

# Oxytocin sharpens self-other perceptual boundary



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**Summary** Recent cross-species research has demonstrated that the neurohormone oxytocin plays a key role in social interaction and cognitive processing of others' emotions. Whereas oxytocin has been shown to influence social approach, trust, and bond formation, a potential role of the oxytocinergic system in blurring or enhancing the ability to differentiate between one's self and other's related stimuli is unknown. Thus, we investigated whether oxytocin affects the ability to differentiate between self- and other-related stimuli using a facial morphing procedure.

In a placebo-controlled, double-blind study, 44 healthy men received either 24 IU oxytocin or placebo intranasally. After 45 min, we measured participants' ability to differentiate their own identity while viewing a photo of themselves morphing into the photo of an unfamiliar face.

Oxytocin administration shortened the latency of self-other differentiation. Additionally, when asked to rate the pleasantness of the unmorphed photos, the oxytocin-treated participants rated their own and the unfamiliar face as comparably pleasant.

Oxytocin increases the ability to recognize differences between self and others and increases positive evaluation of others. Our findings are consistent with the hypothesis that impaired oxytocin signaling may be involved in the development and manifestation of human psychopathologies in which self-recognition is altered.

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## 1. Introduction

The recognition of self-other dissimilarities and a positive perception of others are crucial for initiating social approach and developing social bonds. Beginning in the first months of life, before the development of conceptual self-knowledge, human infants are capable of distinguishing whether certain stimuli pertain to the self or to someone else (Rochat and Striano, 2000, 2002). The ability to recognize that the other is distinct from the self is considered an early marker of typical development, and it is central to the ability to form social bonds and engage in successful social interactions (Lewis and Brooks-Gunn, 1979; Rochat and Striano, 2000; Keenan et al., 2003). Conversely, a diminished ability to discriminate whether stimuli are related to the self or to others is associated with deficits in interpersonal interactions often seen in various psychopathologies. For instance, individuals with schizophrenia exhibit both social deficits and impairment in self-recognition processes (Irani et al., 2006).

Social transactions are based on the interplay between self-other relatedness and self-other differentiation processes. As self-other perceptual differentiation and recognition are rooted in brain and mind development, based on various poorly understood neural functions, it is critical to explore the neurobiological mechanisms that regulate perceptual boundaries between the “self” and “others”.

In recent years, cross-species research has demonstrated that several evolutionarily conserved neuropeptides play a key role in diverse social behaviors (Nelson and Panksepp, 1998; Ferguson et al., 2000; Insel and Young, 2001; Panksepp, 2009; Bos et al., 2012). Among them, the neuropeptide oxytocin appears to regulate fundamental aspects of mammalian social affiliative behaviors and social cognition (Carter, 1998; Insel and Young, 2001; Donaldson and Young, 2008; Heinrichs et al., 2009; Meyer-Lindenberg et al., 2011). The oxytocinergic system also plays a critical role in diverse social behaviors, including mother–infant attachment and pair bonding (Panksepp, 1992; Carter, 1998; Pedersen et al., 2006; Donaldson and Young, 2008). In humans, oxytocin is also crucial for social interactions (Heinrichs and Domes, 2008; Heinrichs et al., 2009; Meyer-Lindenberg et al., 2011; Van IJzendoorn and Bakermans-Kranenburg, 2012). After receiving a single dose of intranasally administered oxytocin, healthy adults show decreased reactivity to social stress (Heinrichs et al., 2003) and increased approach, trust, empathy, and attachment (Kosfeld et al., 2005; Baumgartner et al., 2008; Ditzen et al., 2008; Buchheim et al., 2009; Hurlmann et al., 2010), although these effects are strongly modulated by the social context. For example, stronger oxytocin effects have been found toward in-group than out-group members (Chen et al., 2011; De Dreu, 2012; De Dreu et al., 2012). Oxytocin also dampens amygdala reactivity to threatening faces (Kirsch et al., 2005; Domes et al., 2007; Petrovic et al., 2008; Gamer et al., 2010) and modulates social memory (Heinrichs et al., 2004; Rimmele et al., 2009). In addition, oxytocin administration improves emotion recognition (Lischke et al., 2012b), responsiveness to others (Kosfeld et al., 2005), and social behavior in individuals with autism (Andari et al., 2010; Guastella et al., 2010).

Several studies from social neuroscience have found that self-other differentiation is crucial for social approach and the formation of social bonds (Rochat and Striano, 2000; Keenan et al., 2003). While several studies have demonstrated that oxytocin administration facilitates the differentiation and recognition of unfamiliar facial features, we are unaware of any studies that have specifically targeted the potential role of oxytocin in modulating recognition of self-other perceptual differences in a controlled laboratory setting. Hence, we set out to study whether oxytocin might modulate the ability to differentiate the self from others. Since in humans one's own face is considered among the most salient self-related stimuli (Brédart et al., 2006), we used a face morphing paradigm, wherein participants viewed a photo of themselves morphing into the photo of an initially unfamiliar face during a self-other differentiation task (Keenan et al., 2000; Tsakiris, 2008). As the interactions between oxytocin administration and hormonal fluctuation in women have been not systematically investigated, only men were tested.

We predicted that an increased central nervous system availability of oxytocin would increase the speed of self-other perceptual differentiation and would decrease the self-serving bias regarding the pleasantness of the own face as compared to an unfamiliar one.

## 2. Materials and methods

### 2.1. Participants

A total of 44 male participants, aged 22–31 ( $SD = 2$ ) years, were recruited from the University of Freiburg, Germany, and randomly assigned to receive oxytocin ( $n = 22$ ) or placebo ( $n = 22$ ) intranasally in a placebo-controlled, double-blind, between-subject design. An additional male subject was recruited and asked to provide his picture for the preparation of the “unfamiliar other” social stimulus. The participants and the unfamiliar “other” had comparable demographic characteristics (e.g., age, sex, nationality, and ethnicity). All subjects were right-handed, had normal or corrected-to-normal vision, and had a normal body mass index. Exclusion criteria included self-reported medication use, substance abuse, and presence of medical or psychiatric disorders.

To control for possible differences between substance groups with respect to psychological characteristics, 2 weeks prior to participation in the study, all subjects completed a set of validated questionnaires: the Adult Attachment Scale (AAS, Collins and Read, 1990), Autism Spectrum Quotient (AQ, Baron-Cohen et al., 2001), Interpersonal Reactivity Index (IRI, Davis, 1983), State-Trait Anxiety Inventory – Trait Anxiety (STAI, Spielberger et al., 1983), State-Trait Anger Expression Inventory (STAXI-T, Spielberger, 1991), Freiburg Personality Inventory – Openness Scale (FPI, Fahrenberg et al., 1984) and a test of verbal intelligence (Wortschatztest, WST, Schmidt and Metzler, 1992). To control for possible non-specific mood differences in baseline and following substance administration, the participants completed the 12-item Multidimensional Mood Questionnaire (MDBF, Steyer et al., 1994) before substance administration, 45 min after administration and after the experimental task. Forty-five minutes before the experiment, each participant received a

single dose of either oxytocin (24 IU in 6 puffs of Syntocinon-Spray, Novartis, Basel, Switzerland) or placebo (containing all ingredients except for the neuropeptide) intranasally (see Heinrichs et al., 2003). All participants signed written informed consent, and approval was obtained from the Institutional Review Board (IRB) of the University of Freiburg, Germany.

## 2.2. Stimuli and procedure

For the preparation of the stimuli, we used four photos depicting the face of two actors selected from the NimStim database (<http://www.macbrain.org/resources.htm>), the participant's face, and the face of the unfamiliar individual. To reduce bias for perceived expression and attractiveness, we used photos depicting neutral facial expressions.

The stimuli were tailored to each subject. One week prior to the test, a digital photo (Nikon, Coolpix S4000, 12 MP) of each subject's neutral facial expression was taken in the laboratory under uniform lighting conditions.

For all the photos, the nonfacial attributes (e.g., background, hair, and ears) were masked by an oval with the GIMP2.8 editing program (GNU Image Manipulation Program). In addition, to present the pictures as in a mirror reflection, the color pictures were left/right reversed. The set of stimuli for the test session consisted of a series of morph videos constructed from photos of the subject's own face ("self") and the face of the unfamiliar person ("other"). The photo of subject's face was morphed to the photo of the unfamiliar face ("self to other" direction) and vice versa ("other to self" direction) in 1% steps using the Abrasoft Fantamorph morphing program ([www.fantamorph.com](http://www.fantamorph.com)). The stimuli for the practice session consisted of morph videos constructed from two photos from the NimStim database. On each pair of photos, we marked approximately 105 points to create a fine-grained transition from one face to another. An additional video of two unfamiliar faces was created for the practice trials.

The test consisted of a practice session and a test session. The practice session consisted of two blocks. During each block, the two NimStim faces were morphed one into the other and the participants were instructed to press the space bar on the computer keyboard as soon as they detected a change of identity.

To investigate possible oxytocin influences on self-other differentiation during a familiarization process, the test session comprised four blocks. During each block, two videos, one for each direction of morphing (i.e., the "self-to-other" and the "other-to-self" direction), were presented, with a delay of 0.5 s between presentations. The participants were instructed to press the space bar as soon as they perceived that the frame contained more the features of the other than the self during the "self to other" morphing video, and vice versa during the presentation of video in the direction "other to self". Presentation (Neurobehavioral Systems Inc., <http://www.neuro-bs.com/>) was used for stimulus presentation and for the recording of reaction times.

To measure possible subtle effects of oxytocin on self vs. other face evaluations, immediately after the self-other differentiation task, all participants completed a pleasantness and familiarity 5-point Likert scale for the "self" and "other" unmorphed picture (100% self and 100% other).

**Table 1** Mean and SD of participants' psychological characteristics.

	Placebo ( <i>n</i> = 22)		Oxytocin ( <i>n</i> = 22)		Statistics	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>t</i> (42)	<i>p</i>
AAS-A	9.6	3.5	10.3	3.6	−0.7	0.5
AAS-C	19.4	4.7	19.7	5.8	−0.2	0.8
AAS-D	20.4	4.3	20.7	3.5	−0.2	0.8
AQ	17.4	6.6	16.7	6.9	0.3	0.8
IRI	55.4	9.9	54	9.7	0.5	0.6
STAI-T	37.1	8.6	34.7	6.7	1	0.3
STAXI-T	18.1	3.5	17.7	4.4	0.3	0.8
WST	35.6	3.1	34.2	2.8	1.5	0.1
FPI	8	2.3	7.9	2.2	0.1	0.9

AAS-A, Adult attachment Scale – Anxious; AAS-C, Adult Attachment Scale – Close; AAS-D, Adult Attachment Scale – Depend; AQ, Autism Quotient; IRI, Interpersonal Reactivity Index; STAI-T, State Trait Anxiety Inventory – Trait Anxiety; STAXI-T, State-Trait-Anger Expression/Regulation Inventory; WST, Wortschatz-Test, verbal IQ test; FPI, Freiburg Personality Inventory – Openness Scale.

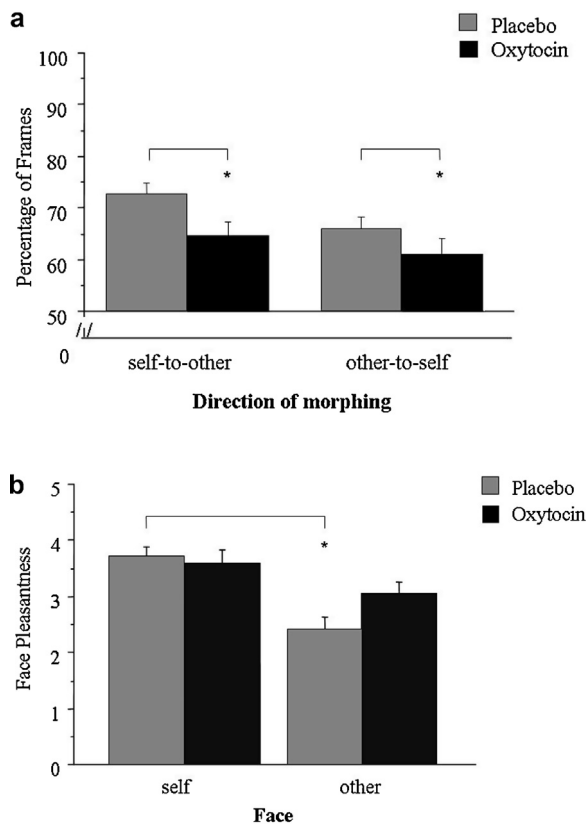
Finally, the participants completed a questionnaire to control for awareness of substance received and presence of any psychological side effects.

## 2.3. Statistical analysis

Baseline group differences in psychological characteristics were analyzed with unpaired *t* tests. Since there were no differences between groups on any of the psychological characteristics measured (all *p* > 0.1, Table 1), these factors were not further considered in the analysis. The data from the self-other differentiation task and the MDBF met the criteria for the parametric analysis. For the self-other differentiation task, we used a repeated measures ANOVA with substance (oxytocin vs. placebo) treated as a between-subject factor and block (blocks 1–4) and morphing direction ("self to other" vs. "other to self") as within-subject factors. Likewise, for the MDBF, we used a repeated measures ANOVA with substance (oxytocin vs. placebo) treated as a between-subject factor and testing time (before the substance administration, 45 min after administration, and post self-other differentiation task) as a within-subject factor. Differences between groups on the familiarity and pleasantness scales were analyzed using ANOVA, with "face" treated as a within-subject factor. To satisfy assumptions regarding normality and homogeneity of variance, the values of the pleasantness scale were log transformed before analyses. The post hoc analyses were performed using Tukey's honestly significant difference (HSD, Wilcox, 1987).

## 3. Results

During the self-other differentiation task, participants who received oxytocin exhibited a significantly shorter latency to discriminate between "self" and "other" (main effect of substance:  $F(1,42) = 4.7$ ,  $p = 0.03$ ,  $\eta_p^2 = 0.5$ , mean  $\pm$  SE % of frames, placebo:  $69 \pm 1.7$ , oxytocin:  $63 \pm 1.9$ ), without any differences between groups in relation to the video morphing



**Figure 1** (a) Mean  $\pm$  SE percentage of frames at which the face was perceived to look more like “self” or more like “other” by the placebo and oxytocin groups during the self-other differentiation task. 50% represents 50% of one’s own face morphed with the 50% of the other’s face. \* $p < 0.05$ , after post hoc comparison. (b) Mean  $\pm$  SE of non-log-transformed scores of self and others’ faces by the two substance groups on the 5-point Likert pleasantness scale. \* $p < 0.05$ , after post hoc comparison.

directions (substance  $\times$  direction interaction:  $F(1,42) = 0.5$ ,  $p > 0.05$ ) (Fig. 1a). Overall, the reaction time was shorter when the subject’s own face was emerging from the picture of the “other” face than when the “other” was coming into view from the picture of “self” (main effect of direction:  $F(1,42) = 5.7$ ,  $p = 0.02$ ,  $\eta_p^2 = 0.4$ ; mean  $\pm$  SE, self-to-other:  $68.6 \pm 1.8$ ; other-to-self:  $63.4 \pm 1.9$ ). The reaction time was longer during the first block than during the following blocks (block:  $F(3,126) = 5.3$ ,  $p = 0.001$ ,  $\eta_p^2 = 0.1$ , mean  $\pm$  SE, block 1:  $70 \pm 1.9$ ; block 2:  $64 \pm 1.6$ ; block 3:  $65.6 \pm 1.7$ ; block 4:  $64.3 \pm 1.4$ ). The substance  $\times$  block interaction was not significant ( $F(3,126) = 1.5$ ,  $p = 0.2$ ).

On the pleasantness scale, while the participants receiving placebo rated their own face as more pleasant than the unfamiliar face, the participants receiving oxytocin rated the two faces as comparably pleasant (substance  $\times$  face interaction,  $F(1,42) = 4.8$ ,  $p = 0.03$ ; mean  $\pm$  SE for placebo – self:  $0.56 \pm 0.01$  and other:  $0.34 \pm 0.04$ ; and for oxytocin – self:  $0.53 \pm 0.03$ ; other:  $0.45 \pm 0.04$ , Fig. 1b).

As expected, on the familiarity scale, all participants recognized their own picture and indicated it to be very familiar (main effect of face:  $F(1,42) = 143.4$ ,  $p < 0.0001$ ; mean  $\pm$  SE, self:  $4.5 \pm 0.1$ ; other:  $2.4 \pm 0.1$ , on the 5 point

Likert scale). The placebo and oxytocin groups showed no differences on overall familiarity ratings of the faces (main effect of substance:  $F(1,42) = 0.07$ ,  $p > 0.8$ ) nor on the rating of any specific face (substance  $\times$  face interaction:  $F(1,42) = 0.3$ ,  $p = 0.6$ ).

The additional subjective change analyses revealed no differences between substance groups on beliefs about which substances they had received. In addition, no differences between placebo and oxytocin groups were found on calmness (substance:  $F(1,42) = 0.6$ ,  $p = 0.4$ ; substance  $\times$  session:  $F(2,84) = 0.007$ ,  $p = 0.9$ ), wakefulness (substance:  $F(1,42) = 1.2$ ,  $p = 0.3$ ; substance  $\times$  session:  $F(2,84) = 0.05$ ,  $p = 0.1$ ), or mood following substance administration (substance:  $F(1,42) = 1$ ,  $p = 0.7$ ; substance  $\times$  session:  $F(2,84) = 1$ ,  $p = 0.3$ ).

## 4. Discussion

Our study demonstrates for the first time that oxytocin administration sharpens self-other perception. In particular, during the self-other face differentiation task, oxytocin reduced the threshold to distinguish between one’s own and an unfamiliar face. This finding complements previous studies showing that oxytocin increases awareness for briefly presented facial stimuli (Schulze et al., 2011), the ability to identify facial dissimilarities between unknown individuals and subtle changes of emotional expressions, social salience of stimuli, and social recognition (Savaskan et al., 2008; Rimmele et al., 2009; Leknes et al., 2012; Prehn et al., 2013). It is consistent with findings of elevated frontal activity during a mental state attribution task (Pincus et al., 2010), and that oxytocin administration is associated with increased activity in brain areas involved in processing facial features in autism (Domes et al., 2013). Thus, oxytocin administration increases, *a fortiori*, the recognition of differences between a highly familiar, personally salient stimulus (i.e., the subject’s own face) and a self-unrelated social stimulus.

Our study demonstrates that, at the behavioral level, oxytocin effects on self-other differentiation are not dependent on familiarity levels of the “other” face. Indeed, the differences between oxytocin and placebo groups persisted across test blocks. Independent fMRI studies on the neurobiological basis of self-recognition have shown an overlapping of areas involved in processing own and familiar faces, but a stronger activation of the anterior cingulate gyrus for the own versus familiar faces (Platek et al., 2006). Thus, future studies should specifically investigate to what extent oxytocin modulates the activation of brain areas involved in processing of one’s own face compared to highly familiar faces.

An additional finding emerging from the present study is that oxytocin administration enhances the rating of pleasantness of initially unfamiliar faces. This is in general agreement with previous work showing that oxytocin promotes the perception of attractiveness of unknown faces (Theodoridou et al., 2009). Our results suggest that under the present experimental conditions, oxytocin promotes the perception that the other is almost as pleasant as oneself, further supporting the role of the oxytocin system in modulating social cognition.



From an evolutionary perspective, the two phenomena (i.e., the differentiation between stimuli related to self vs. other and the perception that the other is a positive and emotionally salient stimulus) may be interconnected. For instance, by minimizing attractiveness differentials, one may be better able to focus more on objective morphological details that lead to faster discrimination of faces. Indeed, social bonding, mutual support, mate preference, and parental investment, which are all mediated by the oxytocinergic system, rely on the ability to appreciate that self and others are both different and valuable (De Bruine et al., 2008).

Thus, it seems reasonable that oxytocin may facilitate overall performance on social perception tasks and, in the present study, self- and other-recognition, while potentiating the positive affective appreciation of initially unknown partners. Taken together, previous and present data indicate that oxytocin effects extend from face-recognition of unfamiliar others to self-other recognition. The sharpened attention toward subtle changes in facial stimuli, along with the generally increased positive valuation of novel social stimuli might be related to oxytocin's substantial dampening of amygdala activation and reduction of human fear and stress reactivity (Heinrichs et al., 2003; Labuschagne et al., 2010, but see Lischke et al., 2012a for oxytocin effects in women).

During the morphing task, the participants were required to tolerate the manipulation of the photo of their own face and the associated ambiguity of facial identity. Notably, the amygdala is involved in the elaboration of ambiguous stimuli (Hsu et al., 2005; Davis and Whalen, 2001) and processing of stressful stimuli (Ulrich-Lai and Herman, 2009). Presumably, oxytocin, by virtue of its regulatory effects on the amygdala, facilitated self-other differentiation by enhancing tolerance for ambiguity and, in turn, depressed threat-related responses and increased approach-oriented attention to facial identities. However, further research is needed to elucidate whether oxytocin increases gaze fixation during a self-other differentiation test. Indeed, while several studies have demonstrated that oxytocin administration increases approach-oriented gaze fixation (Guastella et al., 2008) and influences pupil dilation during the processing of static facial stimuli (Leknes et al., 2012; Prehn et al., 2013), a recent study using video morphs of facial expressions demonstrated that oxytocin facilitates emotion recognition without influencing eye-gaze fixation (Lischke et al., 2012b).

The role of oxytocin in mitigating fear and social distress and, in turn, potentially increasing differentiation between social stimuli is supported indirectly by studies on social attachment bonds and self recognition. When confronted with threats, individuals often tend to perceive others as more similar to oneself. For example, healthy individuals show an impaired ability to recognize their own face following negative social evaluation (Ma and Han, 2009). As suggested by attachment theory and various clinical studies, better self-other differentiation and elevated interest toward unfamiliar others are positively associated with feelings of emotional confidence and security (Ainsworth and Bell, 1970; Bowlby, 1988; Mikulincer et al., 1998). Notably, oxytocin also promotes the perception of attachment security in humans (Buchheim et al., 2009). The present findings therefore offer support to future studies aimed at

investigating the relationship between attachment style, oxytocin effects, and the recognition of self or unfamiliar others. Moreover, considering gender differences in face processing and oxytocin-induced modulation of amygdala activity (Proverbio et al., 2006; Domes et al., 2010; Lischke et al., 2012a), future studies should directly compare men and women's responses on a self-recognition task following oxytocin administration.

In accord with previous studies on the cognitive self-serving bias during the processing of highly familiar stimuli and self-relevant information (Keenan et al., 2000; Leary, 2007; Ma and Han, 2010), we found that participants were faster in identifying self relative to other faces. Furthermore, in agreement with the literature indicating that individuals tend to evaluate themselves above the average (Koole and DeHart, 2007; Epley and Whitchurch, 2008), we found that the placebo-treated participants demonstrated the common self-serving effect, rating their own face as more pleasant than others' faces. In contrast, the oxytocin-treated individuals rated both their own face and others' faces as similarly pleasant. In other words, oxytocin increased the ability to distinguish between self and others while increasing the perception that "others" are pleasant, without boosting the traditional cognitive self-serving bias. This result is in line with previous studies showing that explicit self-esteem is not influenced by oxytocin administration (Bartz et al., 2010; Cardoso et al., 2012). On the other hand, recent studies have demonstrated that the oxytocinergic system is involved in the positive perception of one's self (Saphire-Bernstein et al., 2011; Cardoso et al., 2012), without influencing self-reported mood changes. For example, following oxytocin intranasal administration, healthy individuals increased self-ratings of positive emotions, openness to values and ideas and others (Cardoso et al., 2012). Thus, future studies should investigate whether oxytocin influences the affective perception of self, with a special focus on possible interconnections between self- and reward-related processing (Northoff and Hayes, 2011). If such effects are observed, it is easy to imagine potential benefits of oxytocin in promoting a positive self-view, perhaps for the long term, especially when combined with psychotherapy.

In sum, considering the increasing interest in investigating the therapeutic potentials of oxytocin for mental disorders with social-affective deficits (Heinrichs et al., 2009; Meyer-Lindenberg et al., 2011), our findings may have strong relevance for clinical interventions, specifically in disorders in which social deficits are accompanied by altered self-awareness and impaired self-other boundary discrimination. Thus, our results might lead to fertile research on the role of oxytocin in the expression of positive self-related processing in "social disorders".

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## Conflict of interest statement

None declared.

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