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„Early Communication Through Maternal Touch: Infant Social Engagement and the Role of Oxytocin“

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1. Introduction

The neuropeptide and hormone Oxytocin (OT) plays an important role in social interactions and relationships, such as the attachment between mother and infant (see Uvnäs Moberg, 2003). It is also associated with an individual's physical and emotional well-being (see Uvnäs Moberg, 2003). In parent-infant interactions parental OT is associated with the provision of touch, among others (e.g., Feldman et al., 2012). Physical contact and tactile stimulation between mother and infant influences infants' development and social engagement (e.g., Bystrova et al., 2009; Feldman, Eidelman, Sirota, & Weller, 2002; Feldman, Weller, Sirota, & Eidelman, 2002; Feldman, Weller, Sirota, & Eidelman, 2003; Peláez-Nogueras et al., 1996). Particularly in mother-infant interactions, maternal touch may promote infant's social engagement by increasing maternal and infant OT (Feldman, Gordon, Schneiderman, Weisman, & Zagoory-Sharon, 2010; Feldman, Gordon, & Zagoory-Sharon, 2010). Interestingly, the optimal provision of touch (Feldman & Eidelman, 2007; Fergus, Schmidth, & Pickens, 1998, as cited in Stack, 2010; Herrera, Reissland, & Shepherd, 2004) and the OT system seem to be disturbed when mothers are depressed, putting infants at developmental risk (Apter-Levy, Feldman, Vakart, Ebstein, & Feldman, 2013). The goal of the present study was to investigate if different forms of maternal touch are associated with OT levels of mothers and infants as well as with infant social engagement while taking into account the influence of maternal depression.

Touch seems to be an effective communicator of emotions (Hertenstein, Holmes, McCullough, & Keltner, 2009; Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006). Through touch, adults were able to detect distinct emotions that strangers intended to communicate, even though they could not see or hear them (Hertenstein et al., 2009; Hertenstein et al., 2006). According to Hertenstein (2002), perceiving distinct

messages is possible as receptors of the skin can register different qualities and parameters of touch. Qualities are the specific kind of touch (e.g., stroking vs. poking), the pressure or intensity, the rate and abruptness, as well as the temperature at which touch is exerted (Hertenstein, 2002). Parameters of touch determine for example how long, where, and how frequent someone is touched (Hertenstein, 2002). Varying qualities and parameters of touch constitute unique combinations that seem to communicate specific messages.

Moreover, what kind of touch a mother provides and what she communicates to her infant depends on her intentions, because mothers use different forms of touch for various functions (Jean & Stack, 2009). Infants are able to recognize intentions (Legerstee & Markova, 2007) and react to them, because mothers are successful in eliciting a certain behavior in the infant through the use of touch (Stack & Arnold, 1998; Stack & LePlage, 1996). In this way, different forms of touch may communicate different messages. As Tronick (1995) suggests, "certain forms of touch, such as gentle holding, might convey the message, 'You are safe,' whereas other forms of touch, such as poking or jabbing, may convey the message, 'You are physically threatened'" (p. 53). In addition, context factors, such as the immediate environment and conditions an infant grows up in, preceding events and other external stimuli that accompany maternal touch may shape its meaning (Hertenstein, 2002). A study showed that adults perceived touch as more or less pleasant when touch was accompanied by positive or negative faces respectively (Ellingsen et al., 2014). In this way, co-occurring non-verbal or verbal maternal behavior might shape infants' perception of touch as well. Consequently, when depressed or non-depressed mothers display negative facial expressions, infants might perceive touch as less pleasant. Moreover, touch provided with negative facial expressions might be less supportive for the infant to socially engage in the interaction.

Taken together, intentions and emotions seem to determine the way touch is provided, and the context in which touch is embedded may shape the perception of touch to convey different messages and emotions.

According to Tronick (1989), infant social competencies evolve from experiences of "mutually regulated" (p. 115) or coordinated mother-infant interactions by attending to each other's emotional expressions and underlying communicated messages. Because touch is bidirectional and affects both communication partners (Stack, 2010), it is possible that physical contact between mother and infant functions to regulate each other (for review see Winberg, 2005). When infants received skin-to-skin contact or breast-feeding after birth, even one year later, mother-infant interactions have been found more mutual and reciprocal, mothers were more sensitive and responsive, and infants were better able to self-regulate (Bystrova et al., 2009). Particularly studies with premature infants show that infant cognitive and motor development (Feldman, Eidelman, et al., 2002) and the ability to self-regulate (Feldman, Weller, et al., 2002) improved following skin-to-skin contact. In addition, when premature infants received skin-to-skin contact, their later social behavior in interactions increased as they were more attentive and exploratory (Feldman, Weller, et al., 2002), and displayed less negative affect (Feldman et al., 2003) and gaze aversion (Feldman, Eidelman, et al., 2002). Thus, physical contact between mother and infant seems to have regulatory functions and improves infant development and the ability to socially engage in interactions.

Beside the beneficial outcomes of early physical contact between mother and infant, infants showed an immediate preference for maternal touch in interactions compared to interactions without touch (Peláez-Nogueras et al., 1996). In face-to-face interactions, maternal touch increased infants' positive and decreased negative social

engagement (Peláez-Nogueras et al., 1996). Furthermore, touch reduced infants' stress by lowering the stress hormone cortisol when it was provided in a stressful situation like the Still-Face procedure (Feldman, Singer, & Zagoory, 2010), enabling the infant to show more positive social engagement behaviors (Stack & Muir, 1990, 1992). Based on animal research, OT's effects include reduced stress and increased readiness to engage in social interactions (see Uvnäs Moberg, 2003). Thus, touch might increase infant social engagement by heightening OT.

OT is a neuropeptide, functions as hormone, neurotransmitter and neuromodulator, and is produced in the hypothalamus (see Uvnäs Moberg, 2003). It is present in all mammals and was originally found to be involved in the process of birth and lactation (see Uvnäs Moberg, 2003). Based on animal research, OT's effects range from growth and healing to increased curiosity, social interaction, prosocial behavior like maternal caregiving, to reduced stress (heart rate, blood pressure, stress hormones), anxiety and pain (see Uvnäs Moberg, 2003). In rats, tactile stimulation had similar effects on growth, sociability, stress and pain (see Uvnäs Moberg, 2003). Thus, through the sense of touch OT may be released leading to these OT-specific outcomes.

In humans, maternal OT rises during the initiation of breast-feeding as the infant stimulates the maternal breast by massaging and sucking (Matthiesen, Ransjö-Avirdson, Nissen, & Uvnäs-Moberg, 2001). This finding might be specific to breast-feeding and the release of OT in mothers only. However, subsequent studies showed that massage and other forms of physical contact were associated with OT-like effects in infants and non-mothers as well. For example, skin-to-skin contact and breast-feeding had an analgesic effect on newborns (Gray, Miller, Philipp, & Blass, 2002; Gray, Watt, & Blass, 2000). Similarly, various studies with premature (Field, Diego, Hernandez-Reif, Deeds & Figuereido, 2006) as well as full-term infants (Field, Hernandez-Reif, Diego,

Feijo, Vera, & Gil, 2004), pregnant women (Field, Diego, Hernandez-Reif, Deeds, & Figueiredo, 2009; Field et al., 2008) and adults with (Hernandez-Reif et al., 2004) or without illnesses (Diego, Field, Sanders, & Hernandez-Reif, 2004) show that (moderate pressure) massage is associated with physiological OT-like effects such as reduced stress, pain and depression, increased growth or improved health. These findings indicate that physical contact and tactile stimulation with nurturing, affectionate or soothing properties, such as skin-to-skin contact, breast-feeding or massage, are associated with OT and can significantly improve infants' development.

Although findings in humans are inconsistent, there is evidence that massage resulted in an increase in OT (Morhenn, Beavin, & Zak, 2012). Furthermore, increased touch among couples led to elevated OT levels and reduced physiologic stress-measures (Holt-Lunstad, Birmingham, & Light, 2008). Similarly, partner massage had a stress-buffering effect on women, although no OT increase was found (Ditzen et al., 2007). Interestingly, in intensive care patients, touch did not increase, but no touch decreased OT levels (Henricson, Berglund, Määttä, Ekman, & Segesten, 2008). These findings suggest that specifically in close relationships, massage and touch have the ability to reduce stress and increase OT. In close relationships, the provision of physical contact may communicate emotions like love, affection or simple appreciation or the intention and willingness to care for the other. In this way, touch may indicate social support, and, consequently, may be a vital component to maintain higher OT levels particularly in mother-infant relationships, where infants depend on the care of others.

It could be argued that OT motivates the mother to provide her infant with caregiving and touch, in particular. Animal studies showed that maternal tactile caregiving behavior – licking and grooming – is associated with higher levels of OT receptors in the brain (e.g. Champagne, Diorio, Sharma, & Meaney, 2001). Similarly in

humans, OT levels during and after pregnancy were found to be associated with the provision of maternal caregiving behavior including affectionate touch (Feldman, Weller, Zagoory-Sharon, & Levine, 2007), and parental OT was associated with the provision of more frequent touch toward the infant (Feldman et al., 2012). Moreover, when fathers were administered OT, they provided more touch (stimulatory and affectionate) to their infants (Weisman, Zagoory-Sharon, & Feldman, 2012).

Furthermore, OT administration to fathers was associated with parallel increases of infant OT (Weisman et al., 2012). Similarly, infant OT was found to increase in parallel to their parents' OT levels during interactions (Feldman, Gordon, & Zagoory-Sharon, 2010). In parent-infant interactions, OT increased in mothers who provided high amounts of affectionate touch as well as in fathers who provided high amounts of stimulatory touch (Feldman, Gordon, Schneiderman, et al., 2010). Thus, it is likely that infant OT increases in response to maternal touch as well.

Several studies found that parental OT was interrelated to child OT and stable over time (e.g., Feldman, Gordon, Influs, Gutbir, & Ebstein, 2013; Feldman, Gordon, & Zagoory-Sharon, 2010). Furthermore, studies suggest that OT may be transmitted across generations through caregiving behavior (Feldman et al., 2013; Feldman, Gordon, & Zagoory-Sharon, 2010). Adults who had experienced more caregiving by their own parents as a child had higher OT levels and provided more frequent touch to their infants (Feldman et al., 2012). After OT administration, not only fathers' touch, but also infants' socially engaged behavior increased (Weisman et al., 2012). Infant's OT and father's OT were related to father's touch (Weisman et al., 2012), thus it is likely that infant's OT increased in response to father's increased touch. Findings in fathers might be comparable to mothers, as OT in mothers and fathers did not show differences (across the study period of the first 6 months; Gordon, Zagoory-Sharon,

Leckman, & Feldman, 2010). Studies suggest that parental OT might be transmitted to infants through touch in specific and thus influences infant's social engagement in interactions.

Furthermore, studies showed that infant and parent OT is associated with infant and parent social engagement (Feldman, Gordon, & Zagoory-Sharon, 2010, 2011), and a child's OT to be associated with reciprocity during interactions (Feldman et al., 2013). The ability to reciprocally interact with another person seems to be acquired from early interactions with the mother (Feldman et al., 2013). At 3 years, social reciprocity with a friend was predicted by reciprocity with parents, and OT in child and parent (Feldman et al., 2013). Specifically, maternal OT, early maternal caregiving behavior and interactive reciprocity between mother and child seem to be determinant for a child's sociability with other persons (Feldman et al., 2013). Thus, social engagement and reciprocity in interactions seem to depend on OT levels. Increasing maternal OT by enhancing touch in interactions may lead to more infant OT, and consequently to more social engagement and reciprocity in interactions.

Interestingly, the optimal provision of touch (Feldman & Eidelman, 2007; Fergus et al., 1998, as cited in Stack, 2010; Herrera et al., 2004) and OT systems seem to be disturbed when mothers are depressed, putting infants at developmental risk (Apter-Levy et al., 2013). A 6-year longitudinal study showed that chronic maternal depression was associated with lower OT levels, in mothers, children and fathers as well (Apter-Levy et al., 2013). Furthermore, children were less empathic, less socially engaged, and 61% experienced psychiatric disorders (Apter-Levy et al., 2013). Maternal depression also interferes with the optimal provision of touch, as depressed mothers often interact with the infant in an intrusive or withdrawn manner (for review see Field, Diego, & Hernandez-Reif, 2009), provide less affectionate touch (Feldman & Eidelman,

2007), more inadequate touch like lifting (Herrera et al., 2004) or over-stimulatory and intrusive touch (Fergus et al., 1998, as cited in Stack, 2010). Moreover, infants show less social engagement and self-regulation, more negative affect and higher stress reactivity (cortisol; Feldman et al., 2009). Particularly in premature infants, maternal depressive symptoms were associated with less cognitive development and affectionate touch (Feldman & Eidelman, 2003). Also feeding disorders were predicted by less maternal touch, higher maternal depression and intrusiveness (Feldman, Keren, Gross-Rozval, & Tyano, 2004). The importance of touch in cases of maternal depression is further demonstrated as infants of depressed mothers touched themselves more, probably to compensate for the missing appropriate touch from their mothers (Herrera et al., 2004). Overall, these findings show that symptoms of maternal depression have a negative impact on maternal touch, are associated with lower levels of OT in mother and infant, and impede infants' positive social engagement in interactions.

2. The Present Study

The goal of the present study was to investigate if the frequencies and durations of different forms of maternal touch are associated with OT levels of mothers and infants as well as with infant social engagement in a natural mother-infant interaction, while taking into account the influence of maternal depressive symptoms.

Hypothesis 1: Controlling for the influence of maternal depressive symptoms, frequencies and durations of different forms of maternal touch are associated with levels of maternal OT and infant OT.

Hypothesis 2: Controlling for the influence of maternal depressive symptoms, frequencies and durations of different forms of maternal touch are associated with infant social engagement.

It was expected that higher levels of affectionate touch will be associated with higher levels of OT in mothers and infants and with more positive infant social engagement. Moreover, it was hypothesized that maternal OT and infant OT were interrelated and associated with positive infant social engagement.

It was expected that higher scores of maternal depression were negatively related to the duration of overall maternal touch, and affectionate touch in particular. Furthermore, it was expected that more depressive symptoms were related to lower levels of OT in mothers and infants and less positive or more negative infant social engagement.

3. Method

3.1. Participants

Sixty-four mothers and infants were recruited from prenatal classes and activity classes for mothers and their infants. Twenty-one dyads did not finish the experiment (e.g. as infants were too fussy or saliva samples were unusable) and were excluded, so that 43 mother-infant dyads (24 girls) participated in the study. Data from 6 dyads were excluded from the analyses because touch could not be recorded (e.g. due to the face-to-face interaction being interrupted as infants were lifted or held in arms). Consequently, data from the final sample of 37 mother-infant dyads (21 girls) were analyzed.

Infants were 4 to 6 months old (M = 137.32 days, SD = 17 days) when the study was carried out. All infants were born at full term, with at least 36 gestational weeks, and healthy (5-min APGAR score was 7-10). The majority of infants (89.2%) were first-borns and breast-fed by their mothers (89.2%).

Mothers' mean age at childbirth was 30.65 years (SD = 3.82 years) and they had an average of 5.14 years (SD = 2.65 years) of higher education. On the basis of parental education, mothers and infants came from middle to upper class families, and were

European Caucasian. For their participation in the study, mothers and infants received a small present.

3.2. Materials

The experiment was conducted in an infancy laboratory. Infants sat in an infant seat placed on a table (95 x 65 x 50 cm). Mothers sat in a chair, facing the infant (with an approximate distance of 30 cm), which allowed a face-to-face interaction.

The interaction was recorded using two digital video cameras. One was positioned to film the infant, the other was pointing at the mother. Recordings from both cameras were combined to a split screen image.

3.3. Procedure

Visits at the laboratory were arranged between 1 and 4 pm. To ensure reliable measures of salivary OT, mothers were asked to arrive at least one hour after ingesting food or drinks (except for water) and at least half an hour after breast-feeding.

Upon arriving, mothers obtained information about the experimental procedure including saliva collection and signed their written consent. Mothers rinsed their mouth before the collection of the first saliva sample.

The experimental procedure was composed of two main parts that were always conducted in the same fixed order: (1) baseline and (2) natural interaction. The original study included a third sequence called modified interactions that was not analyzed in the present study.

Baseline. To set up a neutral condition, for 10 minutes no interaction between mothers and their infants took place. Instead, mothers filled out questionnaires while infants were watching a DVD (Baby Einstein®) for children aged three months and older.

Natural interaction. To gain insight into typical maternal and infant behavior during a naturally occurring interaction, mothers were told to interact with infants in the same way they usually did at home for 10 minutes. There were no toys available.

3.4. Saliva Collection

Saliva samples were collected from mothers and infants at four time-points, before and after each part of the study, to measure OT levels.

Saliva samples were obtained by the use of oral swabs (Salimetrics® SalivaBio Oral Swab for mothers, Salimetrics® SalivaBio Infant's Swab for infants). Mothers were asked to place swabs under the tongue for the duration of two minutes. Infants' saliva was collected as infants sucked on swabs that were held by a research assistant. The oral swabs were placed into a tube (Swab Storage Tube) and left in a cooled polystyrene ice box for the duration of the procedure. Later, tubes were frozen at −20°C.

3.5. OT Analysis

Because no standardized protocol for the collection of OT existed, a pre-experiment was performed. In the pre-experiment 10 OT samples (5 from infants, 5 from adults) were analyzed. OT was determined using a commercial Oxytocin EIA kit (ADI-901-153, Enzo Life Science), a competitive enzyme immunoassay with colorimetric detection sensitive to a minimum of 11.7pg/mL.

Saliva swabs were centrifuged at 4°C at 2500x g for 10 minutes. OT samples were not modified or concentrated before the assay, but measured directly. Each sample was measured in duplicate and the assay was performed following the kit's instructions. Reagents were incubated at 4°C overnight and 1 hour at room temperature the following day. Absorbance was then read at 405nm. OT concentrations (pg/mL) were calculated using Softmax Pro 5.2 on the basis of the relevant standard curves. The pre-experiment

was successful in determining OT concentrations and the intra-assay coefficient of variability amounted to 13.28 %. Thus, this procedure was performed for all OT samples in the experiment.

3.6. Measures

Questionnaires. Demographic data were collected including maternal age and years of education, infant age, health and feeding style (breast-feeding or other). Furthermore, mothers completed the Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996) to be screened for depressive symptomatology. By self-report, 21 items were rated on a scale from 0 to 3 to describe the severity or persistence of a symptom. A total score of 0 to 13 characterizes minimal or no depression, whereas 14 to 19 indicates mild, 20 to 28 indicates moderate and 29 to 63 is considered as severe depression.

Maternal touch. In line with other studies (e.g,. Ferber, Feldman, & Makhoul, 2008), affectionate, stimulatory, and functional maternal touch was coded. Definitions were adopted, adapted and modified from other studies (Feldman & Eidelman, 2007; Ferber et al., 2008; Jean & Stack, 2009).

Affectionate touch was defined as rather slow, soft or soothing, without a lot of movement, performed with a clear positive affect and no functional purpose. It could be static or passive holding (hands resting on the infant's body, leaving the finger in infant's hand or mouth), as well as kissing, caressing, stroking or massaging to demonstrate affection or to regulate negative affect.

Stimulatory touch was defined as dynamic, with a lot of movement and repetition. It could be playful or used to activate, stimulate and to get more of the infants' attention. Typical forms of stimulatory touch were tapping, tickling, squeezing, pinching, lifting, rocking or swaying, grabbing or moving the infants' limbs.

Functional touch was defined as purposeful, utilitarian, and instrumental. It was used to serve a specific function, such as wiping infant's mouth, fixing infant's clothes, lifting to sit upright, or removing the infant's hands from the mouth.

Maternal touch was coded frame-by-frame, whereas in episodes of alternating affectionate and stimulatory touch, it had to last at least 1 second to be coded. Maternal touch had to be clearly visible and accidental touch was not coded.

The duration and frequency of each touch category was assessed and proportionally adjusted to the individual duration of each interaction to be used for analyses. In addition, overall touch frequency and duration built two variables, defined as the sum of frequencies and durations across all categories.

Inter-rater reliability was conducted as two coders independently coded 30 % of data that was randomly selected. Computed as intra-class correlations (ICC), inter-rater reliability was ICC = .925 for affectionate touch, ICC = .974 for stimulatory touch, and ICC = .962 for functional touch.

Infant social engagement: attention and affect. During the natural interaction, overall infant social engagement was assessed as infant attention was observed via gazes, and infant affect was observed via facial expressions and vocalizations. Definitions of infant behavioral measures were adopted from other studies (Legerstee & Markova, 2007; Markova & Legerstee, 2006; Peláez-Nogueras, Field, Hossain, & Pickens, 1996).

Gazes at the mother's face and *gazes away* from the mother's face were coded. Infant gazes were coded frame-by-frame and had to last 1 second at least. According to the individual duration of each interaction, proportional durations were calculated and used for the analyses.

Positive facial expressions and *negative facial expressions* were coded. Positive facial expressions were defined as smiles when the mouth (open or closed) was turned upward. Negative facial expressions were coded when the infant showed negative emotions like distress, fretting, anger or discontentment (e.g. grimacing or curled mouth). Facial expressions were coded frame-by-frame. Proportional durations were calculated according to the individual duration of each interaction and were used for the analyses.

Positive vocalizations and *negative vocalizations* were coded. Positive vocalizations were coded when infants produced sounds with a positive or neutral facial expression. They were defined as sounds with varied pitch and oral resonance, produced syllable-like and relaxed, what is often called babbling. Negative vocalizations were coded when infants produced sounds with negative facial expression, with effort or forced, nasal with uniform pitch and vowel-like (e.g. cry sounds, whimpers, fusses and wails). Vegetative sounds were excluded (e.g. hiccups, cough, sneezes, wheezes and effort sounds like grunts). If the sound was separated by a silence of 1 second at least, two separate sounds were coded. Infant vocalizations were coded frame-by-frame and, according to the individual duration of each interaction, proportional frequencies of positive and negative vocalizations were calculated and used for the analyses.

Inter-rater reliability was conducted as two coders independently coded 30 % of data that was randomly selected. Computed as intra-class correlations, inter-rater reliability was ICC = .980 for gazes at mother, ICC = .994 for gazes away, ICC = .935 for positive facial expressions, ICC = .960 for negative facial expressions, ICC = .944 for positive vocalizations, and ICC = .908 for negative vocalizations.

3.7. Video analysis

Video recordings of the natural interactions were used to measure maternal touch and infant social engagement through event-sampling. Datavyu® (Datavyu Team, 2014), an open and free video coding software that can be downloaded online, was used for the coding of maternal and infant behavioral measures.

IBM® SPSS® Statistics software (22. version) was used for all statistical analyses of the present study.

4. Results

Results are presented in two sections. In the first section, preliminary analyses are presented including results from data screening, descriptive statistics, correlational analyses of main study variables that were not subject to main hypotheses testing. In the second section, main hypotheses were tested and results of correlational and subsequent regression analyses are presented.

4.1. Preliminary Analyses

All main study variables were screened for outliers ($z > \pm 3.29$). To avoid statistical bias, identified outliers were given a new value one unit above or below the next highest or lowest score respectively (Tabachnick & Fidell, 2001). After adjustment, all variables were normally distributed except for overall touch duration.

Repeated-measures analyses of variance (ANOVAs) were performed on OT levels of mothers and infants with time (across collection points) as the within-subjects factor. The results revealed that neither maternal OT ($p = .239$) nor infant OT ($p = .809$) significantly differed across time. Thus, the means of maternal OT and infant OT were calculated and used in all further analyses.

Furthermore, repeated-measures ANOVAs were performed for durations and frequencies of touch with category (affectionate, stimulatory and functional) as the

within-subjects factor. The results revealed that the durations of touch significantly differed across all categories, $F(1.143, 41.158) = 57.173$, $p < .001$, $\eta^2 = .614$. Each pairwise difference was significant (all ps $\leq .001$), so that stimulatory touch was provided the longest time and functional touch the shortest time. Moreover, results indicated that touch frequencies differed significantly, $F(2, 72) = 26.362$, $p < .001$, $\eta^2 = .423$. Pairwise comparisons showed that functional touch was significantly less frequent than affectionate ($p < .001$) and stimulatory touch ($p < .001$).

Table 1 shows descriptive statistics for all variables of maternal touch and infant social engagement. Across the sample, the mean of the calculated scores of intraindividual maternal mean OT was 165.902 (SD = 95.918, range = 36.20 – 365.56) and the mean of the intraindividual scores of infant mean OT was 174.763 (SD = 91.717, range = 55.25 – 413.01).

Table 1

Descriptive Statistics for Maternal Touch and Infant Social Engagement

	M	*SD*	*Range*	*M*	*SD*	*Range*
	Duration (% of time)			Frequency		
Maternal touch						
Affectionate touch	29.8	20.1	1.2 – 87.9	14	7	2 – 31
Stimulatory touch	55.2	22.3	6.6 – 92.8	15	7	2 – 34
Functional touch	4.4	4.0	0.0 – 14.0	7	6	0 – 21
Touch (overall)	89.8	14.6	42.0 – 100.0	36	17	8 – 82
Infant social engagement						
Gaze at	41.6	23.7	6.6 – 86.0			
Gaze away	58.0	23.7	13.7 – 93.1			
Positive face	10.5	8.9	0.0 – 35.0			
Negative face	8.3	8.1	0.0 – 26.9			
Positive vocalizations				20	16	0 - 60
Negative vocalizations				16	11	0 - 39

Note. Values of oxytocin are pg/mL.

Postpartum depression. The majority of mothers (81.1 %) reported no or minimal symptoms of depression ($M = 8.81$, $SD = 6.25$, *range* = 0 – 25). Five mothers reached a score for mild depression and two for moderate depression. No significant correlations were found between BDI-II scores and other main study variables.

Relationship between OT and infant social engagement. Table 2 shows correlations between OT levels and variables of infant social engagement as well as intercorrelations between these variables. Maternal mean OT and infant mean OT were highly correlated. Neither maternal nor infant OT was associated with variables of infant social engagement.

Within variables of infant social engagement, significant relationships were found between positive vocalizations (frequency) and gazing at the mother (duration) as well as between negative facial expressions (duration) and negative vocalizations (frequency).

Table 2

Intercorrelations Between OT Levels and Variables of Infant Social Engagement

	1.	2.	3.	4.	5.	6.	7.
1. Infant mean oxytocin	-						
2. Maternal mean oxytocin	.615***	-					
3. Gazes at mother (duration)	.098	-.208	-				
4. Positive face (duration)	-.165	.033	.219	-			
5. Negative face (duration)	-.235	-.117	-.125	-.112	-		
6. Positive vocalizations (frequency)	.182	.107	.576***	.266	-.289	-	
7. Negative vocalizations (frequency)	-.076	-.044	-.102	-.242	.629***	-.012	

Note. ***$p < .001$.

4.2. Hypotheses Testing

Relationship between maternal touch and OT, controlling for maternal depression. To find out if frequencies and durations of different forms of maternal

touch were associated with maternal and infant OT, correlational analyses were performed. Pearson correlations were not significant. Controlling for maternal depression in partial correlations, a marginally significant relation was observed between maternal mean OT and affectionate touch frequency, $r(24) = .380$, $p = .055$.

Relationship between maternal touch and infant social engagement, controlling for maternal depression. To find out if frequencies and durations of different forms of maternal touch were associated with variables of infant social engagement, correlational analyses were performed. Marginally significant and significant correlations were found between frequent touch, especially functional touch, and less positive as well as more negative infant social engagement (see Table 3).

To control significant Pearson correlations with the variable touch (duration) that is not normally distributed, non-parametrical correlations (Spearman) were performed. The non-parametrical (Spearman) correlation between touch (duration) and positive vocalizations (frequency) was not significant. The correlation between touch (duration) and negative vocalizations (frequency) was statistically significant, $\rho(37) = .474$, $p = .003$.

Table 3

Correlations Between Maternal Touch and Infant Social Engagement

	Gazes at mother (duration)	Positive face (duration)	Negative face (duration)	Positive vocalizations (frequency)	Negative vocalizations (frequency)
Affectionate touch (frequency)	-.233	-.256	.343*	-.148	.224
Affectionate touch (duration)	-.128	-.196	-.127	-.212	-.071
Stimulatory touch (frequency)	-.181	-.014	.367*	.080	.294††
Stimulatory touch (duration)	.040	.085	.161	.023	.208
Functional touch (frequency)	-.324†	-.070	.461**	-.379*	.154
Functional touch (duration)	-.262	-.113	.323†	-.312†	.035
Touch (frequency)	-.301††	-.144	.481**	-.168	.285
Touch (duration)	-.154	-.166	.138	-.292††	.201††

Note. ††$p < .08$. †$p < .06$. *$p < .05$, **$p < .01$

Partial correlations, controlling for maternal depression, were performed. The significance of correlations between infant gaze at the mother and maternal functional touch (frequency and duration) and overall touch frequencies increased substantially (see Table 4).

Table 4

Partial Correlations (BDI-II as Covariate) Between Maternal Touch and Infant Social Engagement

	Gazes at
Functional touch (frequency)	-.381*
Functional touch (duration)	-.321†
Touch (frequency)	-.328†

Note. †$p < .06$, *$p < .05$

For significant correlations, regression analyses were performed. For the significant partial correlation, a hierarchical regression was performed with maternal depression score in the first block, and maternal touch in the second block. Frequent functional touch was a significant unique predictor for gazing at the mother in the model (see Table 5).

Table 5

Predicting Infant Gazing at the Mother

Predictor	R^2	ß
Step 1	.053	
Beck depression inventory		.230
Step 2	.190*	
Beck depression inventory		.297††
Functional touch (frequency)		-.377*

Note. $\triangle R^2 = .138$, $\triangle F(1, 34) = 5.777$, $p = .022$.

††$p < .08$. *$p < .05$.

Table 6 shows a regression analysis predicting the duration of infant negative facial expressions. The frequencies of different forms of touch explained about a quarter of variance (see Table 6). Similarly, overall touch frequency predicted infants negative facial expressions (duration), $R^2 = .232$, $F(1, 35) = 10.549$, $p = .003$; ß = .481, $p = .003$. Especially functional touch was a unique significant predictor (see Table 6) that negatively influenced infant positive vocalizations as well, $R^2 = .144$, $F(1, 35) = 5.884$, $p = .021$; ß = -.379, $p = .021$. Overall touch duration was not a significant predictor of negative vocalizations (frequency), $p = .232$.

Table 6

Predicting Infant Negative Facial Expressions

Predictor	ß
Affectionate touch (frequency)	.074
Stimulatory touch (frequency)	.196
Functional touch (frequency)	.357*

Note. $R^2 = .262$, $F(3, 33) = 3.905$, $p = .017$.

*$p < .05$.

5. Discussion

The aim of the present study was to investigate the relationship between maternal touch and maternal and infant OT as well as infant social engagement when controlling for the influence of maternal depression. In a natural interaction, the frequencies and durations of different forms of maternal touch (affectionate, stimulatory and functional touch), infant attention (gaze) and affect (facial expressions and vocalizations) were recorded, salivary OT levels were collected and maternal depressive symptoms were assessed with the BDI-II.

Results showed little support for the first main hypothesis. Maternal touch was not significantly associated with OT levels of mothers and infants. In the present study, mothers used significantly more stimulatory touch than affectionate touch during the natural interaction. Interestingly, mothers provided affectionate and stimulatory touch in very similar proportions of time like fathers in a different study (Feldman, Gordon, Schneiderman, et al., 2010). In the present study, mothers provided affectionate touch about 30% of the time and stimulatory touch in about 55% of the time. Similarly, in the other study, fathers provided affectionate touch 25% (mothers 56%) of the time and stimulatory touch 58% (mothers 19%) of the time (Feldman, Gordon, Schneiderman, et al., 2010). Furthermore, only mothers who used high amounts of affectionate touch showed increased OT after the interaction with the infant (Feldman, Gordon, Schneiderman, et al., 2010). In the present study, OT levels did not differ significantly across collection points, so that no increases in OT following the interaction were found either. Thus, the present study might have failed to show associations between durations of touch and OT levels, because mothers did not engage in the typical mode of interaction.

The results showed a marginally significant correlation between affectionate touch frequency and maternal mean OT, when controlling for maternal depressive symptoms. This result is in line with the literature underpinning that maternal OT is associated with the provision of more touch (e.g. Feldman, Gordon, Schneiderman, et al., 2010; Feldman et al., 2012). However, the results indicated that touch frequencies, including affectionate touch frequency, were associated with infant negative affect, which contradicts all existing evidence.

In general, previous research showed associations between more optimal parental care, higher levels of OT and social engagement or reciprocity in parent-infant interactions (e.g. Feldman et al., 2013; Weisman et al., 2012). In contrast, in a recent study authors found that highly sensitive mothers had lower plasma OT levels than less sensitive mothers (Elmadih et al., 2014). Furthermore, OT further decreased in highly sensitive mothers after a playful interaction with the infant (Elmadih et al., 2014). The authors suggested that higher OT in less sensitive mothers might be due to the experience of higher stress as caring for the infant might be more demanding, whereas for highly sensitive mothers interacting with the infant might be relaxing (Elmadih et al., 2014). According to this, higher levels of maternal OT may indicate higher levels of stress in the present study. Thus, the marginally significant association between maternal OT and maternal affectionate touch frequency may be due to higher levels of stress in mothers.

Contrary to expectations, maternal depressive symptoms did neither significantly influence OT in mother or infant, nor maternal touch, nor infant social engagement in the present study. Although previous research showed that lower levels of maternal OT were associated with maternal depressive symptomatology (Apter-Levy et al., 2013), there are also studies showing that depressive symptoms were associated

with higher levels of OT (Holt-Lunstad, Birmingham, & Light, 2011). Both depressive symptoms and higher OT levels were associated with more perceived stress (Holt-Lunstad et al., 2011). Indeed, perceived stress partly mediated the relationship between higher levels of OT and depressive symptomatology (Holt-Lunstad et al., 2011). Thus, it seems that not maternal depressive symptomatology per se, but rather the amount of perceived stress accounts for higher levels of OT. This might serve as explanation why the present study did not find any significant relationship between maternal depressive symptoms and OT levels.

Based on animal studies, increased stress is known to be a short-term effect of OT (see Uvnäs Moberg, 2003). Furthermore, a recent study showed that the administration of OT increased fathers' stress (cortisol) in the Still-Face paradigm (Weisman, Zagoory-Sharon, & Feldman, 2013) and had a stress-reducing effect on infants of less synchronic dyads only. The authors suggested that OT may only or specifically have positive effects in disadvantaged dyads, and concluded that OT effects are not uniform and may depend on social skills (Weisman et al., 2013).

OT was found to increase sensitivity and responsiveness in fathers (Naber, Poslawsky, van IJzendoorn, van Engeland, & Bakermans-Kranenburg, 2013; Naber, van IJzendoorn, Deschamps, van Engeland, & Bakermans-Kranenburg, 2010), because it might increase the ability to read others' minds (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007). For less sensitive parents the administration of OT may help to activate their focus on the infant and facilitate their recognition and understanding of infant social cues, so that these parents may be more willing to adjust their behavior to the infant. This in turn affects infants and their social engagement. In the study by Weisman et al. (2012), fathers provided more touch after OT administration and, in turn, infants' readiness to socially engage in the interaction increased. However, lower endogenous

OT in high sensitive and high OT in low sensitive mothers may be due to short-term stress, such as stress due to the demands of an observational situation (Elmadih et al., 2014). Therefore, maternal stress due to the laboratory condition may explain the results of the present study.

In line with previous findings, maternal and infant OT levels were interrelated and intraindividually stable across time (e.g. Feldman et al., 2013; Feldman, Gordon, & Zagoory-Sharon, 2010) and situations. Thus, the results support the assumption that OT is transmitted across generations in humans (Feldman et al., 2013; Feldman, Gordon, & Zagoory-Sharon, 2010). Contrary to previous findings (Feldman, Gordon, & Zagoory-Sharon, 2010, 2011), infant social engagement was neither associated with infant nor with maternal OT. This might be due to the fact that OT did not show significant reactivity to the natural interaction as mentioned before and was not significantly associated with maternal touch either.

There was partial support for the second main hypothesis. Results showed that the frequent use of different forms of touch accounted for more than 25% of variability in the time infants' showed negative facial expressions. In particular, functional touch had adverse effects on infant social engagement, and was associated with shorter gazes at the mother, less positive vocalizations and longer negative facial expressions. While the role of frequencies of touch might be subject to critical discussion, it was more surprising that the duration of overall touch as well was related to infants' displays of negative affect in vocalizations.

Overall frequencies of touch might be interpreted as switches between different forms of touch. This is because most mothers hardly ever stopped touching their infants at all, but rather changed the form of the touch, such as from affectionate to stimulatory. In the interactions, mothers touched their infants about 90 % of the time. Thus,

frequencies of touch might be interpreted as inconsistent, frequently changing behavior. Frequent touch might be unfavorable as it is intrusive to the infant.

Although there is no consistent definition of maternal intrusiveness in the literature, it may be characterized as insensitive, over-stimulatory, interfering, restraining, disruptive or "frequent, noncontingent behavior directed toward the child" (Ispa et al., 2004, p. 1614). Furthermore, an intrusive mother might be preoccupied with her own thoughts and agenda (Ainsworth et al., 1978, as cited in Ispa et al., 2004), rather than focusing on the infant. In this way, the mother might be willing to overrule the infant by restraining or interfering with the infant's self-selected behavior or focus of attention.

As mentioned earlier, maternal depression is associated with withdrawn or intrusive behavior (for review see Field, Diego, & Hernandez-Reif, 2009), providing more inadequate (Herrera et al., 2004) or over-stimulatory and intrusive touch (Fergus et al., 1998, as cited in Stack, 2010). It is also associated with more stress and negative affect in the infant (Feldman et al., 2009). Assuming that the intrusiveness of the depressed mother and her infant's higher levels of distress are due to mother's higher perceived stress, non-depressed mothers might display intrusive behavior when they are stressed. Consequently, infants might get stressed as well.

In the present study, stress in mothers might have led to unusually high amounts of stimulatory touch and frequent, inconsistent touching behavior. Due to the fact that mothers and infants were observed in a laboratory, mothers might have felt uncomfortable, under pressure to perform or to show off their best possible behavior as a mother or person in general. The awareness of being observed and additionally recorded on video doubtlessly changes the behavior of study participants. The wish to appear socially desirable might have been unconsciously the number one goal of

mothers in the study. The mother might have been concerned with the current experimental condition rather than focusing on the infant and the interaction. This might have disabled her to engage into the interaction appropriately.

Because intentions and emotions are communicated through touch, the frequent and intrusive style of mother's touch might have communicated the mother's stress or insecurity to her infant. The infant might have become irritated, worried and insecured as the mother acted unusual. Similarly, the higher amount of stimulatory touch might have been intrusive and uncommon, probably overwhelming the infant. The unusual high amount of stimulatory maternal touch might also account for the finding that overall touch duration was related to more frequent negative vocalizations.

There were indications that the infant was stressed, agitated or felt uncomfortable due to the experimental procedure in the first place. Six mother-infant dyads had to be excluded from the video analysis, because infants were not ready and too agitated to be placed into the infant seat, making a face-to-face interaction impossible in the first place. This might as well be an indication for maternal stress that was passed on to infants. Furthermore, it might be considered that particularly first-time mothers of infants only a few months old might have a hard time to adjust to an unusual situation like the experimental procedure. Moreover, the interaction was stopped when the infant was crying and could not be soothed in the face-to-face interaction, so that they were taken out of the seat. This led to varying lengths of videoed natural interactions and was a limitation of the study.

In general, the observed natural interaction as experimental condition might not correspond to a real natural interaction. Beside the argument of what is known as the Hawthorne or observer effect, a situation where the mother focuses exclusively on the infant may not occur in everyday life. A first-time mother might be busy and interact

with her infant along the way, incorporating incidental occurrences and activities into the interaction.

Additionally, mother's facial expressions or other non-verbal or verbal behavior might have contributed to the infant's evaluation of the situation. In combination with the mother's use of touch, maternal facial expressions might have influenced infant's behavior in the interaction. Because viewing negative or positive facial expressions influenced the perceived pleasantness of touch in adults (Ellingsen et al., 2014), maternal facial expressions might have influenced infant's affective displays and social engagement in the interaction as well. Because the present study did not measure and analyze maternal behavior other than touch, this might be implemented in future studies.

Another limitation of the study was the analysis of salivary OT. Although salivary OT was found to correlate with plasma OT (e.g. Feldman, Gordon, Schneiderman, et al., 2010), it might lead to different study results, also because no standardized protocol about the collection of OT existed. Furthermore, some OT samples were unusable in the present study, although the method tested in the pre-experiment was successful.

In the present study, mean OT was used for the analyses, because OT levels did not differ significantly throughout the experimental procedure. Contrary to a previous finding (Feldman, Gordon, & Zagoory-Sharon, 2010), maternal OT and infant OT did not increase from pre- to post-interaction. Different findings may be due to different methods used to analyze OT (e.g., Feldman, Gordon, & Zagoory-Sharon, 2010). Although concentrations of OT might not be comparable across studies, the variability within a study should lead to comparable results. Furthermore, it might be considered that most studies investigating OT in parents and infants in interactions, that set the base

for the expected results of the present study, arise from the research around Prof. Feldman. Moreover, as mentioned earlier, studies about measures of endogenous OT might be interpreted differently than studies that apply the administration of OT. The generalizability of the results may be limited to dyads of European Caucasian origin with healthy full-term infants and not clinically depressed mothers from middle to upper class.

Taken together, it seems that OT measurements cannot be interpreted straightforward, because it has various functions and depends on many intraindividual factors. Thus, future studies may include additional measures of stress like cortisol in order to interpret OT's actual function. Thus, the measurement of cortisol and OT in parents and infants in a natural interaction may contribute to a better understanding of OT functioning. Further research may include fathers to compare differences in OT and touch between fathers and mothers. Likewise, more parental behavior like gaze, facial expressions and vocalizations might be taken into account to investigate the influence of combinations of touch and other behaviors in natural interactions. Moreover, sequential analyzes would allow to make inferences about the causality and to draw conclusions about what kind of infant social engagement is followed by what kind of parental touch and vice versa.

In conclusion, the findings of the present study contribute to the understanding of the role of OT and maternal touch in mother-infant interactions. Particularly, the association between frequent maternal touch and negative infant social engagement points to the impact of touch on communication about internal states. Independent of the possible influence of subclinical maternal depressive symptoms, this study emphasizes the importance of appropriate maternal touch and positive mother-infant interactions for infants' ability to socially engage in interactions.

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Abstract

The neuropeptide Oxytocin (OT) plays an important role in the mother-infant relationship. Touch between mother and infant seems to increase OT and to be important for infant's development and social engagement. Touch seems to increase OT by communicating emotions like love and affection. Interestingly, less optimal touch, lower OT levels and less infant social engagement are present in dyads with depressed mothers. The goal of the present study was to investigate if different forms of maternal touch were associated with OT levels of mothers and infants as well as with infant social engagement, controlling for the influence of maternal depression. Videos of natural interactions between 37 mothers and their 4-month-old infants were analyzed for frequencies and durations of different forms of maternal touch (affectionate, stimulatory and functional touch), infant attention (gaze) and affect (facial expressions and vocalizations). Salivary OT was collected from mothers and infants, and maternal depressive symptoms were assessed with the BDI-II. Results showed a marginally significant relationship between maternal OT and affectionate touch frequency, when controlling for the influence of maternal depressive symptoms. Frequent touch, especially functional touch, was associated with more negative infant social engagement. Maternal intrusiveness due to stress as well as the role of OT in maternal stress are discussed.

Keywords: maternal touch, oxytocin, mother-infant interaction, infant social engagement, maternal depression

Zusammenfassung

Das Neuropeptid Oxytocin (OT) spielt eine wichtige Rolle in der Mutter-Kind-Beziehung. Berührung zwischen Mutter und Kind scheint, OT zu erhöhen und für die kindliche Entwicklung und der Beteiligung in sozialen Interaktionen wichtig zu sein. Interessanterweise gibt es weniger optimale Berührung, niedrigere OT-Spiegel und weniger Beteiligung in sozialen Interaktionen des Kindes in Dyaden mit depressiven Müttern. Das Ziel dieser Studie war es zu untersuchen, ob unterschiedliche Formen von mütterlicher Berührung mit OT-Spiegel von Mutter und Kind sowie mit der Beteiligung des Kindes in der sozialen Interaktion in Zusammenhang stehen, wenn man den Einfluss von mütterlicher Depression kontrolliert. In Videos von natürlichen Interaktionen zwischen 37 Müttern und ihren Säuglingen (4 Monate alt) wurden Häufigkeit und Dauer der unterschiedlichen Formen von mütterlicher Berührung (liebevoll, stimulierend und funktional), Aufmerksamkeit (Blick) und Affekt (Gesichtsausdrücke und Laute) der Kinder untersucht. Es wurde OT aus dem Speichel von Müttern und Kindern und depressive Symptome der Mutter mit dem BDI-II erhoben. Die Ergebnisse zeigten einen marginal signifikanten Zusammenhang zwischen OT der Mutter und der Häufigkeit von liebevoller Berührung, wenn der Einfluss von mütterlichen depressiven Symptomen kontrolliert wurde. Häufige Berührung, vor allem funktionale Berührung, hing mit mehr negativer Beteiligung des Kindes in der Interaktion zusammen. Mütterliche Intrusivität aufgrund Stress sowie die Rolle von OT in mütterlichem Stress wurde diskutiert.

Schlüsselwörter: Mütterliche Berührung, Oxytocin, Mutter-Kind Interaktion, Säugling, Sozialverhalten, mütterliche Depression

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