Shaping internal working models:

Parental love withdrawal, oxytocin, and asymmetric frontal brain activity affect socio-emotional information processing

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Contents

1 General introduction

Humans are inherently social beings, and rely on a range of both verbal and non-verbal skills for effective social interaction and behavior. Emotional expressions play an important role in the social environment, being primary sources of information about others' mental states and intentions (e.g. Bowlby, 1969; Ekman, 1993). It is therefore not surprising that the human brain contains extensive circuitry for processing and responding to socio-emotional information, including both sub-cortical and cortical structures such as the amygdala, anterior insula, cingulate cortex, and various areas within the frontal and temporal cortices (Esslen, Pascual-Marqui, Hell, Kochi, & Lehmann, 2004; Lindquist, Wager, Kober, Bliss-Moreau, & Feldman-Barett, in press). Various factors may influence the development, functioning, and responsiveness of this circuitry, as well as, ultimately, social behavior. Potential contributions of some of these factors are the subject of the current dissertation.

Parenting: use of love withdrawal

Parents provide the earliest social environment an individual comes into contact with and interacts in, and relationships with parents usually remain important throughout life (Bowlby, 1969; Hrdy, 1999). Evidently, the way in which parents raise their children has a significant impact on their later social functioning and well-being. Some of the strategies used to socialize children, though very effective in the short run, may come at a considerable cost in terms of the later well-being and functioning of the child. The use of love withdrawal is such a strategy. Love withdrawal is a disciplinary strategy that involves withholding love and affection when a child misbehaves or fails at a task. When used excessively, it is considered psychological maltreatment (Euser, Van IJzendoorn, Prinzie, & Bakermans-Kranenburg, 2010). By using love withdrawal the parent communicates to the child that his or her love and affection for the child are conditional upon the child's compliance and success. The formation of this link between compliance or performance on the one hand and relational consequences on the other is thought to underlie both the effectiveness and emotional costs of love withdrawal (Assor, Roth, & Deci, 2004; Elliot & Thrash, 2004). Parental, and in particular maternal, use of love withdrawal has been associated with fear of failure, low self-esteem, low emotional well-being, and feelings of resentment toward the parents in adolescence and young adulthood, which may all negatively affect social behavior (Assor et al., 2004; Bowlby, 1973, p. 243; Elliot & Thrash, 2004; Goldstein & Heaven, 2000; Renk, McKinney, Klein, & Oliveros, 2006; Soenens, Vansteenkiste, Luyten, Duriez, & Goossens, 2005).

It remains unclear, however, whether the use of love withdrawal also affects the deeper level of information processing in the brain. It remains to be studied whether the association of compliance and performance with relational consequences, formed through the experience of parental love withdrawal, affects the perception and processing of information relevant to this association. This is investigated in Chapters 2 and 3, focusing on event-related potentials (ERPs) to one type of information that is especially relevant to this association: emotional facial expressions accompanying performance feedback.

'Social' hormones: oxytocin

Various hormones have been found to be somehow involved in human social behavior and emotion, including testosterone (e.g., Archer, 2006; Sánchez-Martín et al., 2000), estrogen (e.g., Österlund & Hurd, 2001), cortisol (e.g., Schmidt, Fox, Goldberg, Smith, & Schulkin, 1999; Tops et al., 2005), and the neuropeptides vasopressin and oxytocin (e.g., Heinrichs, von Dawans, & Domes, 2009). Over the past decade, attention for the role of oxytocin, in particular, in social behavior, thinking, and perception has increased in scientific investigations (e.g., see Heinrichs et al., 2009; MacDonald & MacDonald, 2010; Van IJzendoorn & Bakermans-Kranenburg, in press). Oxytocin is a neuropeptide that is synthesized in magnocellular neurons of the supraoptic (SON) and paraventricular (PVN) nuclei of the hypothalamus that project to the posterior pituitary from which oxytocin is released into the bloodstream. In addition, neurons in the PVN project to various limbic, mid- , and hindbrain structures (e.g., hippocampus, amygdala, and nucleus accumbens) containing oxytocin receptors. Within the brain, oxytocin can act both as a neurotransmitter and as a neuromodulator (Landgraf & Neumann, 2004; Suske & Gallagher, 2009). In mammals, oxytocin is well known for its role in parturition and lactation, is involved in regulation of the hypothalamic-pituitary-adrenal axis, and facilitates reproductive and maternal behavior, infant attachment, and social behavior (Carter, 2003; Galbally, Lewis, Van IJzendoorn, & Permezel, 2011; Insel, 1992; Parker, Buckmaster, Schatzberg, & Lyons, 2005).

A growing body of research suggests that in humans oxytocin also plays a role in mother-infant bonding as well as in parenting behavior (e.g., Bakermans-Kranenburg & Van IJzendoorn, 2008; Campbell, 2008; Feldman, Weller, Zagoory-Sharon, & Levinde, 2007; Naber, Van IJzendoorn, Deschamps, Van Engeland, & Bakermans-Kranenburg, 2010), and that early interpersonal experiences may be important for shaping the oxytocin system (Feldman, Gordon, & Zagoory-Sharon, 2010; Heim et al., 2008). Many studies have addressed the influence of oxytocin on social stress, perception, cognition, and decision making in adults. Oxytocin has been found to attenuate stress responses in social situations, to influence the processing of and memory for salient social stimuli, to promote trust and generosity toward an opponent (for reviews see Heinrichs et al., 2009, and MacDonald & MacDonald, 2010; for a meta-analysis see Van IJzendoorn & Bakermans-Kranenburg, in press), and to increase the amount of money donated to charity (Barraza, McCullough, Ahmadi, & Zak, 2011; Van IJzendoorn, Huffmeijer, Alink, Bakermans-Kranenburg, & Tops, 2011). Although quite a few studies have focused on the effects of oxytocin on the processing of social and emotional stimuli, the vast majority of these studies have been conducted with male participants, in some cases using fMRI methodology. The lack of studies in this area focusing on women is understandable, because of effects of the female menstrual cycle on circulating levels of oxytocin (Mitchell, Haynes, Anderson, & Turnbull, 1981; Salonia et al., 2005), but nevertheless striking (but see Domes et al., 2010; Riem et al., 2011). Chapter 3 of this thesis focuses on effects of oxytocin (as well as experiences of love withdrawal) on women's event-related potential (ERP) responses to emotional facial expressions accompanying feedback.

Individual differences: asymmetric frontal brain activity

Individual differences in asymmetric frontal cortical activity have been widely implicated in (socio-)emotional processes in individuals of all ages (e.g., Coan & Allen, 2004; Davidson & Fox, 1989; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Early studies of asymmetric frontal activity focused on emotional valence, showing a relation between greater relative left activity and a tendency to experience certain positive emotions (e.g., happiness) and between greater relative right activity and a tendency to experience certain negative emotions (e.g., fear).

More recent research, however, suggests that asymmetric frontal activity relates to motivational direction (of emotions) rather than emotional valence (for a review see Harmon-Jones, Gable, & Peterson, 2010). Frontal asymmetries seem to be best characterized as reflecting a general tendency for approach versus withdrawal, with greater left activity reflecting greater approach motivation, and greater right activity reflecting greater withdrawal motivation, although there is more evidence for the link between left frontal activity and approach than for the link between right frontal activity and withdrawal (Demaree, Everhart, Youngstrom, & Harrison, 2005; Harmon-Jones & Allen, 1997; Harmon-Jones et al., 2010). Measures of asymmetric frontal activity have been shown to reflect both a general trait of and state-related fluctuations in approach-withdrawal motivation, with the contributions of trait- and state-related variation estimated to be about 50% each (Coan & Allen, 2004; Hagemann, Hewig, Seifert, Naumann, & Bartussek, 2005).

As a measure of approach-withdrawal motivation, asymmetric frontal activity may be expected to relate to certain aspects of social behavior, particularly when emotional expressions or displays are involved. This is investigated in Chapter 4, which focuses on effects of asymmetric frontal brain activity on a well-known prosocial behavior, donating money to charity, after viewing a charity's (emotion eliciting) promotional video showing a child in need.

Goal of the study

The general aim of the current thesis is to gain more insight into the associations between experiences of parental love withdrawal, oxytocin, and asymmetric frontal brain activity (reflecting basic motivational tendencies) on the one hand, and (neural) processing of and responses to socio-emotional stimuli on the other. The first chapters of this thesis focus on the processing of emotional stimuli in the brain, investigating whether experiences of love withdrawal (Chapters 2 and 3) and oxytocin administration (Chapter 3) are related to event-related potential (ERP) responses to emotional facial expressions accompanying feedback, within a double-blind, placebo-controlled, within-subjects design. Chapter 4 focuses on behavioral responses to emotionally relevant information: donating money (earned during the ERP experiment) to charity after viewing a video of a child in need. The central question in this chapter is whether asymmetric frontal brain activity, as a measure of approach-withdrawal motivation, predicts donations to charity, and, in addition, the possibility that asymmetric frontal brain activity mediates or moderates the combined effect of oxytocin and parental love withdrawal on donating behavior is explored (see Van IJzendoorn et al., 2011).

Because there are considerable differences between males and females in the oxytocin system (Suske & Gallagher, 2009), because the effects of oxytocin on the neural processing of emotional stimuli are less frequently studied in women than in men, and because it is particularly the use of love withdrawal by mothers with their daughters that has been linked to unfavorable outcomes in adolescence and young adulthood (e.g., Elliot & Thrash, 2004; Renk et al., 2006), the current thesis focuses on effects of love withdrawal, oxytocin administration, and asymmetric frontal brain activity in women.

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2 Love withdrawal is related to heightened processing of faces with emotional expressions and incongruent emotional feedback: Evidence from ERPs

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Abstract

Parental use of love withdrawal is thought to affect children's later psychological functioning because it creates a link between children's performance and relational consequences. To investigate whether love withdrawal is also associated with the underlying level of basic information processing in the brain, we studied event-related potentials to feedback stimuli that combined performance feedback with emotional facial expressions. We focused on the VPP (face processing) and N400 (incongruence processing). More maternal use of love withdrawal was related to more positive VPP amplitudes, larger effects of the emotional facial expression on VPP amplitude, and more negative N400 responses to incongruent combinations of feedback and facial expressions. Our findings suggest a heightened processing of faces with emotional expressions and greater sensitivity to incongruence between feedback and facial expression in individuals who experienced more love withdrawal.

Introduction

Love withdrawal is a disciplinary strategy that involves withholding love and affection when a child misbehaves or fails at a task. When used excessively, it is considered psychological maltreatment (Euser, Van IJzendoorn, Prinzie, & Bakermans-Kranenburg, 2010). By using love withdrawal the parent communicates to the child that his or her love and affection for the child are conditional upon the child's compliance and success. The formation of this link between compliance or performance on the one hand and relational consequences on the other is thought to underlie both the effectiveness and emotional costs of love withdrawal (Assor, Roth, & Deci, 2004; Elliot & Thrash, 2004). Parental, and in particular maternal, use of love withdrawal has been associated with low self-esteem, low emotional well-being, feelings of resentment toward the parents, and fear of failure in adolescence and young adulthood (Assor et al., 2004; Elliot & Thrash, 2004; Goldstein & Heaven, 2000; Renk, McKinney, Klein, & Oliveros, 2006; Soenens, Vansteenkiste, Luyten, Duriez, & Goossens, 2005b). It remains unclear, however, whether the use of love withdrawal also affects the deeper level of information processing in the brain. It remains to be studied whether the association of compliance and performance with relational consequences, formed through the experience of parental love withdrawal, affects the perception and processing of information relevant to this association. As a first step toward filling this gap we present a study on event-related potentials to one type of information that is especially relevant to this association, emotional facial expressions accompanying feedback.

Because parental use of love withdrawal is thought to affect psychological functioning through the establishment of a link between performance and compliance on the one hand and relational consequences, including intense emotional expressions, on the other, emotional information and expressions within the context of performance situations may be more relevant for, more attended by, and processed to a larger extent by persons who have experienced high levels of maternal love withdrawal compared to those who have experienced less love withdrawal. This would increase the amplitude of a component of the event-related potential (ERP) called the Vertex Positive Potential (VPP).

The VPP is a positive deflection in the ERP that peaks at frontocentral electrode sites, roughly between 140 and 180 ms after stimulus onset. Evidence suggests that the VPP and N170, a negative going occipito-temporal right hemisphere dominant component, represent two sides of the same generator dipoles in occipito-temporal cortex (Joyce & Rossion, 2005). Both components have been associated with the configural processing of faces, with larger amplitudes indicating more extensive processing, and show larger amplitudes in response to emotional compared to neutral expressions (Luo, Feng, He, Wang, & Luo, 2010). VPP and N170 are often found to be sensitive to intensity, but not valence of emotional expressions (Luo et al., 2010; Sprengelmeyer & Jentzsch, 2006), although larger amplitudes in response to negative (often fearful) compared to positive (often happy) expressions have been observed in some studies (Ashley, Vuillemier, & Swick, 2004; Krombholz, Schaefer, & Boucsein, 2007; Williams, Palmer, Liddell, Song, & Gordon, 2006).

In addition to heightening the processing of facial expressions in performance situations, parental use of love withdrawal may also affect the processing of incongruence between performance feedback and emotional expressions. Because a link between performance and relational consequences is established through the experience of love withdrawal, the violation of this link may become an especially salient and unexpected event. Such a violation occurs when performance feedback is presented with an emotional expression that does not match the feedback (e.g., presenting positive feedback with a disgusted facial expression). One component of the event-related potential (ERP) that is particularly sensitive to incongruence (mismatch) is the N400. The N400 is a negative-going ERP component that peaks at parietal electrode sites, around 400 ms after the presentation of a stimulus that is incongruent with its context (e.g., the word ‘knife’ at the end of the sentence ‘soup is eaten with a ...’). The N400 is sensitive to the amount or salience of this discrepancy (Caldera, Jermann, Lopez Arango, & Van der Linden, 2004).

Neural generators of the N400 effect may vary according to the demands of the task at hand, and include a network of areas involved in the processing of learned associations, including the anterior temporal lobes, superior temporal sulcus, parahippocampal gyri, superior parietal regions, inferior frontal gyrus, and insular regions (Frühholz, Fehr, & Herrmann, 2009; Silva-Pereyra et al., 2003). The N400 is typically studied in the context of language processing, but has also been observed following facial stimuli, often lateralized toward the right when emotional expressions are involved (Bobes, Martín, Olivares, & Valdés-Sosa, 2000; Caldera et al., 2004; Frühholz et al., 2009; Münte et al., 1998). Because incongruence between feedback and emotional expression violates the performance-relational consequence link, we expect this incongruence to be more salient and therefore N400 responses to be larger for persons who have experienced high maternal love withdrawal than for those who have experienced less maternal love withdrawal.

Some support for the idea that love withdrawal may be related to the processing of facial expressions and performance feedback comes from a recent study in which one characteristic associated with love withdrawal, fear of failure, has been associated with the amplitudes of the N400 and VPP (Tops & Wijers, 2011). The participants in this study performed a flanker task, in which a picture of a happy or disgusted face was presented after every response. The pictures were presented in green after a correct response and in red after an error. Tops and Wijers (2011) found that the amplitude of the N400 to incongruent feedback stimuli (disgusted faces in green and happy faces in red) increased when participants reported higher levels of fear of failure. Also, when higher levels of fear of failure were reported the amplitude of the VPP in response to disgusted facial expressions was larger compared to VPP amplitude in response to happy expressions.

In the present study, we investigate the relations between maternal use of love withdrawal and the VPP and N400 using a similar design. Because it is particularly the use of love withdrawal by mothers with their daughters that has been linked to unfavorable outcomes in adolescence and young adulthood (e.g., Elliot & Thrash, 2004; Renk et al., 2006), we focus on maternal use of love withdrawal in females. We expect higher maternal use of love withdrawal to be related to larger N400 and VPP amplitudes. To evaluate the unique contribution of love withdrawal, we controlled for fear of failure in our analyses. In this manner, we aim to add to previous findings by investigating how parenting practices contribute to information processing biases.

Method

Participants

Data were acquired from 27 participants who participated in a larger study that additionally focused on the role of oxytocin. Data for the current study were derived from the placebo condition. All participants were female undergraduate students, aged 18-30 years (M = 20.59, SD = 3.08), and were paid 50 Euros for participation. Exclusion criteria included colorblindness, smoking, alcohol and drug abuse, neurological and psychiatric disorders, pregnancy, breastfeeding, and use of medication (except oral contraceptives). The study was approved by the ethics committee of the Leiden University Medical Center.

Procedure

Participants completed questionnaires on maternal use of love withdrawal and fear of failure during an introductory course in child and family studies. The questionnaires were administered to 391 18-30 year old women who were willing to participate in an EEG experiment. Within this sample of 391 students, the distribution of scores on the love withdrawal questionnaire was skewed toward the right, indicating that in this pool of students high maternal love withdrawal is (relatively) underrepresented. To ensure an acceptable coverage of the full range of scores on the love withdrawal questionnaire within the sample of students taking part in the EEG experiment, participants for this experiment were selected stratified from the pool of 391 students: Half of the participants were selected randomly from the group scoring in the upper quartile of the questionnaire (n = 13 for the current sample), and half of the participants were selected randomly from the group scoring in the other three quartiles (n = 14 for the current sample). They were asked to come to our laboratory for two experimental sessions, separated by approximately four weeks.

Informed consent was obtained at the beginning of the first session. Concerning the administration of oxytocin, participants were told that they would receive oxytocin during one session and a placebo during the other, but that the order was not known even to the experimenter. This message was repeated at the beginning of the second session. When participants were asked, at the end of the second session, which substance they thought they had taken during that session their guesses were not significantly better than chance (p > .05). Participants were not informed about the effects of oxytocin under investigation, only about the possible side effects they might experience (which was required by the ethics committee). We therefore believe that influences of the procedure of nasal spray administration on overall performance, if any, have been negligible.

At the start of each session, a saliva sample was collected and participants completed a number of questionnaires. The participants then received nasal spray containing either 24 IU of oxytocin or a placebo (saline solution). All participants received both substances once, either the placebo during the first session and oxytocin during the second, or oxytocin during the first session and the placebo during the second. The order of administration was counterbalanced across participants and unknown to both the participant and the experimenter.

Participants were then fitted with an electrode net after which they completed a flanker task (with a short break after the fourth block). Halfway through and after completion of the task saliva samples were collected and participants completed several questionnaires. Data regarding oxytocin, saliva samples, and questionnaires will be presented elsewhere.

Questionnaires

To assess the level of fear of failure, participants filled out the 9-item Concern over Mistakes-subscale of the Multidimensional Perfectionism Scale (Frost, Marten, Lahart, & Rosenblate, 1990). Participants rated their agreement with nine statements (e.g., "People will probably think less of me when I make a mistake") on a 5-point scale ranging from 1 (completely disagree) to 5 (completely agree). The average score on the fear of failure questionnaire was 23.00 (SD = 6.73). Both skewness (-0.04) and kurtosis (-0.35) were acceptable and a Shapiro-Wilks test indicated that the distribution within the current sample was not significantly different from the normal distribution ($W = .97$, $p > .50$). Cronbach's alpha was .88 for the current sample.

To measure maternal use of love withdrawal, a questionnaire containing 11 items was completed by the participants. This questionnaire contained all five items of the Withdrawal of Relations subscale of the Children's Report of Parental Behavior Inventory (CRPBI; Beyers & Goossens, 2003; Schludermann & Schludermann, 1988), two items that were adapted from this same questionnaire, and four items adapted from the Parental Discipline Questionnaire (PDQ; Hoffman & Saltzstein, 1967; Patrick & Gibbs, 2007). Participants rated how well each of the 11 statements described their mother (e.g., "My mother is a person who, when I disappoint her, tells me how sad I make her") on a 5-point scale ranging from 1 (not at all) to 5 (very well). The average score on the love withdrawal questionnaire was 25.67 (SD = 6.83). Both skewness (-0.05) and kurtosis (-0.58) were acceptable and a Shapiro-Wilks test indicated that the distribution within the current sample was not significantly different from the normal distribution ($W = .98$, $p > .50$). Internal consistency of this questionnaire was adequate, Cronbach's alpha was .79 for the current sample. Reliability and validity of the CRPBI and its subscales have been well established (for information see Locke & Prinz, 2002; Schludermann & Schludermann, 1983, 1988) and various subscales, including the Withdrawal of Relations scale, are frequently used to study both the antecedents and consequences of parental use of psychologically controlling strategies like love withdrawal (e.g., Elliot & Thrash, 2004; Soenens et al., 2005a, 2005b).

Experimental task

Participants completed eight 72-trial blocks of a modified Eriksen flanker task (Eriksen & Eriksen, 1974), preceded by a 72-trial practice block. Target stimuli consisted of a row of five arrows (7.4° x 1.4° visual angle), presented for 50 ms, all pointing in the same direction (congruent targets), or with the middle arrow pointing in the opposite direction (incongruent targets). Target stimuli were preceded by a fixation cross, presented in black for 1000 ms and then in red for 800-1200 ms. The participants had to indicate, as fast as possible, whether the middle arrow pointed left or right by pressing the corresponding button on a response pad. To ensure participants would indeed react as fast they could and consequently would commit a substantial number of errors, response deadlines were employed. Because reaction times are generally faster to congruent than to incongruent targets, separate deadlines were used for both target types. New response deadlines were calculated after every block based on the participants' mean reaction times in the previous block.

Following each response (600-1000 ms after target stimulus offset) a feedback stimulus was presented for 1500 ms. A photograph of a happy or a disgusted face (18.8° x 21.2°) was presented in green if the participant's response was correct or in red if the participant made an error, resulting in four categories of feedback stimuli: green-happy, red-disgust (congruent), green-disgust and red-happy (incongruent). We chose to present disgusted facial expressions, rather than e.g., angry ones, because we anticipated that responses to these expressions would be most relevant for our understanding of the consequences of parental love withdrawal. Parental use of love withdrawal as a punishment triggers feelings of shame and rejection in the child (e.g., Elliot & Thrash, 2004). These same emotions are most likely to be activated by photographs of disgusted faces (Elison, 2005). Photographs were selected from Ekman's (Ekman & Friesen, 1976) standard set of prototypical facial expressions. If the participant's reaction time exceeded the response deadline the text 'too late' (6.8° x 0.9°) appeared on screen. Only ERPs time-locked to the four categories of feedback stimuli (faces) were analyzed, because ERPs time-locked to 'too late' contained excessive artifacts (due to blinks, and eye and head movements). To make sure the participants would stay involved in the task, they could earn points during the last four blocks.

ERPs

Participants' EEG was acquired during performance of the flanker task using 129-channel hydrocel geodesic sensor nets, amplified using a NetAmps300 amplifier, low-pass filtered at half (i.e., 125 Hz) the digitization rate of 250 Hz and recorded using NetStation software (Electrical Geodesics, Inc.). Impedances were kept below 50 kΩ. Further processing of the raw EEG was conducted offline using Brain Vision Analyzer 2.0 software (Brain Products). The EEG was filtered with a passband range of 0.5-30 Hz (-3 dB, 12 dB/octave [high-pass filter], -3 dB, 48 dB/octave [low-pass filter]) and rereferenced to the average of activity in all channels. Segments extending from 200 ms before to 800 ms after the onset of each feedback stimulus were extracted, corrected for ocular artifacts using ICA, and averaged per condition (green-happy, green-disgust, red-happy, red-disgust) after removal of segments containing residual artifacts (whole segments were removed if the difference between the maximum and minimum activity exceeded 60 μV in the vertical EOG channel (channel 8-channel 126) or 40 μV in the horizontal EOG channel (channel 128-channel 125), and individual channels were removed from a segment if the difference between the maximum and minimum activity in that channel during that segment exceeded 150 μV). For each of the four resulting ERPs a 200 ms pre-stimulus baseline was subtracted from all data points. On average, participants provided 486 trials (*SD* = 21), excluding late trials, that were free of artifacts after ocular artifact correction (198 green-happy [96%], 201 green-disgust [97%], 43 red-happy [91%], 44 red-disgust [92%]).

The VPP was measured directly from the ERPs time-locked to the onset of the feedback stimuli. A clear positive peak was observed in the ERPs at approximately 155 ms after feedback onset at frontocentral electrode sites (maximal slightly frontal to Cz). This peak appeared to be more positive following disgusted compared to happy faces, and this difference peaked at approximately 165 ms after feedback onset, close to Cz. The VPP was therefore defined as the average amplitude in the 140-180 ms post-stimulus interval at electrode Cz.

Because the N400 is a relative rather than an absolute negativity, it is best measured from a difference wave. Difference waves were therefore created by subtracting the ERP time-locked to the onset of incongruent feedback stimuli from the ERP time-locked to the onset of congruent feedback stimuli. Separate difference waves were calculated for green and red feedback stimuli. A clear minimum was observed in the difference waves at approximately 375 ms after feedback onset, at right-parietal electrode sites (around CP2 and CP4). The N400 was then defined as the average amplitude of the difference wave in the 300-450 ms post-stimulus interval, averaged over the group of electrodes surrounding CP2 and CP4: 80, 86, 87 (CP2), 93 (CP4) and 105. The N400 is thus more negative when the ERP time-locked to incongruent stimuli has a more negative amplitude relative to the ERP time-locked to congruent stimuli (i.e. when the incongruence effect is stronger).

Analyses

Statistical analyses were performed using SPSS 17 software. In a preliminary phase repeated measures ANOVAs were performed to evaluate the effects of color and facial expression on VPP amplitude and to confirm the occurrence of N400 responses to incongruent combinations of feedback and facial expressions. Next, repeated measures ANCOVAs were performed to evaluate the effects of facial expression (VPP only), color, maternal use of love withdrawal and fear of failure on the amplitudes of the VPP and N400.

Results

Behavioral data

The average error rate for our participants was 16% (SD = 7). Participants responded significantly faster to congruent (M = 263 ms, SD = 31) than to incongruent targets (M = 307 ms, SD = 41), $t(26) = -13.37$, $p < .01$. Maternal use of love withdrawal (LWm) and fear of failure (FoF) were significantly correlated ($r = .47$, $p < .05$). LWm and FoF were not significantly correlated with participants' error percentages and reaction times to congruent and incongruent targets (all rs $< |.25|$, all ps $> .10$).

ERPs: preliminary analyses

Because, as mentioned above, VPP amplitude appeared to be more positive in response to disgusted compared to happy faces, we performed an ANOVA with color (red vs. green) and facial expression (happy vs. disgusted) as the independent variables. We found a significant main effect of facial expression, $F(1,26) = 9.97$, $p < .05$, confirming our observation. There was a significant main effect of color as well (more positive VPP in response to green compared to red photographs), $F(1,26) = 14.52$, $p < .05$, but no significant interaction of color and facial expression, $F(1,26) = 1.77$, $p > .10$.

To confirm the occurrence of N400 responses to incongruent facial expressions, an ANOVA was performed with color (red vs. green) and congruence (congruent vs. incongruent) as independent variables and the average amplitude across the time range (i.e., 300-450 ms) and electrodes (i.e., 80, 86, 87 [CP2], 93 [CP4] and 105) chosen for analysis of the N400 as the dependent variable. We found a significant

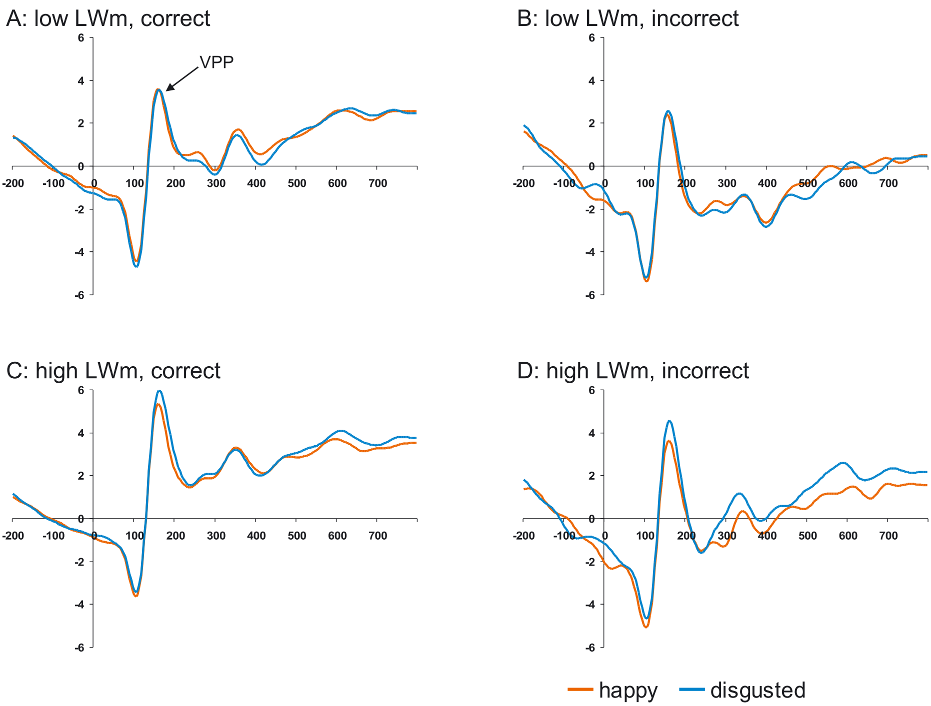

Figure 1. Grandaverage ERPs at Cz, illustrating the VPP. A and B: ERPs to green (A) and red (B) feedback stimuli (i.e., feedback following correct and incorrect responses) for participants reporting low maternal use of love withdrawal. C and D: ERPs to green (C) and red (D) feedback stimuli for participants reporting high maternal use of love withdrawal. Participants were divided into groups for displaying purposes only. Participants reporting higher maternal use of love withdrawal showed a more positive response to the feedback stimuli between 140 and 180 ms after stimulus onset (VPP) and a larger difference in VPP amplitude to happy and disgusted facial expressions (more positive VPP to disgusted than to happy expressions). ERPs were low-pass filtered at 15 Hz for displaying purposes.

main effect of congruence, $F(1,26) = 8.98$, $p < .05$, confirming the presence of the N400. The main effect of color was significant as well, $F(1,26) = 35.70$, $p < .05$ (more positive amplitude in response to green compared to red photographs), but there was no significant interaction of color and congruence, $F(1,26) = 0.03$, $p > .10$.

ERPs: analyses with LWm and FoF

Grandaverage ERPs at Cz and CP4 time-locked to the onset of the feedback stimuli are presented in Figures 1 and 2, illustrating the VPP and N400. Figure 3 presents scalp voltage-distributions for these two components.

All analyses described below were first conducted with order of administration (placebo first vs. oxytocin first) and use of oral contraceptives (used vs. not used) as additional independent variables. Because no significant effects for order of administration (all *F*s < 2.53, all *p*s > .10) and use of oral contraceptives (all *F*s < 2.03, all *p*s > .10) were found, we excluded these variables from the final analyses.

We performed a repeated measures ANCOVA with VPP amplitude as the dependent variable, color (red vs. green) and facial expression (happy vs. disgusted) as within subjects factors, and LWm and FoF as covariates. We obtained a significant main effect of LWm, $F(1,24) = 7.05$, $p < .05$, and a significant

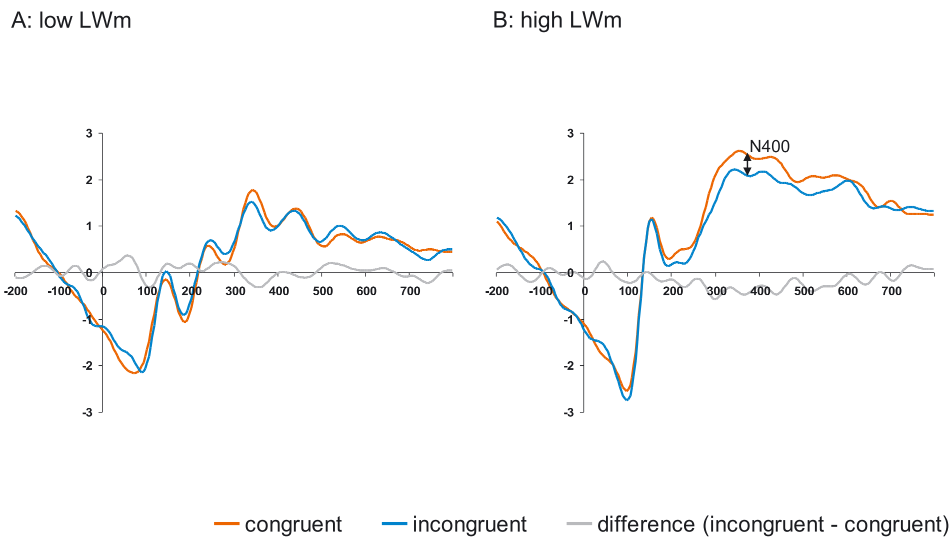

Figure 2. Grandaverage ERPs at CP4, illustrating the N400. A: ERPs to congruent and incongruent feedback stimuli for participants reporting low maternal use of love withdrawal. B: ERPs to congruent and incongruent feedback stimuli for participants reporting high maternal use of love withdrawal. Participants were divided into groups for displaying purposes only. Participants reporting higher maternal use of love withdrawal showed a more negative response to incongruent compared to congruent feedback stimuli between 300 and 450 ms after stimulus onset at right parietal electrode sites (N400). ERPs were low-pass filtered at 15 Hz for displaying purposes.

interaction effect between facial expression and LWm, $F(1,24) = 12.61$, $p < .01$. Higher maternal use of love withdrawal was associated with more positive VPP amplitudes in response to the feedback stimuli and with larger effects of facial expression (more positive VPP to disgusted than to happy faces) on VPP amplitude. Figure 1 presents grandaverage ERPs at Cz to illustrate these effects. No significant main effects of color, facial expression and fear of failure were found, and none of the other interaction effects was significant (all *F*s < 2.88, all *p*s > .10).

Next, we performed a repeated measures ANCOVA with N400 amplitude as the dependent variable, color (red vs. green) as within subjects factor, and LWm and FoF as covariates. The main effect of LWm was significant, $F(1,24) = 7.35$, $p < .05$. Higher maternal use of love withdrawal was associated with a more negative N400 (i.e., more negative voltage to incongruent compared to congruent feedback). No significant main effects of color and FoF were found, and none of the interaction effects were significant (all *F*s < 2.47, all *p*s > .10). Figure 2 presents grandaverage ERPs at CP4 time-locked to the onset of congruent and incongruent feedback stimuli, and the incongruent – congruent difference wave, illustrating the main effect of maternal use of love withdrawal.

Because no significant effects of FoF were found in any of the analyses described above, we repeated the analyses with fear of failure as the only covariate (i.e., excluding LWm from the analyses). No significant main effects of or interactions involving FoF were found (all *F*s < 1.10, all *p*s > .10).

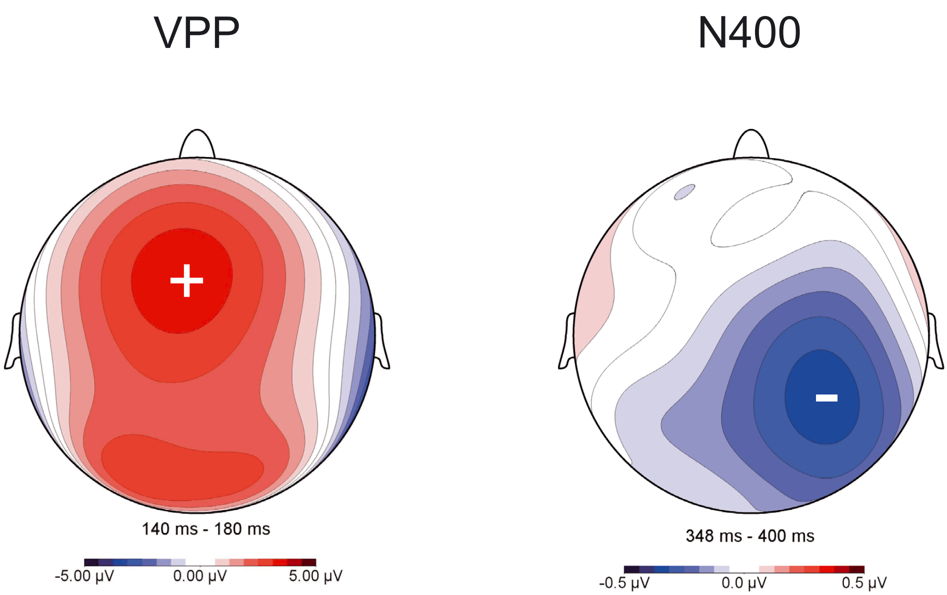

Figure 3. Scalp voltage distributions of VPP and N400. VPP: Voltage distribution of the ERP (averaged over all feedback stimuli) across the 140-180 ms post-stimulus interval. N400: Voltage distribution of the incongruent – congruent difference wave across the 348-400 ms post-stimulus interval. The maximum of the VPP is marked with '+', the minimum of the N400 with '-'.

Discussion

Maternal use of love withdrawal was related to the processing of the feedback stimuli as indexed by VPP and N400 amplitudes, independent of fear of failure. Consistent with our hypothesis, we found that maternal use of love withdrawal significantly predicted the VPP. Participants reporting relatively high maternal use of love withdrawal thus showed heightened processing of faces with emotional expressions.

In addition, we found that maternal use of love withdrawal was related to the difference between VPP amplitudes in response to happy and disgusted facial expressions. For participants reporting higher maternal use of love withdrawal the amplitude of the VPP was clearly larger in response to disgusted compared to happy facial expressions, whereas for participants reporting lower maternal use of love withdrawal this effect of disgust was smaller or absent. Amplitude differences in both VPP and N170 (a functionally similar component, Joyce & Rossion, 2005) to positive and negative facial expressions are thought to reflect the preferential processing of negative expressions, because of their biological significance as signals of threat and danger (Williams et al., 2006; Krombholz et al., 2007). Our results thus suggest a more pronounced preferential processing of disgusted faces compared to happy ones in participants reporting high maternal use of love withdrawal. A possible explanation is that in a performance situation disgusted facial expressions are more relevant or more threatening for them, because of the association between these expressions and the negative relational consequences linked to failure.

Higher levels of maternal love withdrawal were, as was predicted, also related to larger amplitudes of the N400. Participants reporting higher maternal use of love withdrawal thus seem to be more sensitive to a mismatch (incongruence) between the feedback and facial expression accompanying that feedback.

Areas involved in generating the N400, in particular the inferior frontal gyrus (and adjacent anterior insula) and superior temporal sulcus, have been found to contain mirror neurons that respond to emotional expressions and emotional prosody (Gazzola, Aziz-Zadeh, & Keysers, 2006; Wildgruber, Ackermann, Kreifelts, & Ethofer, 2006). Mirror systems are both active when an individual performs an action and when another individual performs an action from the same class of actions or an action with a similar goal or meaning (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). Mirror neurons have been found to be involved in affect mirroring, understanding others' actions, and some aspects of empathy, and areas containing mirror neurons are involved in judging the appropriateness of facial affect (Gazzola et al., 2006; Kim et al., 2005). It is likely that mirror neurons are involved in affect mirroring and contingency detection in mother-child interactions that are central to the development of emotional self-awareness, self-control, and empathy from infancy through adolescence (Feldman, 2007; Fonagy, Gergely, & Target, 2007; Gergely & Watson, 1996). This system is thus a likely candidate for parenting strategies like love withdrawal to take effect.

In contrast to Tops and Wijers (2011) we did not find any effects of fear of failure, measured using the same questionnaire, on VPP and N400 amplitudes. This raises some debate about whether and how fear of failure may be related to these components. Our results suggest that maternal use of love withdrawal, rather than fear of failure, relates to the amplitudes of the VPP and N400, and as maternal use of love withdrawal and fear of failure were significantly, but not perfectly, correlated, one possibility is that the participants reporting high fear of failure in the Tops and Wijers (2011) study would have scored high on maternal use of love withdrawal as well. Another possibility is that our method of sampling affected the distribution of scores on the questionnaire measuring fear of failure (because love withdrawal and fear of failure were correlated). The mean and standard deviation we obtained ($M = 23.00$, $SD = 6.73$) do however not differ significantly (SD: $F(26,15) = 1.61$, $p > .10$; M: $t(41) = 0.81$, $p > .10$) from those reported by Tops and Wijers (2011; $M = 24.6$, $SD = 5.3$), suggesting the distributions were similar. Additional studies are needed to clarify the respective involvement of love withdrawal and fear of failure.

One factor that may have influenced our results is the difference in the frequency of presenting green and red stimuli. Because participants committed about 16% errors, they were presented with more green than red stimuli. Future studies could (additionally) use more difficult tasks resulting in higher error percentages and thus more equal numbers of green and red feedback stimuli. Furthermore, we measured maternal use of love withdrawal and fear of failure with self-report questionnaires. There are obvious limitations to the accuracy and reliability of participants' self-reports. A word of caution should also be added regarding the generalizability of our findings. Although our selection procedure ensured a normal distribution of scores on the love withdrawal questionnaire within the current sample, in comparison to the pool of 391 students that the sample was drawn from high maternal use of love withdrawal was overrepresented, and the current sample may not be representative of the general population. Lastly, our participants were all female. We chose to include only women in this study, because most of the studies on the behavioral/ psychological outcomes of love withdrawal focus on maternal use of love withdrawal with daughters (e.g., Elliot & Thrash, 2004; Renk et al., 2006). It would be interesting to study the same processes in men.

In conclusion, our results suggest that maternal use of love withdrawal is related to the processing of feedback stimuli that combine performance feedback with emotional facial expressions. The findings of a more negative N400, a more positive VPP, and larger VPP responses to disgusted than to happy faces with higher levels of maternal love withdrawal are consistent with the idea that a firm link between performance and affective relationships is established through the experience of love withdrawal, increasing the relevance of and focus on emotional expressions in performance situations, which makes the violation of the expected combination of feedback and emotional expression an especially salient event.

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3 The impact of oxytocin administration and maternal love withdrawal on event-related potential (ERP) responses to emotional expressions with performance feedback

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Abstract

This is the first experimental study on the effect of oxytocin administration on the neural processing of facial stimuli conducted with female participants that uses event-related potentials (ERPs). Using a double-blind, placebo-controlled within-subjects design, we studied effects of 24 IU of intranasal oxytocin on ERPs to pictures combining performance feedback with emotional facial expressions in 48 female undergraduate students. Participants also reported on the amount of love withdrawal they experienced from their mothers. Findings of more positive vertex positive potential (VPP) and late positive potential (LPP) amplitudes after oxytocin compared to placebo administration suggest that oxytocin increased attention to the feedback stimuli (LPP) and enhanced the processing of emotional faces (VPP). Lower maternal love withdrawal was related to larger increases in VPP amplitude after oxytocin administration. Significant associations with LPP amplitude suggest that higher maternal love withdrawal relates to the allocation of attention toward the motivationally most relevant combination of negative feedback with a disgusted face.

Introduction

The way oxytocin affects our social behavior, thinking, and perception is the subject of a rapidly increasing number of scientific investigations (e.g., see Heinrichs, von Dawans, & Domes, 2009; MacDonald & MacDonald, 2010). Although quite a few studies have focused on the effects of oxytocin on the processing of social stimuli, the vast majority of these studies have been conducted with male participants, in some cases using fMRI methodology, and the lack of studies in this area focusing on women is striking (but see Domes et al., 2010; Riem et al., 2011). The present study concerns women, and describes effects of oxytocin and perceived parenting on their event-related potential (ERP) responses to feedback stimuli combining performance feedback with emotional facial expressions.

Oxytocin is a neuropeptide that is synthesized in magnocellular neurons of the supraoptic (SON) and paraventricular (PVN) nuclei of the hypothalamus that project to the posterior pituitary from which oxytocin is released into the bloodstream. In addition, neurons in the PVN project to various limbic, mid- , and hindbrain structures (e.g., hippocampus, amygdala, and nucleus accumbens) containing oxytocin receptors. Within the brain, oxytocin can act both as a neurotransmitter and as a neuromodulator (Landgraf & Neumann, 2004; Suske & Gallagher, 2009). In mammals, oxytocin is well known for its role in parturition and lactation, is involved in regulation of the hypothalamic-pituitary-adrenal axis, and facilitates reproductive and maternal behavior, infant attachment, and social behavior (Carter, 2003; Insel, 1992; Parker, Buckmaster, Schatzberg, & Lyons, 2005).

A growing body of research suggests that in humans oxytocin also plays a role in mother-infant bonding as well as in parenting behavior (e.g., Bakermans-Kranenburg & Van IJzendoorn, 2008; Campbell, 2008; Feldman, Weller, Zagoory-Sharon, & Levinde, 2007; Naber, Van IJzendoorn, Deschamps, Van Engeland, & Bakermans-Kranenburg, 2010), and that early interpersonal experiences may be important for shaping the oxytocin system (Feldman, Gordon, & Zagoory-Sharon, 2010; Heim et al., 2008). Many studies have addressed the influence of oxytocin on social stress, perception, cognition, and decision making in adults. Oxytocin has been found to attenuate stress responses in social situations, to promote trust and generosity toward an opponent (at least in in-group situations, De Dreu et al., 2010), and to influence the processing of and facilitate memory for salient social stimuli; for reviews see Heinrichs et al. (2009), and MacDonald and MacDonald (2010). It is well known that elevations of oxytocin levels in blood (in which it has a half-life of only a few minutes) do not adequately reflect the time-range of its neurobehavioral effects, but little is known about oxytocin in other fluids (McEwen, 2004). As an addition to our study, we therefore measured oxytocin levels in saliva samples collected during the experiment to investigate whether and how long oxytocin levels would be elevated in saliva after intranasal oxytocin administration.

Of particular relevance for the current study are effects of oxytocin on the processing of faces and facial expressions. On a behavioral level, oxytocin has been found to improve recognition memory for faces, both when oxytocin is administered before (Rimmele, Hediger, Heinrichs, & Klaver, 2009) and after (Savaskan, Ehrhardt, Schulz, Walter, & Schächinger, 2008) the initial learning stage, suggesting an effect of oxytocin on memory consolidation. Oxytocin may facilitate memory encoding specifically for positive facial expressions (Guastella, Mitchell, & Mathews, 2008b). Results of several studies describe facilitative effects of oxytocin on the processing of facial expressions that may underlie improvements in memory, although there is some inconsistency regarding differential effects for different emotional expressions, complicated by differences in study designs and outcome measures. For example, Fisher-Shofty, Shamay-Tsoory, Harari, and Levkovitz (2010) found that participants were more accurate at recognizing fear, but not other emotions (happiness, sadness, surprise, and disgust) after oxytocin compared to placebo administration, whereas Di Simplicio, Massey-

Chase, Cowen, and Harmer (2009) found that oxytocin improved recognition of positive emotions (i.e., a reduction in misclassifications of positive emotions as negative ones) and slowed reaction times for fearful expressions. On a cognitive level, oxytocin has been found to improve the ability to make inferences about the mental state of another from the eye-region of the face (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007b). Interestingly and in accordance with the latter finding, oxytocin increased both the number of fixations and the total time of fixation at the eye-region of faces in a study by Guastella, Mitchell, and Dadds (2008a), suggesting that oxytocin increases attention to the eye-region of faces.

Taken together, behavioral studies suggest that oxytocin facilitates the processing of faces and facial expressions, possibly via attentional mechanisms. The neural circuitry underlying the cognitive-behavioral effects has been the topic of a number of investigations using fMRI to image brain activity. These studies typically find reductions of amygdala activation in response to facial expressions (regardless of valence) after oxytocin compared to placebo administration, which has been suggested to reflect reduced arousal resulting from a reduction in uncertainty about the meaning of social stimuli due to more efficient processing or processing biases induced by oxytocin (Domes et al., 2007a; but see Domes et al., 2010, for contrasting effects in females). In addition to reduced amygdala activity, reduced functional coupling between the amygdala and regions of the brainstem that mediate fearful behavior and arousal has been observed after oxytocin administration (Kirsch et al., 2005). A slightly more complicated picture is presented by Gamer, Zurowski, and Büchel (2010), who distinguished between different subregions of the amygdala. They found that oxytocin decreased activity in anterior parts of the amygdala when viewing fearful faces, but increased activity in these parts in response to happy faces. Increased activity in the posterior amygdala and enhanced coupling between the posterior amygdala and superior colliculus were related to increases in reflexive eye-movements toward the eye-region of the facial stimuli after oxytocin compared to placebo administration, in accordance with the role of both these regions in reflexive shifting of attention.

Studies employing fMRI thus associate oxytocin with alterations in amygdala activity in response to facial expressions, reflecting arousal and attentional strategies. It is important to note, however, that virtually all of the fMRI studies described above were conducted with male participants (as were the vast majority of cognitive-behavioral studies). Results obtained with male participants may not be directly applicable to women, because of sex differences in circulating levels of oxytocin (women tend to have higher levels than men) and because of the regulatory influence of sex hormones, particularly estrogen, on the oxytocin system (Suske & Gallagher, 2009). To our knowledge, only one study focusing on the effects of oxytocin on neural responses to face stimuli has been conducted with female participants. Using fMRI to measure activity in response to happy, fearful, and angry faces, Domes et al. (2010) found that, in contrast to typical results in men, oxytocin increased activity in the left amygdala in response to fearful faces. They also found increased activity in brain areas associated with the processing of faces and facial expressions, including the superior temporal cortex (for fearful faces), inferior frontal gyrus (for happy and angry faces), and fusiform gyrus (for happy and fearful faces), suggesting heightened processing of emotional facial expressions after oxytocin compared to placebo administration.

The current study is not only one of the first to investigate effects of oxytocin on the processing of facial stimuli in women, but also the first to study ERP responses to these facial stimuli. In the late 1980s and early 1990s a couple of studies were conducted on the influence of oxytocin on ERP components sensitive to vigilance and arousal, elicited by series of briefly presented auditory stimuli (Fehm-Wolfsdorf, Bachholz, Born, Voigt, & Fehm, 1988; Geenen et al., 1988; Pietrowski, Braun, Fehm, Pauschinger, & Born, 1991). Little or no effects of oxytocin were found, which may be due to the non-social nature of the tasks and stimuli employed (in all three studies) as well as intravenous injection of oxytocin (in Geenen et al., 1988 and Pietrowski et al., 1991), as oxytocin is unlikely to cross the blood-brain barrier in substantive amounts (McEwen, 2004). In a recent study, intranasally administered oxytocin enhanced suppression of alpha and beta rhythms in the EEG while participants viewed point-light displays of a human figure walking away from or toward the participant, suggesting that oxytocin facilitates the allocation of resources toward this type of social task (Perry et al., 2010).

In the current study we focus on two components of the ERP that are sensitive to variations in the extent of processing of facial stimuli and the allocation of attentional resources. The vertex positive potential (VPP) is a positive deflection in the ERP that peaks at frontocentral electrode sites, roughly between 140 and 180 ms after stimulus onset. Evidence suggests that the VPP and N170, a negative going occipitotemporal right hemisphere dominant component, represent two sides of the same generator dipoles in occipitotemporal cortex (Joyce & Rossion, 2005). Both components have been associated with the configural processing of faces, with larger amplitudes indicating more extensive processing, and show larger amplitudes in response to emotional compared to neutral expressions (Luo, Feng, He, Wang, & Luo, 2010). VPP and N170 are often found to be sensitive to intensity, but not valence of emotional expressions (Luo et al., 2010; Sprengelmeyer & Jentzsch, 2006), although larger amplitudes in response to negative (often fearful) compared to positive (often happy) expressions have been observed in some studies (Ashley, Vuillemier, & Swick, 2004; Krombholz, Schaefer, & Boucsein, 2007; Williams, Palmer, Liddell, Song, & Gordon, 2006). If oxytocin increases attention toward (parts of) faces and facilitates the processing and encoding of facial expressions, oxytocin should also increase the amplitude of the VPP.

Whereas the VPP reflects a relatively early, automatic stage of processing, the late positive potential (LPP), a centroparietally distributed, positive-going modulation of the ERP beginning about 300-400 ms after stimulus onset, is thought to reflect the allocation of attention toward emotionally and motivationally significant stimuli (Hajcak, Dunning, & Foti, 2009; Pastor et al., 2008). Evidence suggests that occipital, posterior parietal, and inferotemporal areas are involved in generating the LPP (Keil et al., 2002; Sabatinelli, Lang, Keil, & Bradley, 2007). The amplitude of the LPP is more positive for emotional stimuli, both pleasant and unpleasant, compared to neutral stimuli and may be influenced by both automatic (e.g., capture of attention by unpleasant stimuli) and controlled (e.g., direction of attention toward non-threatening parts of a stimulus) processes (Cacioppo, Crites, & Gardner, 1996; Hajcak et al., 2009; Hajcak, MacNamera, & Olvet, 2010; Pastor et al., 2008). If oxytocin increases the allocation of attention toward faces or facial expressions, this should lead to more positive LPP amplitudes.

Besides oxytocin, other factors may affect ERPs in response to our facial feedback stimuli. Previously we reported on effects of maternal use of love withdrawal on the VPP and N400 components of the ERP (Huffmeijer, Tops, Alink, Bakermans-Kranenburg, & Van IJzendoorn, 2011). Love withdrawal is a disciplinary strategy that involves withholding love and affection when a child misbehaves or fails at a task. When used excessively, it is considered psychological maltreatment (Euser, Van IJzendoorn, Prinzie, & Bakermans-Kranenburg, 2010). By using love withdrawal the parent communicates to the child that his or her love and affection for the child are conditional upon the child's compliance and success. The formation of this link between compliance or performance on the one hand and relational consequences on the other is thought to underlie both the effectiveness and emotional costs of love withdrawal (Assor, Roth, & Deci, 2004; Elliot & Thrash, 2004). Parental, and in particular maternal, use of love withdrawal has been associated with low self-esteem, low emotional well-being, feelings of resentment toward the parents, and fear of failure in adolescence and young adulthood (Assor et al., 2004; Elliot & Thrash, 2004; Goldstein & Heaven, 2000; Renk, McKinney, Klein, & Oliveros, 2006; Soenens, Vansteenkiste, Luyten, Duriez, & Goossens, 2005b). It is less clear, however, whether the use of love withdrawal also affects the deeper level of information processing in the brain.

Because parental use of love withdrawal is thought to affect psychological functioning through the establishment of a link between performance and compliance on the one hand and relational consequences, including intense emotional expressions, on the other, emotional information and expressions within the context of performance situations may be more relevant for, more attended by, and processed to a larger extent by persons who have experienced high levels of maternal love withdrawal compared to those who have experienced less love withdrawal. Our previous findings of a more negative N400 and a more positive VPP with higher levels of maternal love withdrawal were consistent with this idea (Huffmeijer et al., 2011). We expect that this increase in vigilance for and attention to facial expressions will not only result in a more positive VPP amplitude, but also in a more positive LPP.

To summarize, in the present study we investigate relations between oxytocin and maternal use of love withdrawal on the one hand and the VPP and LPP on the other. We controlled our analyses for fear of failure, which has been related to both love withdrawal (e.g., Elliot & Thrash, 2004; Soenens et al., 2005b) and ERPs to feedback stimuli (Tops & Wijers, 2011). We expect that oxytocin will increase the amplitudes of both the VPP and LPP. We also expect higher maternal use of love withdrawal to be related to more positive VPP and LPP amplitudes. In addition, there may be variations in the effects of oxytocin with the amount of love withdrawal experienced by the participants. Oxytocin is well known to have anxiolytic effects, particularly in social situations (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Heinrichs & Domes, 2008). If anxiety about the relational consequences of performance underlies increased attention toward and increased processing of facial expressions for those reporting higher love withdrawal and if oxytocin reduces this anxiety, then attention toward and processing of facial expressions, and thereby VPP and LPP amplitudes, should increase less or even decrease with increasing love withdrawal after oxytocin administration.

Method

Participants

A total of 59 female undergraduate students, aged 18-30 years (M = 20.54, SD = 2.89), took part in the ERP experiment. Two participants completed only one session, and data of nine other participants could not be analyzed because of excessive ocular or motion artifacts (n = 6), or low error rates (n = 3). The final sample thus consisted of 48 female undergraduate students, aged 18-30 years (M = 20.46, SD = 2.71). Excluded and included participants did not differ significantly in age, maternal love withdrawal, and fear of failure (all ts(57) ≤ 0.75, ps > .10). They were paid 50 Euros for participation. Exclusion criteria included colorblindness, smoking, alcohol and drug abuse, neurological and psychiatric disorders, pregnancy, breastfeeding, and use of medication (except oral contraceptives [use of oral contraceptives was recorded as a background variable]). The study was approved by the ethics committee of the Leiden University Medical Center.

Procedure

Participants completed questionnaires on maternal use of love withdrawal and fear of failure during an introductory course in child and family studies. The questionnaires were administered to 391 18-30 year old women who were willing to participate in an EEG experiment. Within this sample of 391 students, the distribution of scores on the love withdrawal questionnaire was skewed toward the right, indicating that in this pool of students high maternal love withdrawal is (relatively) underrepresented. To ensure an acceptable coverage of the full range of scores on the love withdrawal questionnaire within the sample of students taking part in the EEG experiment, participants for this experiment were selected stratified from the pool of 391 students: Half of the participants were selected randomly from the group scoring in the upper quartile of the questionnaire (n = 24), and half of the participants were selected randomly from the group scoring in the other three quartiles (n = 24). This resulted in a normal distribution of love withdrawal scores (see below under *Questionnaires*). Participants were asked to come to our laboratory for two experimental sessions with double-blind administration of oxytocin and placebo, separated by approximately four weeks. To minimize influences of diurnal variations in oxytocin levels, all sessions took place in the afternoon (starting between 12.00 and 15.00). Participants were instructed to abstain from alcohol and excessive physical activity during the 24 hours before the start of each session, and from caffeine on the day the session took place.

Informed consent was obtained at the beginning of the first session. Concerning the administration of oxytocin, participants were told that they would receive oxytocin during one session and a placebo during the other, but that the order was not known even to the experimenter. This message was repeated at the beginning of the second session. When participants were asked, at the end of the second session, which substance they thought they had taken during that session their guesses were not significantly better than chance. Participants were not informed about the effects of oxytocin under investigation, only about the possible side effects they might experience (as required by the ethics committee).

At the start of each session (T0), a saliva sample was collected and participants completed a number of questionnaires. The participants then received nasal spray containing either 24 IU of oxytocin or a placebo (saline solution). All participants received both substances once, either the placebo during the first session and oxytocin during the second, or oxytocin during the first session and the placebo during the second. The order of administration was counterbalanced across participants and unknown to both the participant and the experimenter. Participants were then fitted with an electrode net after which they completed a flanker task (with a short break after the fourth block). The first experimental block of the flanker task began approximately 45 minutes after oxytocin or placebo administration. Halfway through (T1, approximately 1¼ hours after nasal spray administration) and after completion of the task (T2, approximately 2¼ hours after nasal spray administration) saliva samples were collected and participants completed several questionnaires. Data regarding questionnaires other than those measuring Fear of Failure and Love Withdrawal, and a post-task questionnaire will be presented elsewhere.

Questionnaires

To assess the level of fear of failure, participants filled out the 9-item Concern over Mistakes-subscale of the Multidimensional Perfectionism Scale (Frost, Marten, Lahart, & Rosenblate, 1990). Participants rated their agreement with nine statements (e.g., “People will probably think less of me when I make a mistake”) on a 5-point scale ranging from 1 (completely disagree) to 5 (completely agree). The average score on the fear of failure questionnaire was 22.90 (SD = 6.56). Both skewness (0.24) and kurtosis (-0.22) were acceptable and a Shapiro-Wilks test indicated that the distribution within the current sample was not significantly different from the normal distribution ($W = .98$, $p > .50$). Cronbach’s alpha was .88 for the current sample.

To measure maternal use of love withdrawal, the participants completed a questionnaire containing 11 items. This questionnaire contained all five items of the Withdrawal of Relations subscale of the Children’s Report of Parental Behavior Inventory (CRPBI; Beyers & Goossens, 2003; Schludermann & Schludermann, 1988), two items that were adapted from this same questionnaire, and four items adapted from the Parental Discipline Questionnaire (PDQ; Hoffman & Saltzstein, 1967; Patrick & Gibbs, 2007). Participants rated how well each of the 11 statements described their mother (e.g., “My mother is a person who, when I disappoint her, tells me how sad I make her”) on a 5-point scale ranging from 1 (not at all) to 5 (very well). The average score on the love withdrawal questionnaire was 25.21 ($SD = 7.35$). Both skewness (0.13) and kurtosis (-0.71) were acceptable and a Shapiro-Wilks test indicated that the distribution within the current sample was not significantly different from the normal distribution ($W = .98$, $p > .50$). Internal consistency of this questionnaire was adequate; Cronbach's alpha was .83 for the current sample. Reliability and validity of the CRPBI and its subscales have been well established (for information see Locke & Prinz, 2002; Schludermann & Schludermann, 1983, 1988) and various subscales, including the Withdrawal of Relations scale, are frequently used to study both the antecedents and consequences of parental use of psychologically controlling strategies like love withdrawal (e.g., Elliot & Thrash, 2004; Soenens et al., 2005a, 2005b).

At the end of the second session, participants completed a post-task questionnaire that included five questions about their motivation during the task and four about their evaluations of their own performance. Questions were answered on 5-point scales (e.g., ranging from "I performed much better than others" to "I performed much worse than others").

Experimental task

During each session, participants completed eight 72-trial blocks of a modified Eriksen flanker task (Eriksen & Eriksen, 1974), preceded by a 72-trial practice block. Target stimuli consisted of a row of five arrows (7.4° x 1.4° visual angle), presented for 50 ms, all pointing in the same direction (congruent targets), or with the middle arrow pointing in the opposite direction (incongruent targets). Target stimuli were preceded by a fixation cross, presented in black for 1000 ms and then in red for 800-1200 ms. The participants had to indicate, as fast as possible, whether the middle arrow pointed left or right by pressing the corresponding button on a response pad. To ensure participants would indeed react as fast they could and consequently would commit a substantial number of errors, response deadlines were employed. Because reaction times are generally faster to congruent than to incongruent targets, separate deadlines were used for both target types. New response deadlines were calculated after every block based on the participants' mean reaction times during that block.

Following each response (600-1000 ms after target stimulus offset) a feedback stimulus was presented for 1500 ms. A photograph of a happy or a disgusted face (18.8° x 21.2°) was presented in green if the participant's response was correct or in red if the participant made an error, resulting in four categories of feedback stimuli: green-happy, red-disgust (congruent), green-disgust and red-happy (incongruent). We chose to present disgusted facial expressions, rather than e.g., angry ones, because we anticipated that responses to these expressions would be most relevant for our understanding of the consequences of parental love withdrawal. Parental use of love withdrawal as a punishment triggers feelings of shame and rejection in the child (e.g., Elliot & Thrash, 2004). These same emotions are most likely to be activated by photographs of disgusted faces (Elison, 2005). Photographs were selected from Ekman's (Ekman & Friesen, 1976) standard set of prototypical facial expressions. If the participant's reaction time exceeded the response deadline the text 'too late' (6.8° x 0.9°) appeared on screen. Only ERPs time-locked to the four categories of feedback stimuli (faces) were analyzed, because ERPs time-locked to 'too late' contained excessive artifacts (due to blinks, and eye and head movements). To make sure the participants would stay involved in the task, they could earn points during the last four blocks.

ERPs

Participants' EEG was acquired during performance of the flanker task using 129-channel hydrocel geodesic sensor nets, amplified using a NetAmps300 amplifier, low-pass filtered at half (i.e., 125 Hz) the digitization rate of 250 Hz and recorded using NetStation software (Electrical Geodesics, Inc.). Impedances were kept below 50 kΩ. Further processing of the raw EEG was conducted offline using Brain Vision Analyzer 2.0 software (Brain Products). The EEG was filtered with a passband range of 0.5-30 Hz (-3 dB, 12 dB/octave [high-pass filter], -3 dB, 48 dB/octave [low-pass filter]) and rereferenced to the average of activity in all channels. Segments extending from 200 ms before to 800 ms after the onset of each feedback stimulus were extracted, corrected for ocular artifacts using ICA, and averaged per condition (green-happy, green-disgust, red-happy, red-disgust) after removal of segments containing residual artifacts (whole segments were removed if the difference between the maximum and minimum activity exceeded 60 μV in the vertical EOG channel (channel 8-channel 126) or 40 μV in the horizontal EOG channel (channel 128-channel 125), and individual channels were removed from a segment if the difference between the maximum and minimum activity in that channel during that segment exceeded 150 μV). For each of the four resulting ERPs a 200 ms pre-stimulus baseline was subtracted from all data points. There were no significant differences between the placebo and oxytocin conditions in the percentage of trials that were free of artifacts for each of the four stimulus types (green-happy: M = 96%, SD = 6% [placebo], M = 95%, SD = 7% [oxytocin]; green-disgust: M = 96%, SD = 6% [placebo], M = 95%, SD = 7% [oxytocin]; red-happy: M = 92%, SD = 7% [placebo], M = 91%, SD = 10% [oxytocin]; red-disgust: M = 93%, SD = 7% [placebo], M = 91%, SD = 12% [oxytocin]; all ts(47) ≤ 0.89, ps > .10).

The VPP and LPP were measured directly from the ERPs time-locked to the onset of the feedback stimuli. The VPP was defined as the average amplitude in the 140-180 ms post-stimulus interval at electrode Cz. The LPP was defined as the average amplitude in the 400-800 ms post-stimulus interval averaged across 11 centroparietal electrodes (31, 53, 54, 55 [CPz], 61, 62 [Pz], 78, 79, 80, 86 and Cz).

Salivary oxytocin

For each sample at least 1mL of unstimulated saliva was collected into 1.8 mL cryotubes using the passive drool method. Samples were immediately frozen and were stored at -20 degrees Centigrade until batch assay. Level of oxytocin in saliva was assayed using a commercially available kit as per the method previously described (Grewen, Davenport, & Light, 2010; Holt-Lunstad, Birmingham, & Light, 2008). Prior to the enzyme immunoassay procedure, in keeping with the manufacturer's strong recommendation, an extraction step was performed based on instructions accompanying the EIA kit currently available in February

2011 (ADI-900-153, Enzo Life Science, Plymouth Meeting, PA). The result of this extraction was to concentrate the sample 3.2 times, increase precision and reduce matrix interference. OT extraction efficiency was 93%, which was determined by spiking with a known amount of hormone and extracting this known amount along with the other samples. OT levels in extracted saliva were then quantified using the OT EIA, in which the endogenous OT hormone competes with added OT linked to alkaline phosphatase for OT antibody binding sites. After overnight incubation at 4 degrees C., the excess reagents were washed away and the bound OT phosphatase was incubated with substrate. After 1 hour this enzyme reaction, which generates a yellow color, was stopped and the optical density (OD) was read on a Sunrise plate reader (Tecan, Research Triangle Park, NC). The intensity of the color at 405nm is inversely proportional to the concentration of OT. The hormone content (in pg/mL) was determined by plotting the intensity of OD of each sample against a standard curve. Following correction for extraction, the lower limit of sensitivity was 1.25 pg/mL. Less than 1% of the samples fell below the lower level of sensitivity (4 out of 348). These values were subsequently replaced with the lowest detectable level of 1.25 pg/mL. The intra- and inter-assay coefficients of variation were 7.35% and 8.51% respectively. The manufacturer reports that cross-reactivity with similar mammalian neuropeptides is less than 1%.

Among the 48 participants included in our final sample, for one participant one oxytocin value (T1, placebo condition) was considered an outlier ($z > 3.29$) within this time point and condition. For statistical analysis this value was replaced by the highest value occurring at this time point and condition among the remaining participants. In addition, values of one participant at T1 and another participant at T2 of the oxytocin condition fell too far outside the normal curve to be considered reliable. These values were replaced by the mean value of the respective time point and condition across the remaining participants. To normalize data distribution, we computed the natural logarithm of the raw values.

Analyses

Statistical analyses were performed using SPSS 17 software. Variations in task performance across conditions and participants were evaluated using repeated measures general linear model (GLM) analyses with error percentages, percentages of late responses, number of points earned during the task, and reaction times as dependent variables, drug (placebo vs. oxytocin) as within subjects factor, order of administration (placebo first vs. oxytocin first) as between subjects factor, and maternal use of love withdrawal (LWm) and fear of failure (FoF) as covariates. The analysis of reaction time included target type (congruent vs. incongruent) as additional within subjects factor. Because the post-task questionnaire provided ordinal data, logit ordinal regression analyses were performed with answers on each of the 9 post-task questions as dependent variables and drug condition (placebo vs. oxytocin administered during the second session) and LWm as predictors (including the interaction term of the centered predictors). To test whether oxytocin levels in saliva increased after oxytocin administration, a repeated measures GLM analysis was performed with drug (placebo vs. oxytocin) and time (T0, T1, T2) as within subjects factors and order of administration as a between subjects factor. Greenhouse-Geisser corrections were performed when necessary. Analyses of VPP and LPP amplitude respectively were performed using repeated measures GLM analyses with drug (placebo vs. oxytocin), color (green vs. red) and facial expression (happy vs. disgusted) as within subjects factors, order of administration (placebo first vs. oxytocin first) as a between subjects factor, and LWm and FoF as covariates.

Results

Behavioral data

Maternal use of love withdrawal and fear of failure were significantly correlated ($r = .34$, $p < .05$). An overview of behavioral data during the placebo and oxytocin conditions is presented in Table 1. There were no significant effects of any of the independent variables (drug, LWm, FoF, and order of administration) on participants' error percentages, percentages of late responses, and the number of points they earned during the task (all Fs ≤ 2.24, all ps > .10). Participants responded significantly faster to congruent targets than to incongruent targets (main effect of target type), $F(1,45) = 30.61$, $p < .01$. In addition, reaction times were significantly faster during the first session than during the second session (an interaction between drug and order of administration, which was significant here, is the same as a main effect of session), $F(1,45) = 28.19$, $p < .01$, and the difference between reaction times to congruent and incongruent targets was smaller during the second compared to the first session, $F(1,45) = 4.13$, $p < .05$. No other significant effects on reaction time were found (all Fs ≤ 3.13, all ps > .05).

Love withdrawal significantly predicted answers on three of the post-task questions. Participants reporting higher love withdrawal rated their performance worse in general ($p < .01$), were less satisfied with their performance ($p < .01$), and rated their performance less favorably compared to others ($p < .05$). No significant effects of drug or interactions between drug and LWm were found (all ps > .10).

Table 1
Summary of behavioral data

Measure	Placebo	Oxytocin
Points earned	1024 (677)	1195 (485)
Percentage errors	17 (7)	15 (6)
Percentage late responses	12 (2)	12 (2)
Reaction time congruent targets (in ms)	312 (30)	315 (23)
Reaction time incongruent targets (in ms)	352 (38)	359 (31)

Note: Each cell in the table includes the mean, with the standarddeviation between brackets.

Salivary oxytocin

The (ln-transformed) average levels of oxytocin at the different time-points during the placebo and oxytocin condition are plotted in Figure 1. The GLM analysis revealed significant main effects of drug, $F(1,46) = 257.98$, $p < .01$, and time, $F(1.65,76.00) = 77.31$, $p < .01$, qualified by a significant interaction between drug and time, $F(2,92) = 99.87$, $p < .01$. As can be seen in Figure 1, average levels of oxytocin were virtually the same in both conditions before nasal spray administration (T0, $M = 1.85$ [placebo condition], $M = 1.84$ [oxytocin condition]) and markedly increased only after oxytocin administration.

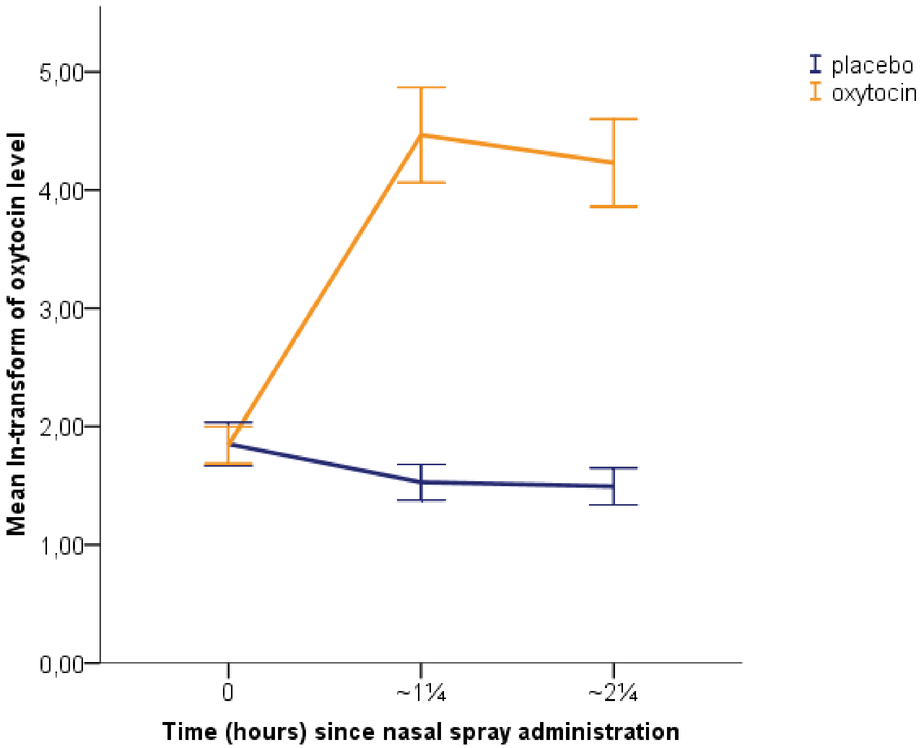

Figure 1. Mean (ln-transformed) levels of salivary oxytocin before (T0), approximately 1¼ hours after (T1), and approximately 2¼ hours after (T2) administration of nasal spray containing 24 IU of oxytocin or a placebo. Vertical bars represent 95% confidence intervals.

ERPs: VPP

Grand average ERPs at Cz time-locked to the onset of the feedback stimuli are presented in Figure 2, illustrating the VPP. Figure 3 presents the scalp voltage-distribution of this component.

The GLM analysis on VPP amplitude revealed a significant main effect of drug, $F(1,44) = 8.84$, $p < .01$, reflecting more positive VPP amplitudes in the oxytocin compared to the placebo condition. Importantly, the interaction between drug and LWm was significant as well, $F(1,44) = 7.33$, $p < .05$. Lower LWm was associated with larger increases in VPP amplitude after oxytocin compared to placebo administration, whereas this effect was smaller or absent for participants with higher scores on LWm. Oxytocin thus heightened processing of the happy and disgusted faces primarily for those reporting lower love withdrawal, as can be seen in Figure 2. An extended description of the results of this analysis can be found in the Supplementary Material. Here we focus only on findings relating to oxytocin and maternal love withdrawal.

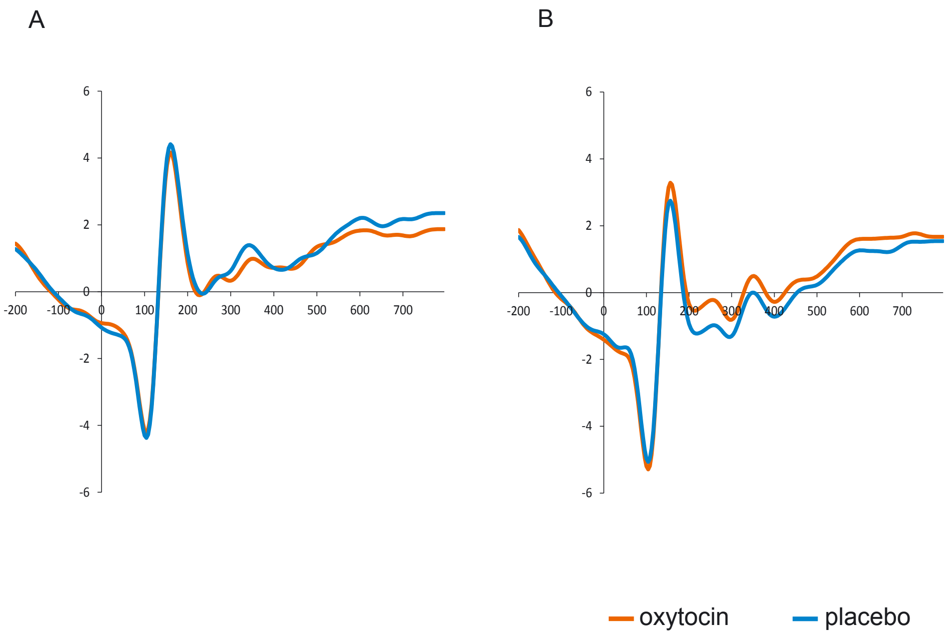

Figure 2. Grandaverage ERPs at Cz, illustrating the VPP. A: ERPs to feedback stimuli for participants reporting high maternal use of love withdrawal. B: ERPs to feedback stimuli for participants reporting low maternal use of love withdrawal. Participants were divided into groups for displaying purposes only. Participants reporting lower maternal use of love withdrawal showed a more positive response to the feedback stimuli after oxytocin compared to placebo administration between 140 and 180 ms after stimulus onset (VPP). ERPs were low-pass filtered at 15 Hz for displaying purposes.

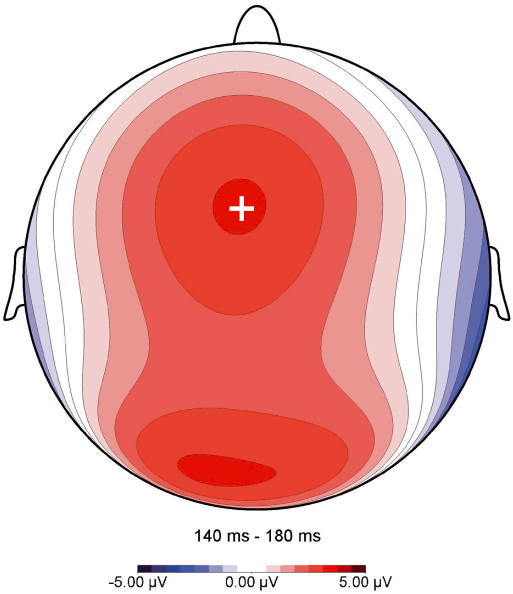

Figure 3. Scalp voltage distribution of the VPP: Voltage distribution of the ERP (averaged over all feedback stimuli) across the 140-180 ms post-stimulus interval. The maximum of the VPP is marked with '+'.

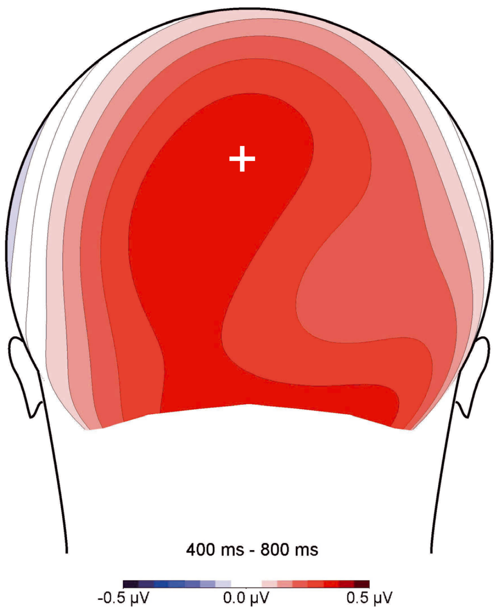

Figure 4. Scalp voltage distribution of the effect of oxytocin on LPP amplitude: Distribution of the ERP in the oxytocin condition minus the ERP in the placebo condition (averaged over all categories of feedback stimuli) across the 400-800 ms post-stimulus interval. The maximum is marked with '+'.

ERPs: LPP

The GLM analysis on LPP amplitude revealed a significant main effect of drug, $F(1,44) = 6.81$, $p < .05$, reflecting more positive LPP amplitudes in the oxytocin compared to the placebo condition. The effect of oxytocin is illustrated in Figure 4, showing the broad posterior distribution of the oxytocin effect. In contrast to the VPP, we did not find a significant interaction effect between drug and LWm on LPP amplitude, $F(1,44) = 2.15$, $p > .10$. Significant interaction effects were found between facial expression and LWm, $F(1,44) = 4.20$, $p < .05$, and between color and facial expression, $F(1,44) = 7.06$, $p < .05$, that were both further qualified

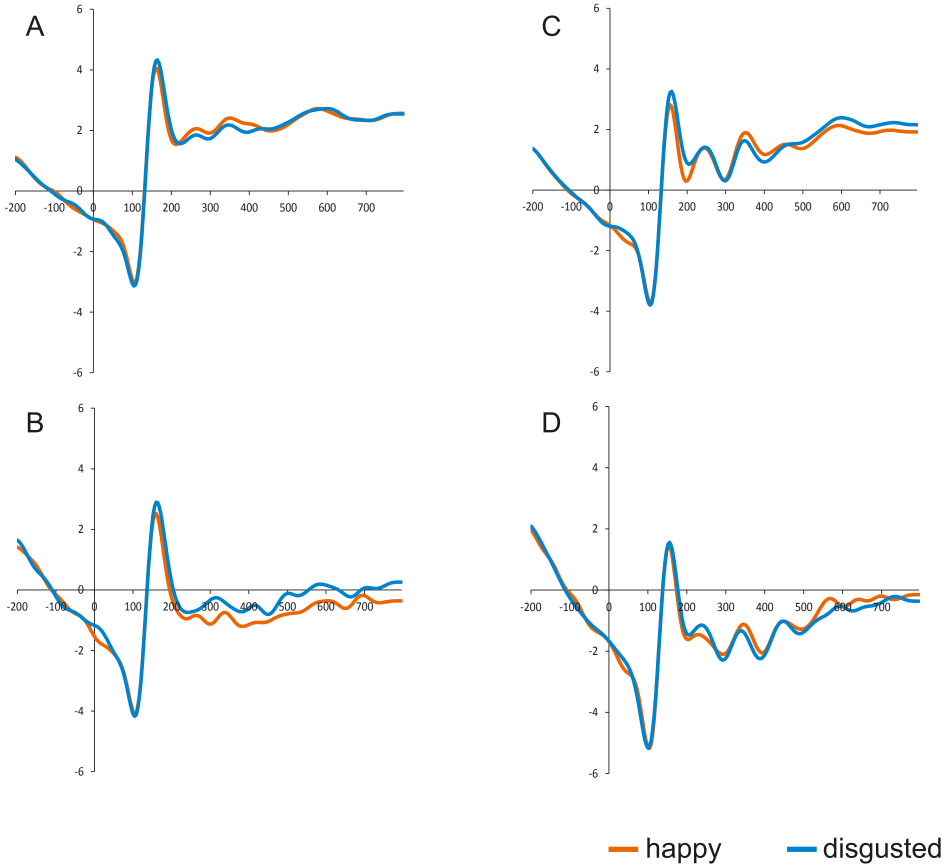

Figure 5. Grandaverage ERPs at CPz, illustrating the LPP. A and B: ERPs to green (A) and red (B) feedback stimuli for participants reporting high maternal use of love withdrawal. C and D: ERPs to green (C) and red (D) feedback stimuli for participants reporting low maternal use of love withdrawal. Participants were divided into groups for displaying purposes only. Participants reporting higher maternal use of love withdrawal showed a larger difference between responses to disgusted and happy faces (more positive for disgust) for red compared to green stimuli in the time interval ranging from 400 to 800 ms after stimulus onset at centroposterior electrode sites (LPP). ERPs were low-pass filtered at 15 Hz for displaying purposes.

by an interaction between color, facial expression and LWm, $F(1,44) = 9.54$, $p < .01$. Higher LWm was related to larger differences in LPP amplitudes in response to disgusted compared to happy faces (with LPP amplitudes in response to disgusted faces more positive than to happy ones), and to larger differences between LPP amplitudes to disgusted and happy faces when presented in red than when presented in green. That is, those reporting higher love withdrawal directed more attention toward disgusted compared to happy faces, especially when they made an error (face presented in red). Figures 5 and 6 present grandaverage ERPs at CPz and Pz time-locked to the onset of the four categories

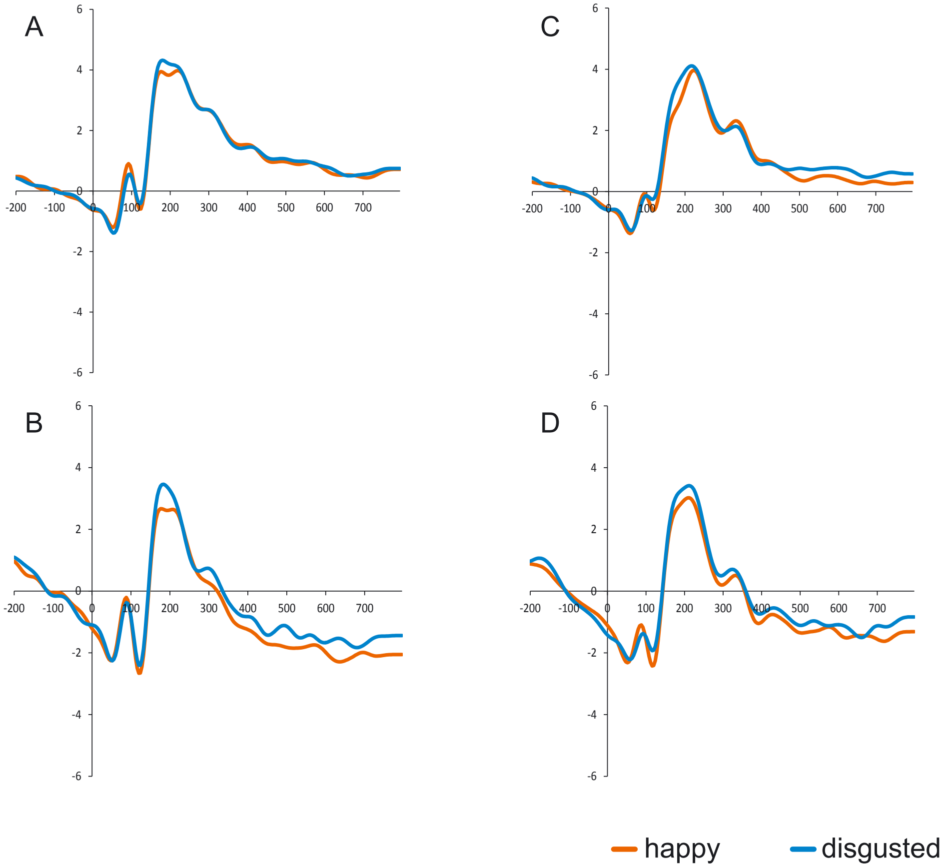

Figure 6. Grandaverage ERPs at Pz, illustrating the LPP. A and B: ERPs to green (A) and red (B) feedback stimuli for participants reporting high maternal use of love withdrawal. C and D: ERPs to green (C) and red (D) feedback stimuli for participants reporting low maternal use of love withdrawal. Participants were divided into groups for displaying purposes only. Participants reporting higher maternal use of love withdrawal showed a larger difference between responses to disgusted and happy faces (more positive for disgust) for red compared to green stimuli in the time interval ranging from 400 to 800 ms after stimulus onset at centroposterior electrode sites (LPP). ERPs were low-pass filtered at 15 Hz for displaying purposes.

of feedback stimuli, illustrating these effects. Again, an extended description of the results of this analysis can be found in the Supplementary Material.

ERPs: Fear of failure

Because no significant effects of FoF were found in any of the analyses described above, we repeated the analyses with fear of failure as the only covariate (i.e., excluding LWm from the analyses). No significant main or interactions effects involving FoF on VPP (all Fs ≤ 2.40, all ps $> .10$) and LPP amplitude (all Fs ≤ 3.79, ps $> .05$) were found.

ERPs: Use of oral contraceptives

Because the influence of oxytocin may be dependent on the use of oral contraceptives the repeated measures GLM analyses (with both LWm and FoF as covariates) described above were repeated with use of oral contraceptives (used vs. not used) as an additional between subjects factor. In the analysis with VPP amplitude as the dependent variable, all the effects described above remained significant (all Fs ≥ 4.10, ps $< .05$). In the analyses with LPP amplitude as the dependent variable only the interaction effect between facial expression and LWm was no longer significant, $F(1,42) = 2.38$, $p > .10$. The main effects of drug and color, and the interaction effects between color and facial expression, and between color, facial expression and LWm all remained significant (all Fs ≥ 6.29, ps $< .05$). Including use of oral contraceptives in the analyses thus did basically not change the outcomes.

Discussion

Oxytocin affected electrocortical responses to facial feedback stimuli, both in relatively early (VPP) and later (LPP) stages of processing, and in the absence of effects on task performance and subjective evaluations. Moreover, we demonstrated the effect of oxytocin administration on salivary oxytocin levels up to 2¼ hours after use of the nasal spray. Thus, clear elevations of oxytocin levels were observed within a time-range comparable to its neurobehavioral effects, suggesting that salivary concentrations may be a valuable biomarker for oxytocin.

As expected, VPP amplitudes were more positive after oxytocin compared to placebo administration, indicating that oxytocin enhanced the (configural) processing of emotional faces, regardless of the expression or feedback. These results are thus consistent with findings by Domes et al. (2010) of enhanced activity in various brain areas involved in face processing after oxytocin administration in healthy women. In addition, oxytocin interacted with maternal use of love withdrawal to affect the processing of emotional faces. Higher maternal love withdrawal was related to smaller increases in VPP amplitude after oxytocin administration compared to placebo administration. An explanation for this interaction between oxytocin administration and love withdrawal may be that participants reporting higher love withdrawal likely show near maximum processing of facial expressions even under placebo conditions, thus limiting potential increases after oxytocin administration. If oxytocin would have caused participants with higher love withdrawal to be less anxious about (the consequences of) task performance and consequently to attend less to facial expressions, we would have expected a similar interaction effect between oxytocin administration and love withdrawal on LPP amplitude. We did, however, not observe such an interaction. In addition, although love withdrawal was related to some of the answers on the post-task questionnaire, no effects of oxytocin and, more importantly, no interaction effects between love withdrawal and oxytocin that would have supported an effect of oxytocin on the perception of the task were found for any of the questions.

Consistent with our hypothesis, LPP amplitudes were more positive after oxytocin compared to placebo administration, indicating that oxytocin enhanced attention to the feedback stimuli. The LPP is known to be strongly modulated by emotional facial expressions, which by definition are motivationally relevant, being primary sources of information about others' emotional states and intentions (Domes et al., 2007b; Haxby, Hoffman, & Gobbini, 2002). Thus, because oxytocin enhanced the processing of emotional faces (as indexed by VPP amplitude), it is tempting to speculate that the increased LPP amplitude observed here reflects the allocation of attention toward the facial expressions specifically. However, we can not rule out the possibility that oxytocin enhanced attention to faces in general or even to the feedback itself, because no neutral facial expressions were included and faces and feedback were presented simultaneously. Maternal love withdrawal was also related to LPP amplitudes, consistent with an attentional bias resulting from an association between performance and relational consequences established through the experience of love withdrawal. Higher love withdrawal was related to more positive LPP amplitudes in response to disgusted compared to happy faces, specifically when faces were presented in red (i.e., after an error). Thus, participants reporting higher love withdrawal increasingly direct attention toward disgusted (compared to happy) faces, implying that their attention is biased toward disgusted faces, specifically after they have made an error. In terms of the emotional or motivational significance of stimuli, the congruent combination of a disgusted face presented in red may well be the most relevant stimulus for participants who experienced more love withdrawal, because of its association with negative relational outcomes linked to failure.

It is interesting to speculate about the brain regions involved in the modulation of LPP amplitude. Sabatinelli et al. (2007) suggest that activity in the areas generating the LPP (inferotemporal, posterior parietal, and occipital visual areas) may result from reentrant connections from the amygdala to visual areas. The amygdala is well known to be connected to and interact with areas such as the inferior frontal gyrus, fusiform gyrus, and superior temporal areas in the processing of facial expressions (Amaral & Price, 1984; Haxby et al., 2002; Iidaka et al., 2001). The inferior frontal gyrus (and adjacent anterior insula) and superior temporal sulcus, have been found to contain mirror neurons that respond to emotional expressions and emotional prosody (Gazzola, Aziz-Zadeh, & Keysers, 2006; Wildgruber, Ackermann, Kreifelts, & Ethofer, 2006). Mirror systems are both active when an individual performs an action and when another individual performs an action from the same class of actions or an action with a similar goal or meaning (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). Mirror neurons have been found to be involved in affect mirroring, understanding others' actions, and some aspects of empathy, and areas containing mirror neurons are involved in judging the appropriateness of facial affect (Gazzola et al., 2006; Kim et al., 2005). In accordance with these social processes involving mirror neurons, oxytocin has been suggested to influence the mirror neuron system (Perry et al., 2010). In addition, it is likely that mirror neurons are involved in affect mirroring and contingency detection in mother-child interactions that are central to the development of emotional self-awareness, self-control, and empathy from infancy through adolescence (Feldman, 2007; Fonagy, Gergely, & Target, 2007; Gergely & Watson, 1996). This system is thus also a likely candidate for parenting strategies like love withdrawal to take effect.

As in our previous analyses of ERP responses under placebo conditions (Huffmeijer et al., 2011) and in contrast to Tops and Wijers (2011), who used the same experimental paradigm, we found no significant effects of fear of failure on VPP and LPP amplitudes in response to the feedback stimuli. Further research is needed to clarify whether and how fear of failure is related to ERP responses to facial feedback stimuli. Future studies could also address some of the limitations of the current study. Neutral facial expressions might be included in future experiments to distinguish between effects of oxytocin on the processing of faces in general and facial expressions in particular. Furthermore, in our study participants committed about 16% errors, and they were therefore presented with more green than red stimuli. Future studies may (additionally) use more difficult tasks resulting in higher error percentages and thus more equal numbers of green and red feedback stimuli. Furthermore, we measured maternal use of love withdrawal and fear of failure with self-report questionnaires. There are obvious limitations to the accuracy and reliability of participants' self-reports. Lastly, our participants were all female. We chose to include only women in this study, because of the considerable differences between males and females in the oxytocin system (Suske & Gallagher, 2009), and because most of the studies on the behavioral or psychological outcomes of love withdrawal focus on maternal use of love withdrawal with daughters (e.g., Elliot & Thrash, 2004; Renk et al., 2006). It would be interesting to study the same processes in men.

In conclusion, we extended previous findings relating maternal use of love withdrawal to ERPs in response to facial feedback stimuli, demonstrating not only that love withdrawal, in interaction with oxytocin, relates to the processing of emotional faces in a performance context, but also that higher maternal love withdrawal relates to the allocation of attentional resources toward the motivationally most relevant combination of negative feedback presented with a disgusted face. Furthermore, the current study is the first to describe effects of oxytocin on electrocortical responses to facial stimuli in females, using pictures combining emotional faces with performance feedback. The findings of more positive VPP and LPP amplitudes suggest that oxytocin increases attention to the facial feedback stimuli (LPP) and enhances the processing of emotional faces (VPP).

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Supplementary material

Analysis of VPP amplitude

Besides the significant main effect of drug and interaction effect between LWm and drug, we also found a significant interaction between drug and order of administration, $F(1,44) = 10.65$, $p < .01$ (this is a session effect, reflecting more positive VPP amplitudes during the first compared to the second session), a significant main effect of color, $F(1,44) = 6.34$, $p < .05$ (more positive amplitudes to green than to red stimuli), and a significant interaction between color, drug and order of administration, $F(1,44) = 5.23$, $p < .05$ (i.e., an interaction between color and session, reflecting a larger color effect during the first compared to the second session). No other effects were significant (all Fs ≤ 2.62, ps > .10).

Analysis of LPP amplitude

Besides the significant effects described in the main paper (main effect of drug, and interactions between LWm and facial expression, between color and facial expression, and between LWm, color, and facial expression), we also obtained a significant main effect of color, $F(1,44) = 6.37$, $p < .05$ (more positive amplitudes in response to green compared to red stimuli). No other effects were significant (all Fs ≤ 3.00, ps > .05).

4 Asymmetric frontal brain activity predicts donating behavior: Moderation of oxytocin and parental love withdrawal effects

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Abstract

Asymmetric frontal brain activity has been widely implicated in reactions to emotional stimuli, and is thought to reflect individual differences in approach-withdrawal motivation. Here, we investigate whether asymmetric frontal activity, as a measure of approach-withdrawal motivation, also predicts charitable donations after viewing a charity's (emotion-eliciting) promotional video showing a child in need, in a sample of 47 young-adult women. In addition, we explore possibilities for mediation and moderation by asymmetric frontal activity of effects of intranasally administered oxytocin and parental love withdrawal on charitable donations. Greater relative left frontal activity was related to larger donations. In addition, we found evidence of moderation: low levels of parental love withdrawal predicted larger donations in the oxytocin condition for participants showing greater relative right frontal activity. We suggest that when approach motivation is high (reflected in greater relative left frontal activity), individuals are generally inclined to take action upon seeing someone in need, and thus to donate money to actively help-out. Only when approach motivation is low (reflected in less relative left/ greater relative right activity), do empathic concerns affected by oxytocin and experiences of love withdrawal play an important part in deciding about donations.

Introduction

Donating to charity is a uniquely human form of prosocial behavior that does not directly benefit the individual who donates. As such, theories explaining charitable donating have focused on indirect or psychological benefits, such as establishing a favorable reputation (Nowark & Sigmund, 2005), or the "warm glow" people experience from doing something good or righting a perceived injustice (Andreoni, 1990; Mayo & Tinsley, 2009). Empathic concern for those in need of help may be an especially important motivator for donating to charity, predicting donations even when socio-demographic variables (age, income, and gender) and past donating behavior are taken into account (Verhaert & Van den Poel, 2011).

Various factors may contribute to (the development of) prosocial attitudes and empathy, and thus affect donating behavior. Recently, we reported on effects of intranasally administered oxytocin and experienced parental love withdrawal on monetary donations in a donating task, in which participants watched a promotional video asking them to donate some money to UNICEF, after they had just earned 50 Euros by participating in an ERP experiment (Van IJzendoorn, Huffmeijer, Alink, Bakermans-Kranenburg, & Tops, 2011). Oxytocin is a neuropeptide hormone that is increasingly shown to facilitate prosocial behavior (at least in in-group situations, De Dreu et al., 2010). Oxytocin has been found to attenuate stress responses in social situations, to influence the processing of and facilitate memory for salient social stimuli, to promote trust and generosity toward an opponent (for reviews see Heinrichs, von Dawans, & Domes, 2009, and MacDonald & MacDonald, 2010), and to increase the amount of money donated to charity (Barraza, McCullough, Ahmadi, & Zak, 2011).

However, we found that oxytocin increased donations only for those reporting lower parental use of love withdrawal. Love withdrawal is a disciplinary strategy that involves withholding signals of love and affection when a child misbehaves or fails at a task. When used excessively, it is considered psychological maltreatment (Euser, Van IJzendoorn, Prinzie, & Bakermans-Kranenburg, 2010). By using love withdrawal the parent communicates to the child that his or her love and affection for the child are conditional upon the child's compliance and success. The formation of this link between compliance or performance on the one hand and relational consequences on the other is thought to underlie both the effectiveness and emotional costs of love withdrawal (Assor, Roth, & Deci, 2004; Elliot & Thrash, 2004). Parental use of love withdrawal has been associated with fear of failure, low self-esteem, low emotional well-being, and feelings of rejection and resentment toward the parents in adolescence and young adulthood (Assor et al., 2004; Elliot & Thrash, 2004; Goldstein & Heaven, 2000; Renk, McKinney, Klein, & Oliveros, 2006; Soenens, Vansteenkiste, Luyten, Duriez, & Goossens, 2005). This may both hinder empathic concern (and its expression in donating behavior), and bias decision making in social situations away from other-oriented (e.g., empathy for a child in need) to self-oriented concerns (doing what relevant others expect, out of fear for negative reactions).

To extend our previous findings, we now turn our attention to another characteristic that has been implicated in emotional and motivational processes: asymmetric frontal cortical activity. Differences in power within the alpha band (8-12 Hz) of the electroencephalogram (EEG) over left and right frontal areas are widely used to quantify asymmetric frontal brain activity. Because greater alpha power is related to deactivation of the underlying cortical tissue (Cook, O'Hara, Uijtdehaage, Mandelkern, & Leuchtner, 1998, Laufs et al., 2003), greater alpha power over right compared to left frontal areas reflects greater activity of the left compared to right frontal cortex, whereas greater alpha power over left than right frontal areas reflects relatively greater activity of the right frontal cortex. Numerous studies have related asymmetric frontal activity to emotional processes in individuals of all ages (e.g., Coan & Allen, 2004; Davidson & Fox, 1989; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Whereas early studies focused on emotional valence, showing a relation between greater relative left activity and a tendency to experience certain positive emotions (e.g., happiness) and between greater relative right activity and a tendency to experience certain negative emotions (e.g., fear), more recent research suggest that asymmetric frontal activity relates to motivational direction (of emotions) rather than emotional valence (for a review see Harmon-Jones, Gable, & Peterson, 2010). Frontal asymmetries seem to be best characterized as reflecting a general tendency for approach versus withdrawal, with greater left activity reflecting greater approach motivation, and greater right activity reflecting greater withdrawal motivation, although there is more evidence for the link between left frontal activity and approach than for the link between right frontal activity and withdrawal (Demaree, Everhart, Youngstrom, & Harrison, 2005; Harmon-Jones & Allen, 1997; Harmon-Jones et al., 2010). Measures of asymmetric frontal activity have been shown to track both a general trait of and state-related fluctuations in approach-withdrawal motivation, with the contributions of trait- and state-related variation estimated to be about 50% each (Coan & Allen, 2004; Hagemann, Hewig, Seifert, Naumann, & Bartussek, 2005).

As a measure of approach-withdrawal motivation, asymmetric frontal activity may be expected to relate to donating behavior when individuals are confronted with a charity's promotional material (typically showing the precarious situation of those in need) and asked for a donation. Higher approach motivation and a greater tendency to experience approach-related emotions, associated with greater relative left frontal activity, may well cause an individual to donate more money to actively help-out those in need. Thus, we expect that asymmetric frontal activity will predict monetary donations to UNICEF in the context of our donating task.

Because asymmetric frontal activity both reflects a trait-like motivational tendency to react in a certain (predictable) way in emotionally evocative situations, and is susceptible to state-related changes, it has been suggested that frontal asymmetries may serve as moderators or mediators of behavior (Coan & Allen, 2004). Therefore, we will also investigate whether frontal alpha asymmetry mediates or moderates the effect of oxytocin administration and parental love withdrawal that we have found previously (Van IJzendoorn et al., 2011).

For mediation to occur, asymmetric frontal activity should not only be related to donating behavior, but also be affected by oxytocin, parental love withdrawal, or both. Many effects of oxytocin on socio-emotional information processing, e.g. increased processing of facial expressions (Domes et al., 2010; Huffmeijer et al., 2011a), and behavior, e.g. increases in trust and generosity (Zak, Kurzban, & Matzner, 2005; Zak, Stanton, & Ahmadi, 2007), may be linked to approach motivation, suggesting that oxytocin might increase relative left frontal activity. Also, oxytocin has been found to have anxiolytic effects in social situations (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003), and anxiety has been related to increased relative right frontal activity (e.g., Thibodeau, Jorgensen, & Kim, 2006). Experiences of parental love withdrawal might also relate to frontal alpha asymmetry. Experiences of parental love withdrawal have been related to fear of failure, i.e. anxiety in performance situations (e.g., Elliot & Thrash, 2004; Soenens et al., 2005). Within the current study, measures of frontal alpha asymmetry were collected before and after participants performed a computerized feedback task (i.e. in a performance situation). Because relative right frontal activity may be related to anxiety primarily within anxiety-provoking situations (Crost, Pauls, & Wacker, 2008), within the current context parental love withdrawal might be related to relative right frontal activity.

In case of moderation, on the other hand, effects of oxytocin and parental love withdrawal would depend on an individual's level (direction and degree) of asymmetric frontal activity. Effects of oxytocin and concerns related to experiences of parental love withdrawal might, for example, exert less influence over decision making in the donating task for those showing greater relative left frontal activity, who may be expected to respond positively to a request for a donation after seeing an individual in need because of a high level of approach motivation.

To summarize, the current study examines whether asymmetric frontal brain activity, as a measure of approach-withdrawal motivation, predicts donations to charity after viewing a promotional video of a child in need. We expect that greater relative left frontal activity, reflecting higher approach motivation, predicts larger donations. In addition, we explore the possibility that asymmetric frontal brain activity mediates or moderates the combined effect of oxytocin and parental love withdrawal on donating behavior.

Method

Participants

A total of 59 female undergraduate students, aged 18-30 years (M = 20.54, SD = 2.89), participated in the study. Two participants did not complete the donating task (because they did not participate in the second session, in which this task took place), nine participants contributed insufficient EEG data because of excessive ocular or motion artifacts, and data collection for one participant was disturbed by loud noise. The final sample thus consisted of 47 female undergraduate students, aged 18-30 years (M = 20.45, SD = 2.80). Exclusion criteria included colorblindness, smoking, alcohol and drug abuse, neurological and psychiatric disorders, pregnancy, breastfeeding, and use of medication (except oral contraceptives). The study was approved by the ethics committee of the Leiden University Medical Center, and informed consent was obtained from participants at the beginning of the experiment.

Procedure

Participants completed a questionnaire measuring parental use of love withdrawal during an introductory course in child and family studies. The questionnaire was administered to 391 18-30 year old female undergraduate students who were willing to participate in an ERP experiment. Participants for this experiment were selected stratified from the pool of 391 students, based on their scores on the maternal version of the questionnaire: Half of the participants were selected randomly from the group scoring in the upper quartile of the questionnaire (*n* = 23 for the current sample), and half of the participants were selected randomly from the group scoring in the other three quartiles (*n* = 24 for the current sample), resulting in a normal distribution of love-withdrawal scores (see below).

Participants were asked to come to our laboratory for two experimental sessions, separated by approximately four weeks. To minimize influences of diurnal variations in oxytocin levels, all sessions took place in the afternoon (starting between 12.00 and 15.00). Here, we report on the second session, which ended with the donating task. Participants were instructed to abstain from alcohol and excessive physical activity during the 24 hours before the start of each session, and from caffeine on the day of the session.

Concerning the administration of oxytocin, participants were told that they would receive oxytocin during one session and a placebo during the other, and that the order was not known even to the experimenter. This message was repeated at the beginning of the second session. Participants were not informed about the effects of oxytocin under investigation, only about the possible side effects they might experience (as required by the ethics committee).

At the start of each session, participants received a nasal spray containing either 24 IU of oxytocin or a placebo (saline solution). All participants received both substances once, either the placebo during the first session and oxytocin during the second, or oxytocin during the first session and the placebo during the second. The order of administration was unknown to both the participant and the experimenter and counterbalanced across participants. Thus, half of the participants received oxytocin during the second session (*n* = 22 for the current sample) and half a placebo (*n* = 25 for the current sample). Participants were then fitted with an electrode net after which their EEG was recorded during two 2-min resting periods (the first with eyes opened, the second with eyes closed). Participants then completed a 1-hr task (for ERP data collection, results presented elsewhere) after which their EEG was again recorded during two 2-min resting periods (again, the first with eyes opened, the second with eyes closed).

Donating to UNICEF

After completion of the last EEG measurements of the second session, participants were paid 50 Euros for participation. They were then left alone and were shown a 2-min UNICEF promotional video, showing a child from a resource-limited country (Bangladesh), forced to work in a stone pit instead of going to school, due to poverty. Immediately following the video a text appeared on screen, asking the participant to donate some money. A money box had been positioned next to the video screen. The money box was filled with several coins to enhance credibility (see Van IJzendoorn, Bakermans-Kranenburg, Pannebakker, & Out, 2010, for a similar task). Because the distribution of donations was somewhat skewed, a square root transformation was used in all analyses. Donated money was transferred to the UNICEF bank account after data collection.

EEG measurement

During EEG data collection, participants were seated in a comfortable chair facing a computer screen (distance approximately 50 cm), in a dimly lit, sound-attenuated room. A white fixation cross was presented on a black background at the center of the screen during resting measurements with eyes opened. Participants were instructed to 'just relax' and keep their eyes focused on the cross as much as possible. Participants' EEG was acquired during the four resting periods using 129-channel hydrocel geodesic sensor nets, amplified using a NetAmps300 amplifier, low-pass filtered at half (i.e., 125 Hz) the digitization rate of 250 Hz and recorded using NetStation software (Electrical Geodesics, Inc.). Impedances were kept below 50 kΩ. Further processing of the raw EEG was conducted offline using Brain Vision Analyzer 2.0 software (Brain Products). The EEG was filtered with a passband range of 0.1-40 Hz (-3 dB, 48 dB/octave) and rereferenced to the average of activity in all channels. Each two-minute recording was divided into 119 2-s segments, with one second overlap between segments, and corrected for ocular artifacts using ICA. Segments containing residual artifacts were removed (segments were removed if the slope at any point during the segment exceeded 100 μV/ms, and if the difference between the maximum and minimum activity exceeded 300 μV within the entire segment or was less then 0.5 μV within any 100 ms period) and a short term Fourier transform (0.5 Hz resolution, 100% Hamming window) was computed to obtain power values (μV^2) for the remaining segments. Power values were averaged across all segments within each resting period, and then averaged across the frequency range of 8-12 Hz to obtain measures of power within the alpha band within each resting period. To normalize data distribution the natural logarithm (ln) of these values was computed.

Ln-transformed values were averaged across sets of eight electrodes to yield measures of left-frontal (20, 23, 24 [F3], 26, 27, 28, 33 [F7], 34), right-frontal (2, 3, 116, 117, 118, 122 [F8], 123, 124 [F4]), left-central (30, 36 [C3], 37, 40, 41, 42, 45, 46), right-central (87, 93, 102, 103, 104 [C4], 105, 108, 109), left-posterior (52 [P3], 53, 58 [P7], 59, 60, 61, 64, 65), and right-posterior (78, 85, 86, 90, 91, 92 [P4], 95, 96 [P8]) alpha activity. As a measure of asymmetry, laterality indices were computed separately for frontal, central and posterior sites by subtracting left alpha activity from right alpha activity (ln[right alpha] – ln[left alpha]). A zero value on this measure thus represents no alpha asymmetry, whereas more positive values result from greater alpha power over right compared to left cortical areas and therefore represent greater relative left frontal activity. Similarly, more negative values represent greater relative right frontal activity. Because no effects involving time (resting periods before vs. after the ERP experiment) or condition (eyes open vs. closed) were found (all Fs ≤ 2.89, ps > .05) in an ANOVA with drug (placebo vs. oxytocin), time and condition as independent variables, asymmetry values were averaged across the four baseline periods for statistical analyses.

Parental use of love withdrawal

Participants completed an 11-item questionnaire, containing all five items of the Withdrawal of Relations subscale of the Children's Report of Parental Behavior Inventory (CRPBI; Beyers & Goossens, 2003; Schludermann & Schludermann, 1988), two items that were adapted from this same questionnaire, and four items adapted from the Parental Discipline Questionnaire (PDQ; Hoffman & Saltzstein, 1967; Patrick & Gibbs, 2007). Participants rated how well each of the 11 statements described their mother and father separately (e.g., "My mother is a person who, when I disappoint her, tells me how sad I make her") on a 5-point scale ranging from 1 (not at all) to 5 (very well). Scores for maternal and paternal love withdrawal were summed, and the resulting scale was normally distributed. Cronbach's alpha was .87 for the current sample.

Analyses

Statistical analyses were performed using SPSS 17 software. To evaluate effects (simple, mediation, moderation) of frontal alpha asymmetry on donating behavior, a series of hierarchical linear regression analyses was performed. In all regression analyses, continuous predictors were centered on their respective means, and contrast codes were used for drug (placebo vs. oxytocin).

Results

Descriptives

Among the 47 participants included in the current sample, 37 donated some money (80%), and the average amount of money donated was 2.77 Euros (SD = 2.83, range 0.00 - 15.00). As described above, a square root transformation was computed to normalize data distribution, and transformed values were used in all analyses. The average score on the love withdrawal questionnaire was 48.06 (SD = 12.75), average values for frontal, central and posterior alpha asymmetry were -0.05 (SD = 0.17), -0.10 (SD = 0.26), and 0.07 (SD = 0.27) respectively. Posterior alpha asymmetry was significantly correlated with both frontal (r = -.45, p < .01) and central alpha asymmetry (r = .39, p < .01), whereas frontal and central asymmetry were not significantly related (r = .16, p > .10).

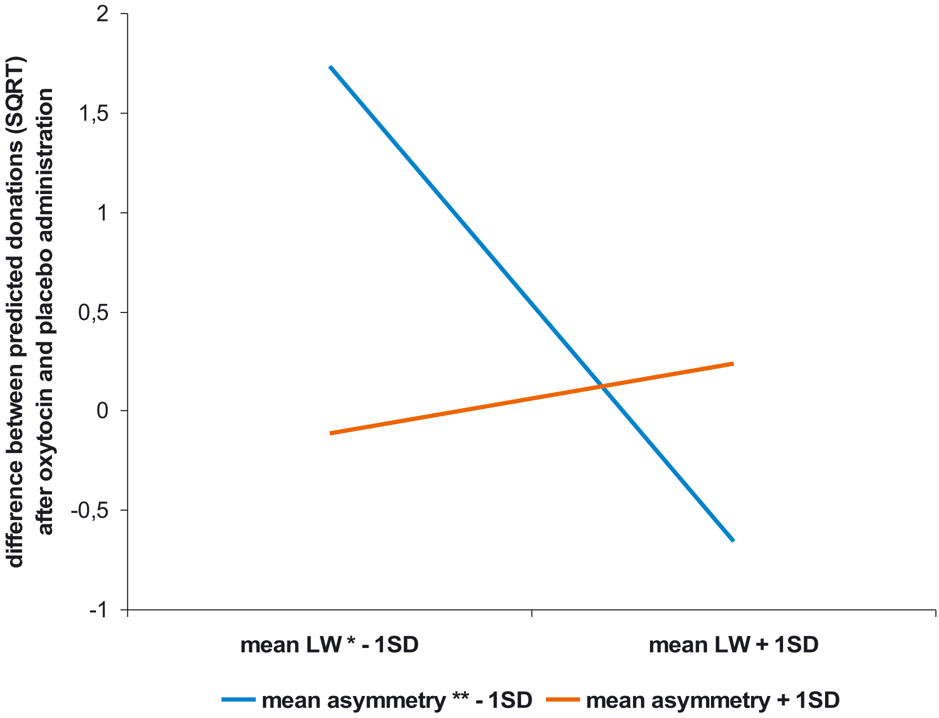
To confirm our previous result that the interaction between drug and love withdrawal predicted donating behavior in the current sample of 47 students, a hierarchical regression analysis was performed with drug (placebo vs. oxytocin) entered in the first step, love withdrawal in the second step, and the interaction between drug and love withdrawal in the third step. As expected, the model was significant ($F(3,43) = 2.91$, $p < .05$, $R^2 = .17$) and only the interaction term significantly predicted donating ($\beta = .32$, $p < .05$; other $|\beta s| \leq .16$, $ps > .10$).

Frontal alpha asymmetry and donating

Simple effect. Frontal alpha asymmetry and donating behavior were significantly and positively correlated (r = .30, p < .05). More positive values, and thus greater relative left frontal activity, were related to larger donations to UNICEF.

Mediation. To test whether frontal alpha asymmetry mediated effects of oxytocin and love withdrawal on donating behavior, we first examined if frontal alpha asymmetry was predicted by oxytocin, love withdrawal, or both. We therefore conducted a hierarchical regression analysis with frontal alpha asymmetry as the dependent variable, in which drug (placebo vs. oxytocin) was entered as a predictor in the first step, love withdrawal in the second, and the interaction term in the third step. No significant effects were found (all $|\beta s| \leq .10$, $ps > .50$; model: $F(3,43) = 0.15$, $p > .50$ $R^2 = .01$), thus ruling out mediation.

Moderation. To test for potential moderating effects of frontal alpha asymmetry, a hierarchical regression analysis was performed with donation as the dependent variable, in which drug (placebo vs. oxytocin) was entered in the first step, love withdrawal and frontal alpha asymmetry in the second step, all two-way interactions of the (centered) variables (drug*love withdrawal, drug*frontal alpha asymmetry, love withdrawal*frontal alpha asymmetry) in the third step, and the three-way interaction (drug*love withdrawal*frontal alpha asymmetry)



* mean LW: mean score on the love withdrawal questionnaire across participants
** mean asymmetry: mean frontal alpha asymmetry score across participants. Note that mean asymmetry - 1 SD reflects relative right frontal activity (M - 1SD = -0.05 - 0.17 = -0.22), whereas mean asymmetry + 1 SD reflects relative left frontal activity (M + 1SD = -0.05 + 0.17 = 0.12).

Figure 1. Differences between the predicted donations (square root transformation) to a charity after oxytocin versus placebo administration (oxytocin - placebo) as a function of frontal alpha asymmetry and love withdrawal. For those showing greater relative right frontal activity, lower love withdrawal was associated with larger donations after oxytocin compared to placebo administration.

in the fourth step. The final model was significant ($F(7,39) = 3,71$, $p < .01$, $R^2 = .40$). As in the analyses described above, the main effect of frontal alpha asymmetry ($\beta = .30$, $p < .05$) and the interaction between drug and love withdrawal ($\beta = .27$, $p < .05$) were significant. These effects were, however, qualified by a significant three-way interaction between drug, love withdrawal and frontal alpha asymmetry ($\beta = -.32$, $p < .05$). No other effects were significant (all $|\beta s| \leq .22$, $ps > .10$). To further explore the three-way interaction, we divided the participants into groups showing above average (more positive values, reflecting greater relative left / less relative right activity, $n = 23$) and below average (more negative values, reflecting greater relative right / less relative left activity, $n = 24$) frontal alpha asymmetry, and then conducted separate hierarchical regression analyses for each group with donation as the dependent variable, and predictors drug (placebo vs. oxytocin) entered in the first step, love withdrawal in the second, and the interaction term in the third step. For the group showing greater relative right / less relative left activity, the model was significant ($F(3,20) = 8.40$, $p < .01$, $R^2 = .56$), and the interaction between drug and love withdrawal significantly predicted donations ($\beta = .68$, $p < .01$; other $|\beta s| \leq .24$, $ps > .10$), whereas for the group showing greater relative left / less relative right activity no significant effects were found (all $|\beta s| \leq .32$, $ps > .10$; model: $F(3,19) = 0.91$, $p > .10$, $R^2 = .13$). As can be seen in Figure 1, lower love withdrawal was associated with larger donations after oxytocin (compared to placebo) administration for those showing greater relative right frontal activity.

Controlling for central and posterior alpha asymmetry

Because we found some significant correlations between alpha asymmetry at frontal, central, and posterior electrode sites, we repeated the analyses (with donation as dependent variable) described above under *Simple effect* and *Moderation* twice, once with central and once with posterior alpha asymmetry replacing frontal alpha asymmetry. Neither central ($r = .17$, $p > .10$) nor posterior alpha asymmetry ($r = -.06$, $p > .50$) was significantly correlated with donations, and in regression analyses no significant effects involving central (all $|\beta s| \leq .19$, $ps > .10$) or posterior alpha asymmetry (all $|\beta s| \leq .15$, $ps > .10$) were found. Finally, we performed a regression analysis (with donation as the dependent variable) in which central and posterior alpha asymmetry were entered as predictors in the first step to control for potential effects of central and posterior alpha asymmetry on donating behavior, before entering drug (placebo vs. oxytocin, step 2), love withdrawal and frontal alpha asymmetry (step 3), and the two- (step 4) and three-way interaction terms (step 5) of these three variables. The final model was significant ($F(9,37) = 2.78$, $p < .05$, $R^2 = .40$), and both the main effect of frontal alpha asymmetry ($\beta = .33$, $p < .05$) and the interaction between drug, love withdrawal, and frontal alpha asymmetry ($\beta = -.31$, $p < .01$) remained significant. Neither central ($\beta = -.02$, $p > .50$), nor posterior alpha asymmetry ($\beta = .08$, $p > .50$) significantly predicted donations. The interaction between drug and love withdrawal just failed to reach significance ($\beta = .27$, $p = .05$) and no other significant effects were found (all $|\beta s| \leq .22$, $ps > .10$).

Discussion

Asymmetric frontal brain activity significantly predicted donating behavior. As was expected, greater relative left frontal activity / less relative right frontal activity was associated with larger donations to UNICEF after viewing a promotional video showing a child in need. This finding is in line with the idea that higher approach motivation and a greater tendency to experience approach-related emotions, associated with greater relative left frontal activity, would cause an individual to donate more money to actively help-out those in need.

Moreover, frontal alpha asymmetry moderated the interactive effect of oxytocin and parental love withdrawal on donating behavior that we had observed previously (Van IJzendoorn et al., 2011). The predictive value of the interaction between oxytocin and parental love withdrawal (larger donations after oxytocin compared to placebo administration for those reporting lower love withdrawal) increased with decreasing relative left / increasing relative right frontal activity. Lower love withdrawal was associated with larger donations after oxytocin compared to placebo administration only for those showing relative right frontal activity. Thus, it seems that effects of oxytocin on prosocial attitudes and behavior, and concerns related to experiences of parental love withdrawal only affect decisions about donating for individuals whose response to emotional material is characterized by withdrawal rather than approach, as suggested by their pattern of frontal brain activity. We tentatively suggest that those showing greater relative left frontal activity are likely to donate money in response to promotional material showing an individual in need, irrespective of how their empathic responding is affected by oxytocin administration or experiences of love withdrawal, because approach-related tendencies motivate them to take action, and thus to donate money. For those less inclined to donate out of approach motivation (i.e., those showing less relative left / greater relative right frontal activity), empathic and other concerns affected by oxytocin and experiences of love withdrawal may play a more important part in deciding whether and how much money they donate.

The most obvious feature of the interaction between oxytocin and parental love withdrawal, both when ignoring differences in asymmetric frontal brain activity (see Figure 1, cf. Van IJzendoorn et al., 2011) and when focusing on individuals showing les relative left/ greater relative right frontal activity (see Figure 1), is the increase in donations after oxytocin (vs. placebo) administration for individuals reporting lower love withdrawal. However, a closer look at Figure 1 reveals that at the higher end of the love withdrawal continuum oxytocin actually seems to decrease donations relative to placebo for those showing less relative left / greater relative right frontal activity. An interpretation of these seemingly opposing effects of oxytocin would necessarily be speculative and is beyond the scope of the current paper (but see Van IJzendoorn et al., 2011, for some suggestions). Nevertheless, it is important to note that although individuals showing less relative left / greater relative right frontal activity appear to be more sensitive to influences of oxytocin and parental love withdrawal on (processes involved in) decision making in the donating task, these influences are not necessarily unidirectional. Compared to those showing greater relative left frontal activity, individuals showing greater relative right frontal activity may show both larger increases and smaller increases or even decreases in donations after oxytocin compared to placebo administration, depending on their experiences of parental love withdrawal.

There is a striking similarity between this observation and findings concerning the model of differential susceptibility of individuals to environmental influences throughout development, showing that children with certain neurobiological dispositions (as evident from genetic, neuroendocrine, or behavioral measures) both benefit more from a favorable caregiving environment and are more affected by negative caregiving experiences (for an overview see Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). The differential susceptibility model has been contrasted with diathesis-stress or dual-risk models that focus on the added negative effects of unfavorable circumstances for some individuals, assuming no differential effects of favorable circumstances (see Ellis et al., 2011). Interestingly, a diathesis-stress model has also been proposed for the role of relative right frontal brain activity in depression (Davidson, 1998).

There are, of course, substantial differences between the differential susceptibility literature and our current study (but see Bakermans-Kranenburg & Van IJzendoorn, 2011). Nevertheless, a recurrent observation in studies of the interplay between neurobiological characteristics and external factors or experiences is that certain characteristics are associated with a greater sensitivity to (influences of) external factors and experiences, and that effects of this heightened sensitivity can go both ways: Depending on the level of the external variable or experiences under consideration, the more susceptible or sensitive individual can be both worse and better off, show both more and less desirable behavior, or, as in our current study, show both similar but larger and opposite effects of oxytocin, compared to the less sensitive individual. Thus, however associative the link between our current results and differential susceptibility theory may be, this type of interaction between neurobiological characteristics, experiences, and external factors deserves attention in future studies.

As the approach-withdrawal model was devised specifically to explain the role of asymmetric frontal brain activity in emotional processes (e.g., see Demaree et al., 2005; Harmon-Jones et al., 2010), including affective reactions to emotional film fragments and photographs (e.g., Perry, Bentin, Bartal, Lamm, & Decety, 2010; Tomarken, Davidson, & Henriques, 1990), showing a UNICEF promotional video of a child in need may be an important component of the current experimental setup. Showing such a video activates emotional systems (by eliciting emotional reactions such as empathy, see for example Burt & Strongman, 2004) and may thus be particularly suited to study the influences of individual characteristics (in this case frontal asymmetries and parental love withdrawal) and substances (in this case oxytocin) involved in emotional processes on donating behavior.

A factor to consider when interpreting our results is that all our participants were female. We included only women in this study because of the considerable differences between males and females in the oxytocin system (Suske & Gallagher, 2009), because the effects of oxytocin in women are less frequently studied than those in men, and because the ERP experiment focused on effects of maternal use of love withdrawal with daughters (see Huffmeijer et al, 2011a; Huffmeijer, Tops, Alink, Bakermans-Kranenburg, & Van IJzendoorn, 2011b). Nevertheless, it would be interesting to study the same processes in men. Future studies could also include behavioral or questionnaire measures of approach-withdrawal motivation (such as the BIS/BAS Scales; Carver & White, 1994), to test our interpretation of the effects of asymmetric frontal activity on donating behavior in terms of approach-withdrawal motivation. Importantly though, our results were specific to frontal alpha asymmetry and not affected by the inclusion of central and posterior alpha asymmetry, increasing confidence in our findings. Finally, because measures of frontal alpha asymmetry have been found to be composed of both a trait level of asymmetry and state-induced variation (Coan & Allen, 2004; Hagemann et al., 2005), future studies could include multiple measures (taken on multiple occasions) of frontal alpha asymmetry to evaluate the respective contributions of trait-related and state-related factors.

In conclusion, greater left compared to right frontal brain activity predicted larger donations after viewing a video of a child in need. Moreover, asymmetric frontal activity moderated effects of oxytocin and parental love withdrawal on donating behavior. We suggest that when approach motivation is high (reflected in greater relative left frontal activity), individuals are inclined to take action upon seeing someone in need, and thus to donate more money to actively help-out. Only when approach motivation is low (reflected in less relative left/ more relative right activity), do empathic and other concerns affected by oxytocin and experiences of love withdrawal play an important part in deciding about donations. Future research, incorporating direct measures of approach-withdrawal motivation, will be necessary to test this interpretation, and to extend findings to a wider population, including men.

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5 General discussion

This thesis examined the relations between love withdrawal, oxytocin administration, and asymmetric frontal brain activity on the one hand, and neural processing of and responses to socio-emotional stimuli on the other. A schematic illustration of the findings is presented in Figure 1. Chapters 2 and 3 focused on the neural processing of emotionally relevant stimuli. The findings presented in these chapters include effects of both maternal love withdrawal and intranasally administered oxytocin on different aspects of the processing of emotional faces presented with performance feedback. Chapter 4 focused on a specific type of prosocial behavior, donating money to charity, after viewing a charity's (emotion eliciting) promotional video showing a child in need. Asymmetric frontal brain activity predicted donations and, moreover, moderated the effect of oxytocin and parental love withdrawal on donating behavior. These findings will be discussed in greater detail below.

Parental use of love withdrawal

Evidence was obtained that maternal love withdrawal relates to both relatively early, automatic and later, more controlled aspects of processing stimuli that combine performance feedback with emotional facial expressions.

First, in Chapter 2, associations between maternal love withdrawal and two ERP components were studied within the placebo condition of our experiment, the vertex positive potential (VPP, a component sensitive to the extent of configural processing of faces [e.g., Luo, Feng, He, Wang, & Luo, 2010]) and N400 (a component sensitive to the salience of a mismatch between information and its context [e.g., Caldera, Jermann, Lopez Arango, & Van der Linden, 2004]). Maternal use of love withdrawal significantly and positively predicted the VPP, indicating that participants reporting relatively high maternal use of love withdrawal showed heightened processing of emotional faces.

In addition, maternal use of love withdrawal was related to the difference between VPP amplitudes in response to happy and disgusted facial expressions. For participants reporting higher maternal use of love withdrawal the amplitude of the VPP was clearly larger in response to disgusted compared to happy facial expressions, whereas for participants reporting lower maternal use of love withdrawal the effect of disgust was smaller or absent. Results thus suggest a more pronounced preferential processing of disgusted faces compared to happy ones in participants reporting high maternal use of love withdrawal. A possible explanation is that in a performance situation disgusted facial expressions are

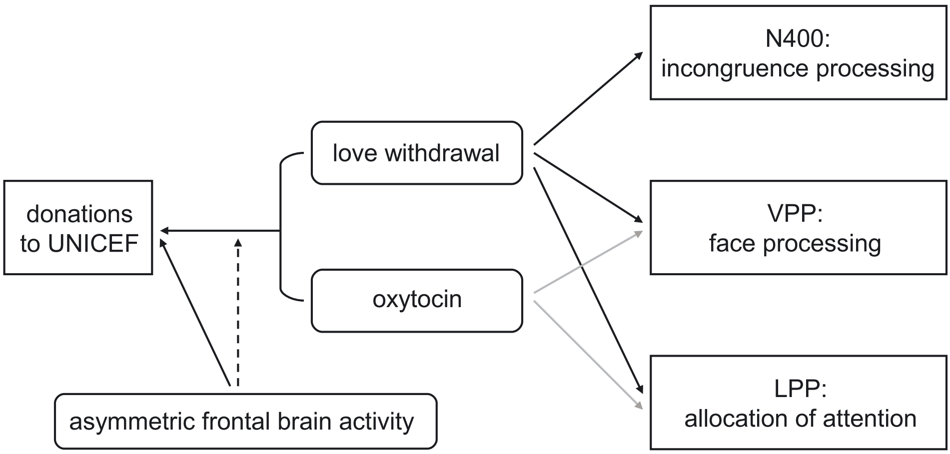

Figure 1. Graphic summary of the effects of love withdrawal, oxytocin, and asymmetric frontal brain activity. Participants reporting higher love withdrawal showed a heightened processing of emotional faces (VPP), appeared to be more sensitive to incongruence between feedback and facial expressions (N400), and preferentially directed attentional resources toward disgusted faces after making an error (LPP). Oxytocin enhanced the processing of emotional faces (VPP) and attention to the feedback stimuli (LPP). Greater left compared to right frontal brain activity, reflecting greater approach motivation, predicted larger donations after viewing a video of a child in need and, moreover, asymmetric frontal activity moderated effects of oxytocin and parental love withdrawal on donating behavior. Parental love withdrawal and oxytocin were related to donations only for those showing greater relative right frontal brain activity (reflecting withdrawal rather than approach motivation).

more relevant or more threatening for them, because of the association between these expressions and the negative relational consequences linked to failure. Higher levels of maternal love withdrawal were also related to larger amplitudes of the N400, suggesting that participants reporting higher maternal use of love withdrawal are more sensitive to a mismatch (incongruence) between the feedback and facial expression accompanying that feedback.

Second, in Chapter 3 the relations between maternal love withdrawal and the VPP and late positive potential (LPP, an ERP component thought to reflect the allocation of attentional resources to motivationally relevant stimuli [Hajcak, Dunning, & Foti, 2009; Pastor et al., 2008]) were studied across both the placebo and oxytocin conditions of our experiment, and in a larger sample of participants. Higher maternal love withdrawal was related to smaller increases in VPP amplitude after oxytocin compared to placebo administration. As no evidence for anxiolytic effects of oxytocin was found (i.e., there was no evidence that oxytocin reduced love withdrawal related anxiety about any relational consequences associated with performance or task performance itself), an explanation for this interaction between oxytocin administration and love withdrawal may be that participants reporting higher love withdrawal likely show near maximum processing of facial expressions even under placebo conditions, thus limiting potential increases after oxytocin administration.

Maternal love withdrawal was also related to LPP amplitudes, consistent with an attentional bias resulting from an association between performance and relational consequences established through the experience of love withdrawal. Higher love withdrawal was related to more positive LPP amplitudes in response to disgusted compared to happy faces, specifically when faces were presented in red (i.e., after an error). Thus, participants reporting higher love withdrawal increasingly direct attention toward disgusted (compared to happy) faces, implying that their attention is biased toward disgusted faces, specifically after they have made an error. In terms of the emotional or motivational significance of stimuli, the congruent combination of a disgusted face presented in red may well be the most relevant stimulus for participants who experienced more love withdrawal, because of its association with negative relational outcomes linked to failure.

Thus, our findings suggest that the association between performance and relational consequences that is established through the experience of love withdrawal does affect the processing of information relevant to this association. Within a performance context, those reporting higher love withdrawal show a heightened processing of facial expressions under placebo conditions (maybe particularly disgusted expressions), which may limit potential increases in processing after oxytocin administration. In addition, they appear to be more sensitive to incongruence between feedback and facial expressions (at least under placebo conditions), which violates the performance-relational consequence link. In a relatively late, controlled stage of processing attentional biases are evident. Higher love withdrawal is associated with the allocation of attentional resources toward the motivationally most relevant combination of a disgusted face presented with negative feedback.

Although the main focus of Chapter 4 was on asymmetric frontal brain activity, it is important to note that love withdrawal not only relates to the neural processing of emotional stimuli, but may also, under certain conditions, affect prosocial behavior. Parental love withdrawal was found to interact with oxytocin and asymmetric frontal brain activity to predict donations to UNICEF. Parental love withdrawal, through its emotional consequences (fear of failure, low self-esteem, low emotional well-being, and feelings of resentment toward the parents), may both hinder empathic concern (Kanat-Maymon & Assor, 2010) and bias decision making in social situations away from other-oriented (e.g., empathy for someone in need of help) to self-oriented concerns (doing what relevant others expect, out of fear for negative reactions), which might ultimately alter effects of oxytocin (cf. Van IJzendoorn, Huffmeijer, Alink, Bakermans-Kranenburg, & Tops, 2011). The consequences of parental love withdrawal for prosocial behavior may be investigated in future studies.

Oxytocin

Effects of intranasally administered oxytocin on electrocortical responses to facial feedback stimuli, both in relatively early (VPP) and later (LPP) stages of processing, were described in Chapter 3. It is well known that elevations of oxytocin levels in blood (in which it has a half-life of only a few minutes) after exogenous administration of the neuropeptide do not adequately reflect the time-range of its neurobehavioral effects, but little is known about oxytocin in other fluids (McEwen, 2004). We demonstrated the effect of oxytocin administration on salivary oxytocin levels up to 2¼ hours after use of the nasal spray. Thus, clear elevations of oxytocin levels were observed within a time-range comparable to its neurobehavioral effects, suggesting that salivary concentrations may be a valuable biomarker for oxytocin (see also Grewen, Davenport, & Light, 2010) .

This study was the first to investigate influences of oxytocin on electrocortical responses in women, although one study using fMRI methodology found enhanced activity in various brain areas involved in face processing after oxytocin administration in healthy women (Domes et al., 2010). Consistent with those findings, VPP amplitudes were more positive after oxytocin compared to placebo administration, indicating that oxytocin enhanced the (configural) processing of emotional faces, regardless of the expression or feedback. LPP amplitudes were also more positive after oxytocin compared to placebo administration, indicating that oxytocin enhanced attention to the feedback stimuli. It is tempting to speculate that the increased LPP amplitude observed here reflects the allocation of attention toward the facial expressions specifically, as the LPP is known to be strongly modulated by emotional facial expressions (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007; Haxby, Hoffman, & Grobbini, 2002) and oxytocin also enhanced the processing of emotional faces (as indexed by VPP amplitude). However, the possibility that oxytocin enhanced attention to faces in general or even to the feedback itself can not be ruled out, because no neutral facial expressions were included and faces and feedback were presented simultaneously.

Oxytocin is well known to enhance prosocial behavior (e.g., MacDonald & MacDonald, 2010) and effects of oxytocin on donating behavior have been described previously (Barraza, McCullough, Ahmadi, & Zak, 2011; Van IJzendoorn et al., 2011). It is therefore interesting to observe that in the current study, as described in Chapter 4, oxytocin administration resulted in larger donations to UNICEF than placebo only for some individuals, i.e. those both showing greater relative right frontal brain activity and reporting relatively low parental love withdrawal. No more than a few studies have focused on the boundaries of oxytocin's prosocial effects (e.g., Bartz et al, 2010; De Dreu et al. 2010; De Dreu, Greer, Van Kleef, Shalvi, & Handgraaf, 2011; Shamay-Tsoory et al., 2009; see for meta-analytic results Van IJzendoorn and Bakermans-Kranenburg, in press) and this topic clearly deserves more attention in the future.

Asymmetric frontal brain activity

The main topic of Chapter 4 was asymmetric frontal brain activity as a predictor of donating behavior. In line with the idea that higher approach motivation and a greater tendency to experience approach-related emotions, associated with greater relative left frontal activity, would cause an individual to donate more money to actively help-out those in need, greater relative left / less relative right frontal activity predicted larger donations.

Moreover, asymmetric frontal activity moderated the interactive effect of oxytocin and parental love withdrawal on donating behavior, in such a way that lower love withdrawal was associated with larger donations after oxytocin compared to placebo administration only for those showing relative right frontal activity (whose response to emotional material is characterized by withdrawal rather than approach). Those showing greater relative left frontal activity seem likely to donate money in response to promotional material showing an individual in need, irrespective of whether and how their empathic feelings are affected by oxytocin administration or experiences of love withdrawal, because approach-related tendencies motivate them to take action, and thus to donate money. For those less inclined to donate out of approach motivation (i.e., those showing less relative left / greater relative right frontal activity), empathic and other concerns affected by oxytocin and experiences of love withdrawal may play a more important part in deciding on the amount of money they donate.

It is important to note that although individuals showing less relative left / greater relative right frontal activity appear to be more sensitive to influences of oxytocin and parental love withdrawal on (processes involved in) decision making in the donating task, these influences are not necessarily unidirectional. Compared to those showing greater relative left frontal activity, individuals showing greater relative right frontal activity may show both larger increases and smaller increases or even decreases in donations after oxytocin compared to placebo administration, depending on their experiences of parental love withdrawal. It is a recurrent observation in studies of the interplay between neurobiological characteristics and external factors or experiences that certain characteristics are associated with a greater sensitivity to (influences of) external factors and experiences, and that effects of this heightened sensitivity can go both ways (e.g., see Bakermans-Kranenburg & Van IJzendoorn, 2011; Ellis, Boyce, Belski, Bakermans-Kranenburg, & Van IJzendoorn, 2011). Future studies should pay attention to this type of interaction.

Mirror neuron systems

The question remains what brain regions mediate effects of love withdrawal, oxytocin, and asymmetric frontal activity on the processing of and responding to (socio-)emotional stimuli. A likely candidate is the mirror neuron system. Mirror systems are both active when an individual performs an action and when another individual performs an action from the same class of actions or an action with a similar goal or meaning (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti & Craighero, 2004). Areas containing mirror neurons, in particular the inferior frontal gyrus (and adjacent anterior insula) and superior temporal sulcus, are involved in generating the N400 (Frühholz, Fehr, & Hermann, 2009; Gazzola, Aziz-Zadeh, & Keysers, 2006; Silva-Pereyra et al., 2003; Wildgruber, Ackermann, Kreifelts, & Ethofer, 2006) and may be linked to the LPP as well. It has been suggested that activity in the areas generating the LPP (inferotemporal, posterior parietal, and occipital visual areas) may result from reentrant connections from the amygdala to visual areas (Sabatinelli, Lang, Keil, & Bradly, 2007). The amygdala is connected to and interacts with areas such as the inferior frontal gyrus, fusiform gyrus, and superior temporal areas in the processing of facial expressions (Amaral & Price, 1984; Haxby et al., 2002; Iidaka et al., 2001). Mirror neurons in the inferior frontal gyrus (and adjacent anterior insula) and superior temporal sulcus have been found to respond to emotional expressions and emotional prosody (Gazzola et al., 2006; Wildgruber et al., 2006).

Furthermore, mirror neurons play an important role in social cognition (Iacoboni & Dapretto, 2006). Mirror systems have been found to be involved in affect mirroring, understanding others' actions, and empathy, and areas containing mirror neurons are involved in judging the appropriateness of facial affect (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Gazzola et al., 2006; Kim et al., 2005). Some of these processes, in particular empathy, are recruited during the donating task (cf. Burt & Strongman, 2004; Verhaert & Van den Poel, 2011). In accordance with these social processes involving mirror neurons, oxytocin has been suggested to influence the mirror neuron system (Perry et al., 2010; Tops, 2010). In addition, it is likely that mirror neurons are involved in affect mirroring and contingency detection in mother-child interactions that are central to the development of emotional self-awareness, self-control, and empathy from infancy through adolescence (Feldman, 2007; Fonagy, Gergely, & Target, 2007; Gergely & Watson, 1996). This system is thus also a likely candidate for parenting strategies like love withdrawal to take effect.

Limitations and future directions

In addition to investigating the consequences of parental love withdrawal for prosocial behavior and the boundaries of oxytocin's prosocial effects, future studies could also address some limitations of the current ERP and donating experiments. Future studies on the neural processing of facial expressions within our paradigm might include neutral facial expressions to distinguish between effects of oxytocin and love withdrawal (and other relevant variables) on the processing of faces in general and emotional facial expressions in particular. Furthermore, in our study participants committed about 16% errors, and they were therefore presented with more green than red stimuli. Future studies may (additionally) use more difficult tasks resulting in higher error percentages and thus more equal numbers of green and red feedback stimuli. To test the interpretation of the effects of asymmetric frontal activity on donating behavior in terms of approach-withdrawal motivation, future studies could include behavioral or questionnaire measures of approach-withdrawal motivation (such as the BIS/ BAS Scales; Carver & White, 1994). Importantly though, our results were specific to frontal alpha asymmetry, which is related to approach-withdrawal motivation, and not affected by the inclusion of central and posterior alpha asymmetry, which are not associated with approach-withdrawal motivation, increasing confidence in our findings.

Parental use of love withdrawal and fear of failure were measured with self-report questionnaires. There are obvious limitations to the accuracy and reliability of participants' self-reports, although without longitudinal data it is difficult to conceive of observational or experimental measures of love-withdrawal. Lastly, our participants were all female. We chose to include only women in this study, because of the considerable differences between males and females in the oxytocin system (Suske & Gallagher, 2009), because the effects of oxytocin on the neural processing of emotional stimuli are less frequently studied in women than in men, and because most of the studies on the behavioral or psychological outcomes of love withdrawal focus on maternal use of love withdrawal with daughters (e.g., Elliot & Thrash, 2004; Renk, McKinney, Klein, & Oliveros, 2006). It would be interesting to study the same processes in men.

Conclusion

The current thesis provides insight into the associations between experiences of parental, particularly maternal, love withdrawal, oxytocin, and asymmetric frontal brain activity on the one hand, and neural processing of and responses to socio-emotional material on the other. The current findings demonstrate that higher maternal love withdrawal is not only related to increased processing of emotional faces in a performance context (VPP) and heightened sensitivity to incongruence between feedback and facial expressions (N400), but also to the allocation of attentional resources toward the motivationally most relevant combination of negative feedback presented with a disgusted face (LPP).

Furthermore, this study was the first to describe effects of oxytocin on electrocortical responses to facial stimuli in females, using pictures combining emotional faces with performance feedback. The findings of more positive VPP and LPP amplitudes suggest that oxytocin increases attention to the facial feedback stimuli (LPP) and enhances the processing of emotional faces (VPP). Finally, greater left compared to right frontal brain activity predicted larger donations after viewing a video of a child in need and, moreover, asymmetric frontal activity moderated effects of oxytocin and parental love withdrawal on donating behavior. When approach motivation is high (reflected in greater relative left frontal activity), individuals are likely inclined to take action upon seeing someone in need, and thus to donate more money to actively help-out. When approach motivation is low (reflected in less relative left/ more relative right activity), empathic and other concerns affected by oxytocin and experiences of love withdrawal do seem to play an important part in deciding about donations.

In conclusion, measures of electrocortical activity constitute subtle indicators of the processing of emotional stimuli that are not under conscious control. As such, they are ideally suited and should be used more often to uncover the operation of internal working models or mental representations as they are being shaped by childhood experiences and neurobiological factors, as well as shaping the individuals' perception of their social world.

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Samenvatting (Summary in Dutch)

Mensen zijn van nature sociale wezens en beschikken over een scala aan verbale en non-verbale vaardigheden die effectief functioneren in sociale situaties en interacties mogelijk maken. Emotionele uitdrukkingen spelen een grote rol in de sociale omgeving, aangezien zij een belangrijke bron van informatie vormen over de innerlijke toestand en intenties van anderen (bijv. Bowlby, 1969; Ekman, 1993). Het zal daarom niet verbazen dat het menselijk brein uitgebreide netwerken bevat voor het verwerken van en reageren op sociaal-emotionele informatie. Verschillende hersengebieden leveren een bijdrage aan de informatieverwerking binnen deze netwerken, waaronder de amygdala, anterieure insula, cingulate cortex en kernen binnen de frontale en temporale cortices (Esslen, Pascual-Marqui, Hell, Kochi, & Lehmann, 2004; Lindquist, Wager, Kober, Bliss-Moreau, & Feldman Barrett, in press). Vele factoren kunnen de ontwikkeling, het functioneren en de gevoeligheid van deze netwerken en, uiteindelijk, sociaal gedrag beïnvloeden. Het in dit proefschrift beschreven onderzoek richt zich op de vraag hoe een aantal van deze factoren – bepaalde kenmerken van de opvoeding, het 'sociale hormoon' oxytocine en bepaalde patronen van hersenactiviteit die de basale motivatie tot toenadering of terughoudendheid reflecteren – verband houden met de verweking van sociaal-emotionele informatie in de hersenen en met prosociaal gedrag.

Om de informatieverwerking in het brein te bestuderen, is gebruik gemaakt van metingen van de elektrische activiteit van de hersenen, het elektro-encefalogram (EEG). Het EEG werd gemeten terwijl proefpersonen achter de computer een eenvoudig taakje uitvoerden, een zgn. flankertaak (Eriksen & Eriksen, 1974), waarbij de proefpersoon telkens zo snel mogelijk moest aangeven of het middelste van vijf pijltjes naar rechts of links wees. Na elk antwoord kreeg de proefpersoon feedback: na ieder goed antwoord kwam een groene foto van een blij of een walgend gezicht in beeld en na iedere fout een rode foto. Door gezichtsuitdrukkingen te combineren met de feedback – er zijn dus vier categorieën: groen-blij, groen-walgend, rood-blij, rood-walgend – werd een communicatieve context voor de verwerking van deze emotionele gezichten gecreëerd. Uit het EEG kan vervolgens de specifieke reactie van de hersenen, het zgn. event-related potential (ERP), op elk van de vier categorieën foto's worden berekend. Een ERP bestaat uit verschillende componenten, meestal zichtbaar als golven of pieken in het ERP. Een component is het best te begrijpen als een signaal dat door een specifiek gebied in de hersenen wordt gegenereerd wanneer daar een bepaald verwerkingsproces plaatsvindt (Luck, 2005). Voor dit proefschrift zijn drie componenten bestudeerd: het *vertex positive potential* (VPP), de N400 en het *late positive potential* (LPP).

Het VPP wordt gegenereerd in occipito-temporale gebieden (iets naast het midden aan de achterkant van het brein) bij de verwerking van de structurele kenmerken van stimuli, met name bij het verwerken van gezichten. Het signaal is zichtbaar als een positieve piek in het ERP op elektrodes op het midden van het hoofd, die ongeveer 140-180 ms na het aanbieden van de stimulus optreedt. De amplitude van het VPP, d.w.z. de sterkte van het signaal, is afhankelijk van de intensiteit van de verwerking. Hoe intensiever of uitgebreider de verwerking, des te positiever, dus sterker, het signaal (Joyce & Rossion, 2005; Luo, Feng, He, Wang, & Luo, 2010).

De N400 is een signaal dat optreedt wanneer iemand geconfronteerd wordt met informatie die niet klopt met de context – bijvoorbeeld het woord 'mes' aan het eind van de zin "Soep eet je met een …", of, in het huidige onderzoek, een groene foto van een walgend gezicht of een rode foto van een blij gezicht. De N400 is een negatieve modulatie van de amplitude van het ERP – een negatief signaal bovenop al aanwezige hersenactiviteit – op pariëtale elektrodes (op het achterhoofd), die ongeveer 400 ms na het aanbieden van een stimulus piekt. Afhankelijk van de vereisten van de taak kunnen verschillende gebieden betrokken zijn bij het genereren van de N400 (Frühholz, Fehr, & Herrmann, 2009; Silva-Pereyra e.a., 2003). De N400 is negatiever, d.w.z. het signaal is sterker, naarmate de mismatch, ook wel incongruentie genoemd, groter of opvallender is (Caldera, Jermann, Lopez Arango, & Van der Linden, 2004).

De derde component, het LPP, is een positieve modulatie van de amplitude van het ERP – een positief signaal bovenop al aanwezige hersenactiviteit – op centro-pariëtale elektrodes (bovenop het hoofd en op het achterhoofd) die ongeveer 400 ms na het aanbieden van een stimulus begint. Bij het generen van het LPP zijn verschillende hersengebieden betrokken (Keil e.a., 2002; Sabatinelli, Lang, Keil, & Bradley, 2007). Dit signaal is gevoelig voor het richten van de aandacht op motivationeel relevante (belangrijke) stimuli. Het LPP is positiever, d.w.z. het signaal is sterker, voor stimuli met een emotionele betekenis dan voor neutrale stimuli. Het signaal is afhankelijk van zowel automatische, reflexieve aandacht (veel onplezierige dingen trekken automatisch de aandacht), als meer gecontroleerde, bewuste aandachtsprocessen (bijv. als afleiding de aandacht op de minst beangstigende delen van een stimulus richten; Cacioppo, Crites, & Gardner, 1996; Hajcak, Dunning, & Foti, 2009; Hajcak, MacNamera, & Olvet, 2010; Pastor e.a., 2008).

Om prosociaal gedrag te meten, is gekeken naar donaties aan een goed doel. Na afloop van het EEG onderzoek, waarvoor de proefpersonen 50 Euro hadden gekregen, kregen de proefpersonen een promotiefilmpje van UNICEF te zien. Daarop was een meisje in een steengroeve te zien dat graag naar school wilde maar moest werken. Na afloop van het filmpje werd aan de proefpersonen gevraagd of zij iets wilden doneren aan UNICEF. Doneren aan het goede doel is een vorm van prosociaal gedrag die de donor geen direct voordeel oplevert. Er zijn daarom veel verklaringen geopperd die de nadruk leggen op (indirecte) psychologische voordelen van doneren, zoals het creëren van een gunstige reputatie (Nowark & Sigmund, 2005) of het 'warme gevoel' dat mensen ervaren door iets goeds te doen (Andreoni, 1990; Mayo & Tinsley, 2009). Empathie, het vermogen om mee te voelen met anderen in nood, lijkt een belangrijke motivator voor doneren. Empathisch vermogen voorspelt donaties zelfs wanneer gecontroleerd wordt voor sociaaldemografische kenmerken (leeftijd, geslacht en inkomen) en eerdere donaties (Verhaert & Van den Poel, 2011).

Uitkomsten van het onderzoek

Opvoeding: het gebruik van love withdrawal

Ouders bieden de eerste sociale omgeving waar een kind mee in aanraking komt en aan deelneemt, en relaties met de ouders blijven gewoonlijk het hele leven van belang (Bowlby, 1969; Hrdy, 1999). De manier waarop ouders hun kinderen opvoeden is duidelijk van invloed op het latere welbevinden en sociaal functioneren van de kinderen. Sommige strategieën die ouders gebruiken bij het socialiseren van kinderen kunnen, hoewel ze op korte termijn erg effectief zijn, een duidelijk nadelige invloed hebben op het latere functioneren en welbevinden van het kind. Het gebruik van *love withdrawal* is zo'n strategie. Love withdrawal is een manier van straffen, waarbij ouders een kind signalen van liefde onthouden wanneer het kind stout is of faalt – bijvoorbeeld het kind een tijdje negeren. Excessief gebruik van love withdrawal is een vorm van psychologische mishandeling (Euser, Van IJzendoorn, Prinzie, & Bakermans-Kranenburg, 2010). Door het gebruik van love withdrawal leren ouders het kind dat hun liefde en affectie voor het kind afhankelijk zijn van diens gehoorzaamheid en prestaties. Het creëren van dit verband tussen gehoorzaamheid en prestaties enerzijds en relationele consequenties anderzijds is de oorzaak van zowel de effectiviteit als de emotionele kosten van love withdrawal (Assor, Roth, & Deci, 2004, Elliot & Thrash, 2004). Ervaringen van love withdrawal door de ouders, vooral door de moeder, zijn in verband gebracht met faalangst, een lage zelfwaardering, een lage mate van welbevinden en gevoelens van wrok ten opzichte van de ouders in de adolescentie en vroege volwassenheid, wat negatieve gevolgen kan hebben voor sociaal gedrag (Assor e.a., 2004; Bowlby, 1973, p. 243; Elliot & Trash, 2004; Goldstein & Heaven, 2000; Renk, McKinney, Klein, & Oliveros, 2006; Soenens, Vansteenkiste, Luyten, Duriez, & Goossens, 2005).

In de Hoofdstukken 2 en 3 van dit proefschrift zijn de relaties onderzocht tussen ervaringen van love withdrawal – waardoor een verband ontstaat tussen gehoorzaamheid en presteren enerzijds en relationele consequenties anderzijds – en ERPs in reactie op de feedbackstimuli die feedback combineren met emotionele gezichten – d.w.z. de verwerking in het brein van informatie die uitermate relevant is voor de link tussen presteren en relationele consequenties. Het ERP experiment bestond uit twee onderzoekssessies. Tijdens de ene sessie kregen de proefpersonen oxytocine toegediend (door middel van een neusspray) en tijdens de andere sessie een placebo. In Hoofdstuk 4 is aandacht besteed aan de gevolgen van love withdrawal voor prosociaal gedrag. Om ervaringen van love withdrawal te meten, is gebruik gemaakt van een vragenlijst. Proefpersonen vulden deze vragenlijst voorafgaand aan het onderzoek in, zowel over hun vader als over hun moeder.

In Hoofdstuk 2 is bij 27 jongvolwassen vrouwen gekeken naar het verband tussen het gebruik van love withdrawal door de moeder en de amplitude van het VPP (verwerking van emotionele gezichten) en de N400 (verwerking van incongruentie tussen feedback en gezichtsuitdrukking) in de placebo conditie van het EEG experiment. Naarmate proefpersonen meer love withdrawal hadden ervaren was het VPP positiever (sterker). Proefpersonen die relatief veel love withdrawal van hun moeder hadden ervaren, vertoonden dus een intensievere verwerking van de emotionele gezichten. Ervaringen van love withdrawal hingen ook samen met het verschil in amplitude van het VPP in reactie op blije en walgende gezichten. Bij proefpersonen die relatief veel love withdrawal van hun moeder hadden ervaren, was het VPP duidelijk positiever, dus sterker, in reactie op walgende dan in reactie op blije gezichten. Als verklaring voor de preferentiële verwerking van negatieve (in vergelijking met positieve) gezichtsuitdrukkingen wordt vaak gewezen op de grote biologische relevantie van negatieve uitdrukkingen, omdat zij functioneren als signalen van gevaar en dreiging (Williams, Palmer, Liddell, Song, & Gordon, 2006). Mogelijk zijn walgende gezichten in een prestatieve context extra relevant of bedreigend voor mensen die veel love withdrawal hebben ervaren, vanwege het verband met negatieve relationele consequenties gerelateerd aan falen. Ten slotte was er een verband tussen love withdrawal en de amplitude van de N400. Proefpersonen die meer love withdrawal hadden ervaren vertoonden een meer negatieve, sterkere N400, en lijken dus gevoeliger voor een mismatch tussen gezichtsuitdrukkingen en feedback.

In Hoofdstuk 3 werden effecten van zowel oxytocine, als het gebruik van love withdrawal door de moeder op ERPs in reactie op de feedbackstimuli onderzocht bij 48 jongvolwassen vrouwen. In dit hoofdstuk is gekeken naar het VPP (gezichtsverwerking) en LPP (aandacht). Er was sprake van een significant interactie-effect van oxytocine en love withdrawal op de amplitude van het VPP. Proefpersonen die relatief veel love withdrawal hadden ervaren, vertoonden een kleinere toename in amplitude van het VPP na toediening van oxytocine. De intensiteit van de verwerking van emotionele gezichten nam onder invloed van oxytocine dus minder toe naarmate proefpersonen meer love withdrawal hadden ervaren. Hiervoor zijn verschillende verklaringen mogelijk, maar duidelijk is (uit Hoofdstuk 2) dat personen die relatief veel love withdrawal hebben ervaren ook onder placebo condities gezichtsuitdrukkingen relatief intensief en uitgebreid verwerken, wat een toename na toediening van oxytocine kan belemmeren. Ook de amplitude van het LPP hing significant samen met love withdrawal. Naarmate proefpersonen meer love withdrawal hadden ervaren, lieten zij een meer positieve (sterkere) LPP zien in reactie op walgende dan in reactie op blije gezichten, in het bijzonder na het maken van fouten. Met name na het maken van een fout richten mensen die meer love withdrawal hebben ervaren hun aandacht dus meer op walgende (in vergelijking met blije) gezichten. In termen van de motivationele relevantie van stimuli is het zeer goed mogelijk dat de congruente combinatie van een walgend gezicht met negatieve feedback (rode foto van een walgend gezicht) de meest relevante combinatie is voor mensen die veel love withdrawal hebben ervaren. Deze houdt immers verband met de negatieve relationele uitkomsten van falen.

Hoewel Hoofdstuk 4 vooral gericht was op de relaties tussen asymmetrische frontale hersenactiviteit en prosociaal gedrag, is het belangrijk om op te merken dat love withdrawal niet alleen samenhangt met de verwerking van sociaal-emotionele informatie in de hersenen, maar onder sommige omstandigheden ook invloed kan hebben op prosociaal gedrag. Ervaringen van love withdrawal (van beide ouders) voorspelden donaties aan UNICEF in interactie met oxytocine en asymmetrische frontale hersenactiviteit. Mogelijk krijgen in beslissingsprocessen in sociale situaties op de ander gerichte (bijv. empathie voor iemand in nood) en meer egocentrische (bijv. doen wat er verwacht wordt uit angst voor negatieve reacties) overwegingen onder invloed van love withdrawal een andere rol, en beperken ervaringen van love withdrawal via de daaraan verbonden emotionele consequenties (faalangst, lage zelfwaardering, laag welbevinden, gevoelens van wrok ten opzichte van de ouders) het empathisch vermogen (Kanat-Maymon & Assor, 2010). Vervolgonderzoek is nodig om meer duidelijkheid te krijgen over de gevolgen van love withdrawal voor prosociaal gedrag.

Oxytocine

De invloed van oxytocine op onze sociale gedachten, gevoelens en gedragingen is het onderwerp van een snel groeiend aantal wetenschappelijke studies (bijv. Heinrichs, von Dawans, & Domes, 2009). Oxytocine is een neuropeptide die wordt aangemaakt in neuronen in de supraoptische (SON) en paraventriculaire (PVN) kernen van de hypothalamus die in verbinding staan met de posterieure hypofyse, van waaruit oxytocine in de bloedbaan wordt gebracht. In de hersenen is oxytocine als neurotransmitter (over zeer kleine afstanden) en als neuromodulator (over grotere afstanden) betrokken bij de communicatie tussen hersencellen en –centra (Landgraf & Neumann, 2004; Suske & Gallagher, 2009).

Bij mensen speelt oxytocine een belangrijke rol bij de geboorte en het geven van borstvoeding, bij het ontstaan van een band tussen moeder en kind en bij oudergedrag, net als bij andere zoogdieren (bijv. Bakermans-Kranenburg & Van IJzendoorn, 2008; Campbell, 2008, Feldman, Weller, Zagoory-Sharon, & Levinde, 2007; Naber, Van IJzendoorn, Deschamps, Van Engeland, & Bakermans-Kranenburg, 2010). Bij volwassenen is veel onderzoek gedaan naar de invloed van oxytocine op sociale stress, waarneming, cognitie en besluitvorming. Uit deze studies blijkt dat oxytocine stressreacties in sociale situaties beperkt, invloed heeft op het verwerken en onthouden van saillante sociale stimuli, vertrouwen en vrijgevigheid bevordert (zie voor een overzicht van bevindingen Heinrichs e.a., 2009; MacDonald & MacDonald, 2010), en donaties aan het goede doel verhoogt (Barraza, McCullough, Ahmadi, & Zak, 2011; Van IJzendoorn, Huffmeijer, Alink, Bakermans-Kranenburg, & Tops, 2011). De overgrote meerderheid van studies naar de effecten van oxytocine op de verwerking van sociale en emotionele stimuli, waarbij soms gebruik is gemaakt van fMRI om hersenactiviteit te meten, is uitgevoerd bij mannelijke proefpersonen. Het gebrek aan studies naar vrouwen is begrijpelijk, aangezien de menstruatiecyclus niveaus van oxytocine beïnvloedt (Mitchell, Haynes, Anderson, & Turnbull, 1981; Salonia e.a., 2005), maar opvallend.

In Hoofdstuk 3 is bij 48 jongvolwassen vrouwen de invloed van oxytocine (en ervaringen van love withdrawal) op ERPs in reactie op emotionele gezichten gecombineerd met feedback onderzocht. Daarbij is gekeken naar componenten die de vroege, automatische gezichtsverwerking (VPP) en latere, meer gecontroleerde aandacht (LPP) reflecteren. Het VPP was positiever, dus sterker, na toediening van oxytocine dan na toediening van een placebo. Oxytocine versterkte dus de verwerking van emotionele gezichten, onafhankelijk van de gezichtsuitdrukking en de feedback waarmee het gezicht werd gecombineerd. De amplitude van het LPP was ook positiever (sterker) na toediening van oxytocine in vergelijking met een placebo. Oxytocine verhoogde dus de aandacht voor de feedbackstimuli. Het is verleidelijk te speculeren dat het verhoogde LPP een toename van de aandacht voor de gezichtsuitdrukkingen weerspiegelt, aangezien bekend is dat de amplitude van het LPP wordt beïnvloed door emotionele gezichtsuitdrukkingen (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007; Haxby, Hoffman, & Gobbini, 2002) en oxytocine ook het VPP versterkte. Het blijft echter mogelijk dat oxytocine de aandacht voor gezichten in het algemeen of zelfs voor de feedback heeft versterkt.

Tijdens het ERP experiment zijn op drie momenten – aan het begin, halverwege en aan het eind – speekselmonsters afgenomen, waarin het oxytocineniveau is gemeten. Het tijdsbestek waarbinnen na toediening van oxytocine verhoogde oxytocineniveaus in het bloed optreden (de halfwaardetijd bedraagt slechts enkele minuten) komt slecht overeen met dat van de neurocognitieve effecten van oxytocine. Over oxytocineniveaus in andere lichaamsvloeistoffen is echter weinig bekend (McEwen, 2004). Het is daarom een belangrijk resultaat dat in het huidige onderzoek oxytocineniveaus in speeksel duidelijk verhoogd bleven gedurende het hele experiment (ongeveer 2¼ uur). Oxytocineniveaus waren dus verhoogd binnen het tijdsbestek waarbinnen ook effecten van oxytocine op ERPs werden gevonden. Dit ondersteunt de bruikbaarheid van in speeksel gemeten niveaus als marker voor oxytocine

Het is bekend dat oxytocine een gunstige invloed heeft op prosociaal gedrag (bijv. MacDonald & MacDonald, 2010) en eerdere studies vonden effecten van oxytocine op donaties aan het goede doel (Barraza e.a., 2011; Van IJzendoorn e.a., 2011). Daarom is het interessant dat in het huidige onderzoek, beschreven in Hoofdstuk 4, oxytocine donaties slechts voor sommige mensen vergrootte – voor degenen die zowel een relatief sterke activiteit van de rechter hersenhelft vertoonden, als relatief weinig love withdrawal hadden ervaren. Tot nu toe is slechts in een klein aantal studies aandacht besteed aan de grenzen van de prosociale effecten van oxytocine (bijv. De Dreu e.a., 2010; Shamay-Tsoory e.a., 2009). Dit onderwerp verdient aandacht in vervolgonderzoek.

Asymmetrische frontale hersenactiviteit

De activiteit van de frontale cortex, het voorste gedeelte van de hersenschors, is niet altijd symmetrisch. De linker frontale cortex kan actiever zijn dan de rechter of juist andersom: de activiteit kan dus asymmetrisch zijn. Individuele verschillen in asymmetrische frontale hersenactiviteit zijn veelvuldig en bij mensen van alle leeftijden in verband gebracht met (sociaal-) emotionele processen (bijv. Coan &

Allen, 2004; Davidson & Fox, 1989; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Asymmetrische frontale hersenactiviteit hangt niet zozeer samen met de aard van emoties, maar met de richting (zie bijv. Harmon-Jones, Gable, & Peterson, 2010). Frontale asymmetrie lijkt vooral een weerspiegeling van de basale motivatie tot toenadering of terughoudendheid, waarbij een sterkere activiteit van de linker hersenhelft overeenkomt met een grotere motivatie tot toenadering, en een sterkere activiteit van de rechter hersenhelft met een grotere motivatie tot terughoudendheid (Demaree, Everhart, Youngstrom, & Harrison, 2005; Harmon-Jones & Allen, 1997; Harmon-Jones e.a., 2010). Metingen van asymmetrische frontale hersenactiviteit zijn gevoelig voor zowel stabiele verschillen tussen personen als toestandsgerelateerde variaties in de motivatie tot toenadering of terughoudendheid binnen een persoon (Coan & Allen, 2004; Hagemann, Hewig, Seifert, Naumann, & Bartussek, 2005).

In Hoofdstuk 4 is bij 47 jongvolwassen vrouwen onderzocht hoe asymmetrische frontale hersenactiviteit, als maat voor motivatie tot toenadering of terughoudendheid, samenhangt met donaties aan een goed doel (UNICEF). Sterkere relatieve activiteit van de linker frontale hersenhelft (geassocieerd met motivatie tot toenadering) voorspelde grotere donaties aan UNICEF na het zien van het promotiefilmpje van een kind in nood. Bovendien modereerde asymmetrische frontale hersenactiviteit effecten van oxytocine en love withdrawal op donaties: proefpersonen die relatief weinig love withdrawal hadden ervaren doneerden meer na toediening van oxytocine dan na toediening van een placebo, maar alleen wanneer zij een relatief sterke activiteit van de rechter hersenhelft (geassocieerd met motivatie tot terughoudendheid) vertoonden. Deze resultaten wijzen erop dat mensen met een relatief sterke activiteit van de linker frontale hersenhelft geneigd zijn om, na het zien van promotiemateriaal van een ander in nood, geld te doneren aan het goede doel, onafhankelijk van de invloed van oxytocine en ervaringen van love withdrawal op empathische gevoelens, omdat de motivatie tot toenadering hen ertoe beweegt actie te ondernemen. Bij mensen die minder geneigd zijn te doneren vanuit de motivatie tot toenadering – degenen met een relatief sterkere activiteit van de rechter frontale hersenhelft – spelen empatische en andere overwegingen die door oxytocine en ervaringen van love withdrawal worden beïnvloed wel een rol bij het beslissen over donaties.

Vervolgonderzoek

In ieder onderzoek blijven aspecten onderbelicht en elke studie levert nieuwe vragen op. Ook de uitkomsten van het in dit proefschrift beschreven onderzoek leveren aanknopingspunten voor vervolgonderzoek op. In aansluiting op de huidige resultaten kunnen nieuwe studies zich richten op de effecten van love withdrawal op prosociaal gedrag of op de grenzen aan de prosociale effecten van oxytocine. Ook kan in vervolgonderzoek rekening gehouden worden met de beperkingen van de huidige studie. In vervolgonderzoek naar de neurale verwerking van gezichtsuitdrukkingen kunnen binnen het huidige paradigma neutrale gezichtsuitdrukkingen worden toegevoegd om onderscheid te kunnen maken tussen effecten van love withdrawal en oxytocine op de verwerking van gezichten in het algemeen en gezichtsuitdrukkingen in het bijzonder. Verder maakten de proefpersonen die meededen aan het ERP experiment vrij weinig fouten (ongeveer 16%), waardoor zij veel meer groene dan rode foto's te zien kregen. Nieuwe studies zouden moeilijkere taakjes kunnen gebruiken, waarbij het percentage fouten groter is en de aantallen groene en rode stimuli minder verschillen. Om de interpretatie van de effecten van asymmetrische frontale hersenactiviteit in termen van de motivatie tot toenadering of terughoudendheid te toetsen, kan in vervolgonderzoek gebruik gemaakt worden van vragenlijsten (zoals de BIS/BAS scales; Carver & White, 1994) om de motivatie tot toenadering of terughoudendheid te meten. Ten slotte zijn voor dit proefschrift slechts vrouwen onderzocht, omdat er grote geslachtsverschillen zijn in het oxytocine systeem (Suske & Gallagher, 2009), omdat er weinig onderzoek naar de neurale verwerking van sociaal-emotionele stimuli bij vrouwen is gedaan en omdat de meeste studies naar de uitkomsten van love withdrawal betrekking hebben op het gebruik van love withdrawal door moeders bij hun dochters (bijv. Elliot & Thrash, 2004, Renk e.a., 2006). Het kan interessant zijn dezelfde processen bij mannen te bestuderen.

Conclusie

Het in dit proefschrift beschreven onderzoek biedt inzicht in de relaties tussen ervaringen van love withdrawal, met name door de moeder, oxytocine en asymmetrische frontale hersenactiviteit enerzijds en de neurale verwerking van en reacties op sociaal-emotionele informatie anderzijds. De resultaten tonen aan dat ervaringen van love withdrawal in een prestatieve context niet alleen samenhangen met een intensievere, meer uitgebreide verwerking van emotionele gezichten (VPP) en verhoogde gevoeligheid voor mismatches tussen feedback en gezichtsuitdrukkingen (N400), maar ook met het richten van de aandacht op de wellicht meest relevante combinatie van negatieve feedback gepresenteerd met een walgend gezicht (LPP). Deze studie was ook de eerste waarin effecten van oxytocine op de verwerking van gezichtsstimuli bij vrouwen zijn bestudeerd met behulp van EEG. Het sterkere VPP en LPP na toediening van oxytocine wijzen erop dat oxytocine de aandacht voor de feedbackstimuli verhoogt (LPP) en de verwerking van emotionele gezichten intensiveert (VPP).

Een relatief sterke activiteit van de linker frontale hersenhelft voorspelde grotere donaties aan een goed doel, en asymmetrische frontale hersenactiviteit modereerde effecten van oxytocine en love withdrawal op donaties. Wanneer sprake is van een sterke motivatie tot toenadering – te zien aan een relatief sterke activiteit van de linker hersenhelft – zijn mensen geneigd actie te ondernemen en dus geld te doneren. Wanneer de motivatie tot toenadering daarentegen laag is - te zien aan een relatief sterke activiteit van de rechter hersenhelft – lijken empathische en andere overwegingen die door oxytocine en ervaringen van love withdrawal worden beïnvloed een belangrijke rol te spelen bij het beslissen over een donatie.

Metingen van de elektrische activiteit van het brein zijn subtiele, niet bewust te manipuleren indicatoren van de verwerking van emotionele stimuli. Daarom zijn ze uitermate geschikt om de activiteit bloot te leggen van interne werkmodellen, die gevormd worden door ervaringen uit de kindertijd en neurobiologische kenmerken, en vormgeven aan de perceptie van de sociale werkelijkheid.

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Curriculum Vitae

Renske Huffmeijer werd geboren op 24 januari 1982 in Rotterdam. In 2000 behaalde zij haar Gymnasium diploma aan het Marnix Gymnasium in Rotterdam. Na het behalen van een propedeuse Theologie aan de Rijksuniversiteit Groningen in 2001 studeerde zij van 2001 tot 2006 Psychologie aan diezelfde universiteit, met als specialisaties Ontwikkelingspsychologie en Neuro-/ Biopsychologie. Tijdens haar studie was zij als student-assistent werkzaam bij verschillende practica. In 2006 is zij cum laude afgestudeerd op een scriptie over de magnocellulaire theorie van dyslexie en een tweede onderzoeksstage binnen een fMRI studie naar geslachtsverschillen in de neurale verwerking van emotionele stimuli. Van 2006 tot 2007 was zij werkzaam als onderzoeksassistent op het gebied van EEG bij de afdeling Cognitieve Psychologie van de Vrije Universitiet in Amsterdam. Sinds november 2007 werkte zij als promovenda bij de afdeling Algemene en Gezinspedagogiek aan de Universiteit Leiden. Haar promotieonderzoek was gericht op de verbanden tussen ervaringen van love withdrawal, oxytocine en asymmetrische frontale hersenactiviteit enerzijds en de neurale verwerking van en reacties op sociaal-emotionele informatie anderzijds. Vanaf november 2011 is zij als postdoc verbonden aan het Center for Moral Socialization Studies van de Erasmus Universiteit Rotterdam.

Lijst van publicaties (List of publications)

Huffmeijer, R., Tops, M., Alink, L.R.A., Bakermans-Kranenburg, M.J., & Van IJzendoorn, M.H. (2011). Love withdrawal is related to heightened processing of faces with emotional expressions and incongruent emotional feedback: Evidence from ERPs. *Biological Psychology, 86,* 307-313.

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Ingediende manuscripten

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