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Oxytocin increases recognition of masked emotional faces

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Summary The neuropeptide oxytocin has been shown to improve many aspects of social cognitive functioning, including facial emotion recognition, and to promote social approach behaviour. In the present study, we investigated the modulatory effects of oxytocin on the recognition of briefly presented facial expressions. In order to diversify the degree of visual awareness for the facial stimuli, presentation duration was systematically varied. Fifty-six participants were administered intranasal oxytocin or a placebo in a double-blind, randomized, between-subjects design. Participants viewed angry and happy target faces or neutral distractors for 18, 35, or 53 ms subsequently masked by neutral faces. Participants had to indicate the presence or absence of the briefly presented target face. Discrimination indices (d') showed that oxytocin generally enhanced detection accuracy of emotional stimuli. This effect was more pronounced for the recognition of happy faces. We provide evidence that a single dose of intranasally administered oxytocin enhances detection of briefly presented emotional stimuli. The possible role of stimulus valence and recognition difficulty is discussed.

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1. Introduction

The neuropeptide oxytocin is essential for bonding and attachment in mammals (Carter et al., 2008; Donaldson and Young, 2008) and has also been associated with human social behaviour (Heinrichs et al., 2009). In recent years, a number of studies focusing on the cognitive and affective effects of oxytocin have shown that intranasally administered oxytocin promotes recognition of emotional states (Domes et al., 2007b; Di Simplicio et al., 2009; Guastella et al., 2010), recollection of social stimuli (e.g., Rimmele et al., 2009) and improves the processing of positive social cues and facial expressions in particular (e.g., Unkelbach et al., 2008; Di Simplicio et al., 2009; Gamer et al., 2010).

Despite these recent advances in characterizing the effects of oxytocin on the processing of socially relevant stimuli such as emotional facial expressions, it is still unclear whether the reported effects of oxytocin are entirely due to modulations in evaluation and appraisal of these stimuli (Guastella et al., 2008) or whether oxytocin also modulates earlier stages of stimulus processing, such as visual attention and awareness (Guastella et al., 2009). Thus, in the present study, we used short presentation times of emotional stimuli in order to assess the effects of oxytocin on recognition of angry and happy facial stimuli under conditions of limited awareness. In order to vary the degree of visual awareness, equidistant increases of presentation durations were used. We expected that intranasally administered oxytocin would improve the recognition of emotional faces, and that the effect would extend even to stimuli presented under conditions of limited awareness.

2. Methods

2.1. Participants

Fifty-six male participants (mean age $\pm$ SD: 24.18 $\pm$ 3.12) were assigned to receive either 24 international units (IU) of oxytocin (N = 28; Syntocinon, Novartis, Basel, Switzerland) or placebo (N = 28) within a double-blind, randomized controlled study design.

All participants had normal or corrected-to-normal visual acuity, were free of medication, and did not report any history of endocrine, neurological or mental disorder. They were instructed to abstain from caffeine and nicotine on the day of the study. Smokers (more than 5 cigarettes a day) were excluded from participation in the study.

We planned to investigate a sample of 50 subjects (25 subjects oxytocin, 25 subjects placebo) to have sufficient power to detect medium-sized differences as determined by G-Power 3. Six additional participants were examined to account for presumed technical difficulties and difficulties in substance application.

The study was approved by the ethics committee of the University of Rostock and was carried out at the Department of Psychiatry, University of Rostock, between November 2009 and January 2010.

2.2. Procedure

After written informed consent was obtained, participants completed questionnaires on depression (Beck Depression Inventory), trait anxiety (State Trait Anxiety Inventory) and were familiarized with the use of the nasal sprays. Participants self-administered 3 puffs of oxytocin (each puff with 4 IU) or placebo per nostril, with the placebo containing all ingredients except for the peptide. Then all participants underwent a training session to ensure appropriate understanding of the experimental task. Forty-five minutes after substance application, participants answered a multidimensional mood questionnaire and started the experiment.

Randomization of substance allocation procedure was generated by the local compounding pharmacist. This sequence was concealed from all persons involved in recruitment and testing of the participants. Unblinding was done after completion of testing.

2.3. Experimental task

The experiment was conducted on a standard computer with a 17″ screen with a resolution of 800 $\times$ 600 and a refresh rate of 170 Hz (confirmed by a photodiode and an oscilloscope). Each trial started with a fixation cross (1000 ms) and a short blank screen (100 ms). Then, an angry, happy, or neutral face was presented for 18, 35, or 53 ms, followed by a ''mask'' showing a neutral face (see Fig. 1). The initial gaze was fixed to the middle of the facial stimulus (between the eyes and the mouth). Participants were explicitly informed that two facial stimuli would always appear in each trial, although they might only perceive one. Facial stimuli (eight male, eight female) were taken from the Karolinska Directed Emotional Faces. They were equivalent with regard to luminance ($F_{2,45}$ = .48, p = .625) and recognizability of the expressed emotions ($F_{2,45}$ = .95, p = .394). Two additional neutral faces (one male, one female) were selected as mask stimuli and presented in a pseudo-randomized order.

The experiment contained 288 trials, divided into eight blocks with 36 trials each. Prior to each block, an instruction was given regarding the target emotion in the following trials. In each block, 12 angry, happy, and neutral facial stimuli were randomly presented with varying durations (18, 35, or 53 ms). Following each target-mask pair, participants had 3 s to indicate whether the target emotion was present or absent (4 blocks angry present/absent and 4 blocks happy present/absent).

2.4. Statistical analysis

Participants' performance was analyzed based on signal detection theory. Conditional probabilities of hits and false alarms were calculated for each condition and participant. Afterwards, individual discrimination indices [$d' = Z_{hits} - Z_{false\ alarms}$] and response biases [$c = -0.5*(Z_{hits} + Z_{false\ alarms})$] were computed and analyzed using separate mixed-design ANOVAs with the within-subject factors of face valence (angry, happy) and presentation time (18, 35, 53 ms) and the group factor of drug condition (oxytocin, placebo). Greenhouse–Geisser corrections were applied if the assumption of sphericity was violated and significant interactions were followed by simple effects analyses. Analyses were performed using SPSS version 17. The significance level for all tests was $p < .05$.

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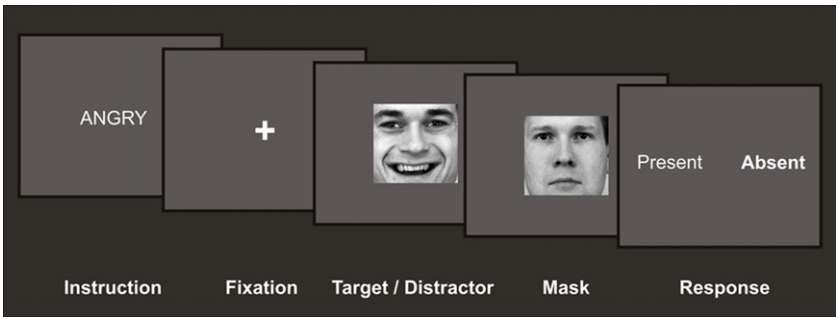

Figure 1 Trial structure of the experiment. Participants viewed an instruction cue prior to each block. A single trial started with a fixation cross presented for 1000 ms. Afterwards, an angry, happy, or neutral facial expression (target) was presented for 18, 35, or 53 ms and immediately followed by a neutral expression (mask) for 165 ms. Participants had 3000 ms to indicate the absence or presence of the target emotion.

3. Results

There were no differences with regard to age ($t_{54} = -.16$, $p = .870$), depression ($t_{54} = -.05$, $p = .960$), and trait anxiety ($t_{54} = -.30$, $p = .764$) between the oxytocin and placebo group. Both groups did not differ on measures of self-reported calmness ($t_{54} = .32$, $p = .750$), wakefulness ($t_{54} = .45$, $p = .657$) or mood ($t_{54} = -.94$, $p = .353$) prior to the start of the experiment.

With respect to recognition accuracy (d'), the ANOVA revealed a significant main effect of the drug condition ($F_{1,54} = 7.93$, $p = .007$; $\eta_p^2 = .128$), with subjects who were administered oxytocin showing enhanced recognition performance for emotional faces regardless of valence and presentation time of the target (see Fig. 2). Recognition accuracy increased with longer presentation of the target stimuli ($F_{1.80,97.17} = 74.09$, $p < .001$; $\eta_p^2 = .578$). In addition, a main effect of valence ($F_{1,54} = 150.08$, $p < .001$; $\eta_p^2 = .735$) illustrated that happy faces were generally better recognized than angry faces. A significant interaction of valence and drug condition ($F_{1,54} = 4.55$, $p = .037$; $\eta_p^2 = .078$) was followed by simple effects analyses, which showed that the effect of oxytocin on emotion recognition was more pronounced for happy ($F_{1,54} = 8.39$, $p = .005$; $\eta_p^2 = .134$) compared to angry faces ($F_{1,54} = 3.21$, $p = .079$, $\eta_p^2 = .056$). Furthermore, we found an interaction of valence and presentation time ($F_{1.77,19.23} = 3.75$, $p = .032$; $\eta_p^2 = .065$), indicating that recognition accuracy increased more rapidly for happy than for angry faces with longer presentation times. The interaction of substance and presentation time was marginally significant ($F_{1.80,97.17} = 2.97$, $p = .061$; $\eta_p^2 = .052$). Simple effects analyses of time illustrated a stronger effect of prolonged presentation on recognition accuracy in the oxytocin group (oxytocin: $F_{2,53} = 43.16$, $p < .001$, $\eta_p^2 = .620$; placebo: $F_{2,53} = 18.71$, $p < .001$; $\eta_p^2 = .414$). Descriptive results are presented in Supplementary Table 1.

With respect to response bias (c), i.e. how liberal or conservative the participants' responses to the stimuli were, the ANOVA revealed more conservative responding to longer presentation times of the target stimuli ($F_{2,108} = 68.16$, $p < .001$; $\eta_p^2 = .558$) and to happy compared to angry target stimuli ($F_{1,54} = 24.80$, $p < .001$; $\eta_p^2 = .315$). Simple effects analyses of the significant interaction of valence and presentation time ($F_{2,108} = 8.25$, $p < .001$; $\eta_p^2 = .133$) indicated that more conservative responding to happy compared to angry facial expressions was particularly present at longer presentation times (18 ms: $F_{1,54} = 3.13$, $p = .082$; $\eta_p^2 = .055$; 35 ms: $F_{1,54} = 31.71$; $p < .001$; $\eta_p^2 = .370$; 53 ms: $F_{1,54} = 24.56$, $p < .001$; $\eta_p^2 = .313$). In addition, the interaction of presentation time and drug condition was significant ($F_{2,108} = 5.01$, $p = .008$, $\eta_p^2 = .085$). Follow-up analyses showed that the effect of time on response behaviour was more pronounced in participants who had received oxytocin ($F_{2,53} = 35.48$, $p < .001$; $\eta_p^2 = .572$) compared to placebo

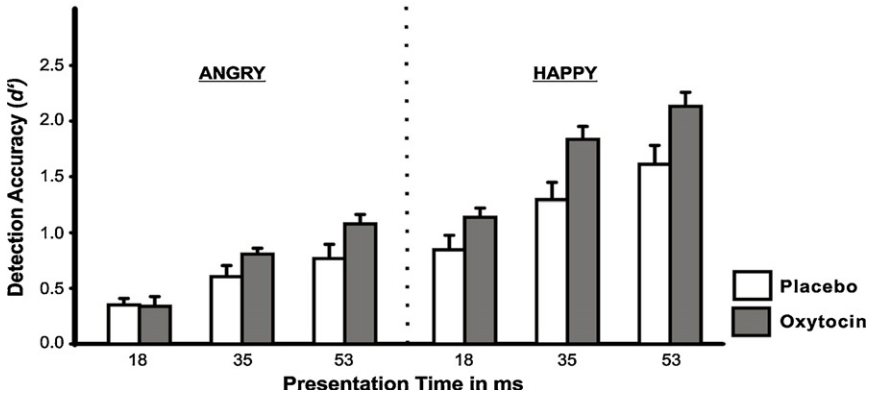

Figure 2 Effects of intranasal OT on recognition accuracy (d') of emotional faces as a function of face valence (angry vs. happy) and the presentation times of the stimuli (18, 35, and 53 ms). Error bars represent standard errors of mean.

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($F_{2,53} = 24.10$, $p < .001$; $\eta_p^2 = .476$). However, the response bias did not differ significantly between both drug conditions at individual presentation times (all $ps > .10$). No further main effects or interactions were significant (all $ps > .05$).

4. Discussion

The present study provides evidence that oxytocin enhances detection of very briefly presented emotional stimuli, suggesting that oxytocin modulates awareness of socially relevant emotional information in the environment. Thus, oxytocin presumably modulates even early stages of stimulus processing, which suggests that consistently reported improvements in facial emotion recognition previously reported in oxytocin administration studies (Domes et al., 2007b; Di Simplicio et al., 2009; Guastella et al., 2010) are not exclusively due to modulations in evaluation and appraisal of the presented stimuli. In addition, it seems that this effect is more pronounced for positive than negative facial stimuli, which is in line with previous reports suggesting a particular role of oxytocin in the processing of positive social stimuli (Unkelbach et al., 2008; Di Simplicio et al., 2009). However, it should be noted that positive stimuli were more easily recognized in general in the present study. Taking stimulus difficulty into account, by comparing recognition of negative and positive emotions with equal d' in the placebo condition (53 ms angry and 18 ms happy target faces), the comparable improvement induced by oxytocin argues against specific interactions with emotional valence, suggesting instead that task difficulty may have influenced the pattern of results.

Apart from the effective restriction of visual presentation necessary for a detailed evaluation of the stimuli, our design also limited the potential confounding influence of gaze behaviour, a factor that was previously found to be modulated by oxytocin (Guastella et al., 2008). Due to the short presentation times, modulations of overt visual attention are unlikely to be a crucial mediating factor in the present study. However, oxytocin-induced modulations of reflexive saccades to the eye region of briefly presented facial stimuli have been reported in a recently published study (Gamer et al., 2010). Consequently, future studies should involve eye tracking in order to further investigate how oxytocin shapes early stages of visual attention.

The most likely neural candidate region for the observed effect of oxytocin on detection of emotional stimuli seems to be the amygdala, especially in light of its general role in the processing of visual emotional stimuli and studies highlighting the importance of the amygdala in detection of briefly presented emotionally relevant stimuli (for a discussion, see Duncan and Barrett, 2007). Recent neuroimaging findings suggest that the impact of oxytocin on social cognitive behaviour might be a result of its attenuating effects on emotional arousal, reflected by reduction of amygdala activity, at least for negative stimuli and in males (Kirsch et al., 2005; Domes et al., 2007a; Gamer et al., 2010). The present results may at first seem to be contradictory with these findings. However, enhanced activity for dorsal and lateral subregions of the amygdala for happy faces presented for 150 ms was reported recently (Gamer et al., 2010), which might be associated with enhanced emotion recognition performance as shown in the present study. Thus, future studies are needed to characterize the time course of oxytocin effects on the behavioural and neural level, ranging from stimulus detection to detailed stimulus evaluation and subjective emotional responding. In addition, recent results suggest gender-specific modulatory effects of oxytocin (Domes et al., 2010). Future studies might thus explicitly investigate, if these distinctions translate to different modulatory effects in the recognition of emotions in male and female facial stimuli. It might be of further interest to investigate whether the effects of oxytocin on recognition accuracy are specific to emotional or social stimuli, as oxytocin might enhance visual processing in general, for instance by increasing sensitivity towards contrast or spatial frequency. Finally, since oxytocin has been shown to modulate eye gaze even for briefly presented stimuli (Gamer et al., 2010), it is an interesting question whether visual attention plays a role in the backward-masking paradigm.

To summarize, the present study demonstrates that a single dose of intranasal oxytocin increases detection accuracy for briefly presented emotional faces. This pattern of results, combined with the results of previous studies, suggests that oxytocin might influence both the early stages of stimulus processing and the subsequent conscious evaluation of stimuli on a conceptual level. In addition, the results suggest more pronounced oxytocin effects on detection of positive stimuli, although future research should address the possible confounding role of valence-specific task difficulty.

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Conflict of interest

None declared.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.psyneuen.2011.03.011.

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