime developmental deficit in psychopathy regarding short-latency mimicry of emotional expressions. Whether this is an innate deficit or whether it stems from adverse experiences in early life, such as poor quality of parental care (Kraaijenvanger et al., 2017), is unknown. We assume that unraveling this lifetime developmental deficit in short-latency mimicry in psychopathic individuals will help to better understand their impaired empathy processing and ultimately lead to elucidating their maladaptive social interactions. Deficits in facial emotional information processing are thought to partly underlie empathy deficits (Rijnders et al., 2021a). The above study in antisocial personality disordered male violent offenders with psychopathy who have difficulty processing fearful facial expressions with increasing emotional intensity (Tully et al., 2023) partially indicates these deficits. There is debate as to whether deficits in facial emotional information processing stem from either a failure to allocate attention to stimuli deemed of secondary importance (according to the response modulation theory of psychopathy; see: Newman and Lorenz, 2003; Baskin-Sommers et al., 2009) or an innate deficient amygdala processing (Blair, 2001, 2005a). Amygdala dysfunction in psychopathy is thought to underlie impaired attention to the human eye region, reducing recognition of emotional facial expressions (Dadds et al., 2011). This forms the basis of integrated emotion systems theory (Blair, 2005b) that describes significant deficits in emotional face recognition as the root cause of a disrupted social interaction process in which facial expressions of fear and sadness are not understood as distress signals that should induce inhibition of aggressive behavior. The ultimate result is impaired empathic behavior. It is thought that amygdala subregions are of great importance in this process (cf. Rijnders et al., 2021a). However, it should be stipulated that it is not completely certain that attentional deficits to the eye region are actually amygdala-based as Terburg et al. (2012) showed improved fear recognition and longer attention to the eye region of fearful faces in nonpsychopathic subjects with bilateral basolateral amygdala damage. Response modulation theory and integrated emotion systems theory are not mutually exclusive, as both contextual factors and motivational forces could influence the likelihood and strength of psychopathic individuals' attentional gaze if it is in their best interest. If it matches their primary goal, they will focus their attention on the other person's eye region, which may lead to enhanced facial emotion recognition (Dadds et al., 2011). This could result in a boost in their empathy processing (Meffert et al., 2013; Rijnders et al., 2021a). Replication studies of mimicry in psychopathic individuals should also include a measure of the participant's current state empathy in order to thereby examine the relationship between empathy processing and mimicry, since mimicry is thought to be a

precursor to the empathy process (Hatfield et al., 1994, 2009; Ho et al., 2023; Rijnders et al., 2021a).

The social salience hypothesis of OT (Shamay-Tsoory and Abu-Akel, 2016) predicts that OT is of great importance in interpersonal relationships, as it is associated with attentional modulation depending on salience of external social cues, e.g., increased attention to emotional facial expressions, especially in men (Boyle et al., 2022). Nevertheless, the effect of OT on facial mimicry was different from what we had previously hypothesized. In fact, compared with placebo, OT has no significant effect on the corrugator responses to happy and angry faces, nor on the zygomaticus response to happy faces. We have no explanation for this null result, but perhaps attentional modulation as predicted by the social saliency hypothesis of OT (Shamay-Tsoory and Abu-Akel, 2016) does not apply to psychopathic individuals. Alternatively, the one-time administration of OT may be too little to bring about change and a multiple OT applications design should be followed to measure effects.

There are a few limitations to the current study. First, although we used a within-patient design, the number of patients was still low, which potentially increased the risk of underpowering of this study (Walum et al., 2016). Given the small effect sizes found (see Table 2), we believe that follow-up research with larger samples is warranted. Second, due to practical reasons the group of normal controls did not administrate OT. As a result, it was not possible to analyze whether OT has different effects in psychopathic patients compared with normal controls. Third, we used morphed facial expressions in which all aspects of facial muscle actions change linearly in a uniform manner, whereas this is not the case with natural expressions. As a result, morphed expressions may have a somewhat unnatural appearance compared with natural expressions (Bernstein and Yovel, 2015; Calvo et al., 2016; Krumhuber et al., 2013)) and have been suggested to be inferior to facial motion captured in video recordings (Becker et al., 2023).

Furthermore, we analyzed mimicry responses during a 600-ms early rise time. The optimal duration in terms of the perceived intensity and naturalness of basic emotions is in the range of 500–740 ms (cf. van Boxtel et al., 2022). Since the refresh rate of the emotional pictures was 40 ms, only 15 of the 40 pictures were displayed during this 600 ms, so the maximum intensity of the emotional expression (apex) was not reached. It is possible that this relatively slowly evolving presentation of stimuli might have negatively affected the strength of the mimicry responses of both psychopathic patients and normal controls.

Notwithstanding these limitations, the current study provides several valuable insights into the relationship between psychopathy and facial mimicry. A unique point of this study is that we investigated a clinically identified and PCL-R confirmed group of forensic psychopathic patients who were not treated with medication like selective serotonin reuptake inhibitors, selective noradrenaline reuptake inhibitors, antipsychotics, or hormonal libido inhibitors. This study showed reduced mimicry of corrugator and zygomaticus of angry and happy expressions, respectively. This finding is consistent with the results obtained in a study with male adolescents with disruptive behavior disorders and high CU traits (van Boxtel et al., 2022), which leads us to posit a lifetime developmental deficit in short-latency mimicry in psychopathy. This deficit may have negative implications for the evolvement of empathy in psychopathic individuals. We believe this finding also warrants new studies with larger numbers of PCL-R confirmed psychopathic patients.

Cleckley (1941) originally described the psychopath's severe deficits in the behavioral, emotional, and interpersonal domains. He stated that psychopathic individuals have a "convincing mask of sanity" and are unable to attribute genuine affective meaning to important experiences, despite their intact rational processes. Although further research is warranted, we assume that our study of short-latency facial mimicry has revealed some insight behind the masks of our group of psychopathic patients. One might also ask whether deficiencies in short-latency facial mimicry are a biomarker of psychopathy. EMG is an interesting parameter in that regard and we advocate future research on that application.

5. Clinical trial

Original title of the study: 'Social-emotional behavior in male psychopaths after double-blind placebo-controlled administration of intranasal oxytocin' Running title 'Behavior responses after OT'.

The study was pre-registered in EudraCT (European Union Drug Regulating Authorities Clinical Trials Database) with Eudractnumber 2010-024432–42. http://eudract.emea.europa.eu/schema/clinical_trial.

The Central Committee on Human Subjects Research (CCMO), as the competent authority for clinical research in the Netherlands, approved the research protocol with number NL35148.041.12 and Eudract number 2010-024432-42, pursuant to Article 13k of the Medical Research Involving Human Subjects Act (WMO), most recently on 25-9-2014. https://english.ccmo.nl/

The study with protocol number 12/056 was approved by the Medical Research Ethics Committee (METC) of the University Medical Centre Utrecht, The Netherlands. https://www.metcutrecht.nl/en/

CRediT authorship contribution statement

Ronald J.P. Rijnders: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anton van Boxtel:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Formal analysis. **Minet de Wied:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Jack van Honk:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Maaike M. Kempes:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Peter A. Bos:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of competing interest

We report no biomedical financial interests or potential conflicts of interest.

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Appendix A. Supplementary data

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