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Oxytocin promotes face-sensitive neural responses to infant and adult faces in mothers

Mikko J. Peltola[a,*], Lane Strathearn[b], Kaija Puura[c,d]

[a] Human Information Processing Laboratory, Faculty of Social Sciences, 33014, University of Tampere, Finland
[b] Stead Family Department of Pediatrics, University of Iowa, and the Center for Disabilities and Development, United States
[c] Department of Child Psychiatry, Tampere University Hospital, Finland
[d] Tampere Center for Child Health Research, Faculty of Medicine and Life Sciences, University of Tampere, Finland

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ABSTRACT

Research utilizing intranasal oxytocin (OT) administration has shown that OT may increase attention and sensitivity to social cues, such as faces. Given the pivotal role of OT in parental behaviors across mammals, the paucity of intranasal OT research investigating responses to social cues in parents and particularly mothers of young children is a critical limitation. In the current study, we recorded cortical event-related potentials (ERPs) to investigate whether intranasal OT affects the early neural responses to emotional faces in mothers of 1-year-old infants. Using a double-blind, within-subjects design, mothers (n = 38) were administered intranasal OT and placebo on separate sessions and presented with happy and sad infant and adult faces while ERP components reflecting face-sensitive brain activation and attention allocation were measured. We hypothesized that ERP responses to faces would be larger in the OT condition and that the effects of OT on ERP responses would be more pronounced for infant faces. The amplitudes of the face-sensitive N170 ERP component were larger in the OT condition to infant and adult faces, but no clear support was found for the hypothesis that the responses to infant faces would be more susceptible to OT effects than the responses to adult faces. The attention-sensitive late positive potential (LPP) component was not modulated by intranasal substance condition. The results are in line with the view that OT acts to enhance the perceptual salience of social and emotional stimuli. Demonstrating such effects in mothers of young children encourages further investigation of the potential of intranasal OT to affect the perception of social cues relevant for parent-child interaction.

1. Introduction

Research investigating the impact of intranasal oxytocin (OT) administration has provided support for a view that OT is a critical neuropeptide affecting how we respond to social signals. Compared to placebo (PL), single-dose OT administration has been shown to increase attention to the eye region (Guastella et al., 2008), improve the recognition of subtle emotions from faces (Domes et al., 2007; Leknes et al., 2013), heighten arousal responses to faces indicated by pupil dilation (Leknes et al., 2013; Prehn et al., 2013), and increase electrocortical activity in response to faces (Huffmeijer et al., 2013). Such findings converge in a model suggesting that a general function of OT is to modulate the perceptual salience of social signals by enhancing attention orienting to social cues through interactions with the dopaminergic system (Shamay-Tsoory and Abu-Akel, 2016; Strathearn, 2011).

The current study sought to investigate whether intranasally administered OT affects cortical brain responses to faces in mothers of 1-year-old infants. Given that OT has been critically implicated in activating parenting behaviors in response to salient infant signals across mammals (Carter, 1998), the paucity of intranasal OT administration studies on the perception of social signals in parents and particularly mothers of young children is striking (see Mah et al., 2017; Rupp et al., 2013, for examples). Correlational studies indicate that peripheral OT concentrations (e.g., in plasma, saliva, or urine) are associated with measures of parental behavior, such as interactive synchrony and maternal orienting sensitivity (Feldman et al., 2007; Strathearn et al., 2012), suggesting that OT may be associated with enhanced responsivity to social signals during parent-child interaction. However, it has been questioned whether peripheral levels of OT reliably indicate OT levels in the brain (Kagerbauer et al., 2013; Valstad et al., 2017), making it difficult to ascertain any causal role of OT on responsivity to social signals based on peripheral measures. Furthermore, given that there are even aspirations to utilize intranasal OT as an augmentative treatment for problems in early parent-child interaction due to

* Corresponding author.
E-mail address: mikko.peltola@staff.uta.fi (M.J. Peltola).

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postpartum depression (Kim et al., 2014), it is critically important that the effects of intranasal OT on the perception of social signals in mothers of young children are first investigated in sufficient detail.

While intranasal OT has been generally associated with greater attention and sensitivity to social signals such as emotional faces (e.g., Domes et al., 2007; Guastella et al., 2008; Huffmeijer et al., 2013), the associations of OT with variations in parenting behavior (e.g., Feldman et al., 2007) further suggest that the effects of intranasal OT might be particularly pronounced in response to child and infant social signals. Moreover, viewing infant stimuli preferentially activates dopaminergic reward circuits of the brain (Kringelbach et al., 2008; Strathearn et al., 2008), and considering that OT might exert its effects on modulating perceptual saliency through crosstalk with the dopaminergic system (Shamay-Tsoory and Abu-Akel, 2016), it could be hypothesized that brain responses to infant faces are more susceptible to intranasal OT effects than responses to adult faces. Marsh et al. (2012) provided initial support for this possibility by asking participants to judge the appeal of infant and adult faces, and finding that OT increased such preferences selectively toward infant but not adult faces. Here, we extended this line of research by measuring event-related potentials (ERPs) of the electroencephalogram (EEG) signal in mothers while they were presented with emotional adult and infant faces. ERP measurement is ideally suited for investigating the modulatory role of OT in the perception of faces with superior temporal resolution. ERPs can be utilized to measure neural activation of face-sensitive occipitotemporal areas involved in the initial processing of facial features (i.e., the N170 ERP component; Rossion, 2014) and differential allocation of attention to faces differing in their emotional or motivational significance, as reflected in attention-sensitive ERP components such as the early posterior negativity (EPN), P3, and the late positive potential (LPP) (see Olofsson et al., 2008, for a review). An increasing number of ERP studies probing parental brain responses to infant stimuli have shown that ERP responses to infant faces differ as a function of parental status (i.e., showing enhanced responses to infant faces in parents; Peltola et al., 2014; Proverbio et al., 2006) and indicators of parental sensitivity, such as reflective functioning (Rutherford et al., 2017), and observer ratings of maternal sensitivity (Bernard et al., 2015). However, very few studies have measured ERPs to investigate OT effects on the temporal dynamics of processing social signals (e.g., Huffmeijer et al., 2013; Waller et al., 2015). Huffmeijer et al. (2013) observed that OT administration increased face-sensitive and attention-sensitive ERP responses in the VPP (i.e., a frontocentral counterpart of the N170; Joyce and Rossion, 2005) and LPP components in response to adult facial expression stimuli in nulliparous females, indicating OT-related enhancement in processing salient facial signals.

To date, there have been no studies investigating OT effects on ERPs to infant and adult stimuli in parents. To address this limitation, in the current study, we used a double-blind, within-subjects design to investigate whether OT administration affects the neural responses to infant and adult faces in mothers of 1-year-old infants. The mothers categorized facial expressions according to their emotional valence while ERPs related to processing facial features (N170) and attention allocation (LPP) were measured. Based on available ERP data from nulliparous females (Huffmeijer et al., 2013) and models positing that OT increases the perceptual salience of social signals (Shamay-Tsoory and Abu-Akel, 2016), we expected ERP responses to faces to be larger in the OT condition. As a critical test of the involvement of OT in mothers' neural sensitivity to infant signals, we hypothesized that the effects of OT on ERP responses are more pronounced for infant faces. Regarding the functional properties of the analyzed ERP components, the social salience model (Shamay-Tsoory and Abu-Akel, 2016) proposed that OT exerts its effects on social salience processing primarily by modulating attention orienting to social cues, which suggests that the effects of OT should be more readily observed in the attention-sensitive LPP responses. However, as OT was previously found to impact both perceptual and attentional ERP responses to adult faces (Huffmeijer et al., 2013), we expected to observe the OT-related increase in ERP responses in both the N170 and the LPP components. Finally, research is mixed on whether OT affects responsivity to emotions generally or more specifically to positive (Marsh et al., 2010) vs. negative (Fischer-Shofty et al., 2010) emotions, and in a previous ERP study (Huffmeijer et al., 2013), OT-related increases in ERP responses to faces were not dependent on facial expression. Therefore, we made no specific predictions as to whether the effects of OT would differ depending on the emotional valence of the faces (sad vs. happy).

2. Methods

2.1. Participants

Fifty-two mothers of one-year-old infants (mothers' age M = 31.92 years, SD = 4.98; infants' age M = 14.51 months, SD = 1.18) participated in the study. Exclusion criteria included smoking, alcohol and drug abuse, neurological, psychiatric, or cardiac disorders, pregnancy, breastfeeding, and use of medication. All participants were right-handed, Caucasian, and predominantly from an urban, middle-class background (average years of education = 16.33, SD = 2.81; annual household income on average within 50,000–69,999 €), and 56% were primiparous. The number of participants included in the ERP analyses was 38. The remaining participants were excluded from the analyses due to excessive artefacts in the EEG data (n = 3), technical problems (n = 3), experimenter error (n = 1), dropping out of the study between assessments (n = 2), or oral contraceptive use (n = 5), as previous research has indicated that the use of oral contraceptives may critically suppress sensitivity to the effects of OT administration (Montoya and Bos, 2017; Scheele et al., 2016). The excluded participants did not differ from those included in the analyses on available demographic variables (age, years of education, family income, parity) or self-reported depressive symptoms, all $t < 0.77$, all $p > .45$. The study was approved by the ethics committee of Pirkanmaa Hospital District, and an informed written consent was obtained from the participants at the beginning of the experiment.

2.2. Procedure

Using a double-blind, within-subjects design, two laboratory sessions were scheduled to occur approximately 4 weeks apart, during the luteal phase of the menstrual cycle (based on participant self-report of menstrual cycle length and expected date of menstrual period), and approximately at the same time of day. The participants were instructed to abstain from excessive physical activity 24 h before, and from caffeine 4 h before the session. In the beginning of the session, participants completed questionnaire items regarding pregnancy, medication, visual impairments, and current nasal disease or obstruction. Immediately after the intranasal substance administration, participants provided information on socioeconomic status (educational level, income) and current mood (using the Edinburgh Postnatal Depression Scale; Cox et al., 1987). An LMA MAD Nasal™ mucosal atomization device (http://www.lmaco.com) was used to administer 24 IU of OT (Syntocinon, Novartis, Switzerland) or placebo (PL; saline). One puff containing 0.3 ml of the substance was administered by the experimenter to each nostril (i.e., a total of 0.6 ml). Half of the participants received OT on the first visit and PL on the second visit, with the other half receiving the substances in reverse order (within the sample included in the analyses, 18 participants received OT first and 20 participants received PL first). The order randomization of the nasal sprays was conducted by a hospital pharmacist. An awareness check at the end of the second laboratory visit confirmed that the number of participants correctly guessing which substance they had received on the second visit did not differ from chance, $t(48) = 0.14$, $p = .89$. The potential influence of the order of substance administration across the two laboratory visits (i.e., OT-PL vs. PL-OT) was tested by adding administration order as a