Oxytocin and the Development of Parenting in Humans

Ilanit Gordon, Orna Zagoory-Sharon, James F. Leckman, and Ruth Feldman

Background: The nonapeptide oxytocin (OT) has been repeatedly implicated in processes of parent-infant bonding in animal models; yet, its role in the development of human parenting has received less attention and no research has addressed the involvement of OT in the transition to fatherhood.

Methods: Using a prospective longitudinal design, 160 cohabitating mothers and fathers and their firstborn infant were visited at home during the first postpartum weeks and again at 6 months postpartum. Mothers’ and fathers’ plasma OT was analyzed at each time point with enzyme-linked immunosorbent assay methodology. Interactions between each parent and the infant were observed in the postpartum and microcoded for parenting behavior.

Results: Overall, parental OT increased across the study period and there were no differences between maternal and paternal OT at each time point. Oxytocin showed high intraindividual stability across the first 6 months of parenting and the OT levels of husband and wife were interrelated at both assessments. Maternal OT was related to the amount of affectionate parenting behaviors, including “motherese” vocalizations, the expression of positive affect, and affectionate touch, whereas paternal OT correlated with the degree of stimulatory parenting behaviors, including proprioceptive contact, tactile stimulation, and object presentation.

Conclusions: Results are the first to describe plasma OT levels in new fathers and mothers across the transition to parenthood in relation to maternal and paternal typical parenting behaviors. These data may provide a normative basis for the study of parenting under conditions of high risk.

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was 6 months old. Three specific goals guided the study: 1) to compare plasma OT concentrations in mothers and fathers across the first 6 months of parenting and to assess interrelatedness in OT levels between cohabitating partners; 2) to assess whether OT levels in mothers and fathers are individually stable across the first postpartum months; and 3) to examine whether maternal and paternal OT are related to a specific set of maternal and paternal behaviors that are characteristic of human mothers and fathers.

Methods and Materials

Participants

Eighty cohabitating couples and their firstborn infant (n = 240 participants) participated in the study. Of these, 128 parents (66 mothers and 62 fathers) were seen again when the infant was approximately 6 months old (M = 24.8 weeks, SD = 4.38). Fathers’ age averaged 29.45 years (SD = 3.87) and education averaged 15.7 years (SD = 2.85), and mothers’ age averaged 27.24 years (SD = 3.67) and education averaged 16.08 years (SD = 2.22). Parents were all residing in central Israel, were of middle class background, had completed at least high school education, and were above 20 years old, and the infant was the first child to both mother and father. Infants (37 boys) were all healthy firstborns of a singleton birth. Sixty-five infants (81.2%) were born by vaginal birth and 15 infants were born by cesarean birth; fathers’ age averaged 29.45 years (SD = 3.85), and mothers’ age averaged 24.8 weeks, SD = 4.38).

Fathers (time 2) 434.12 (401.88) 2233.8 184 56
Mothers (time 1) 337.35 (195.64) 1351 147.8 76

Infants’ mean age at the first time point was 7.1 weeks (SD = 2.11). Interactions were microcoded by trained graduate students on The Observer computerized system (Noldus, Wageningen, Netherlands) in .01 second frames, consistent with previous research on parent-infant interaction in the neonatal period that utilized the same computerized system (31–33). Four nonverbal categories of parenting behavior were coded and each category included a set of mutually exclusive codes (an “uncodable” code was added to each category to address moments when codes could not be determined).

Categories and codes were as follows: parent gaze—to infant’s face, to infant’s body, to object or environment, gaze aversion; parent affect—positive, neutral, negative; parent vocalizations—motherese (high-pitched, sing-song vocalization), adult speech to infant, adult speech to other adult, none; and parent touch—affectionate touch (e.g., hugging, kissing, stroking), touch of infant extremities, functional touch, proprioceptive touch (i.e., changing infant position in space), object presentation, stimulatory touch, none.

Interrater reliability was conducted for 10% of the interactions and averaged 98% (kappa = .84). For each behavior, we computed the proportions of time out of the entire interaction this behavior had occurred. Two composite scores for parental behavior were created in light of previous microanalytic studies of parenting in the postpartum (28,32–35): affectionate parenting behavior was the sum of the proportions of positive affect, motherese vocalization, and affectionate touch, and stimulatory parenting behavior was the sum of the proportions of proprioceptive touch, object presentation, and stimulatory touch.

Results

Oxytocin

Maternal and paternal plasma OT levels in the second and sixth postpartum months are presented in Table 1. As seen, OT levels are consistent with previous studies in adults using enzyme-linked immunosorbent assay methodology (27,28,30). Figure 1 illustrates frequency distributions of OT levels in mothers and fathers during the first and second visits. Prior to data analysis, OT levels were log transformed and outliers higher than three standard deviations of the mean in both time points were omitted (n = 6).

Pearson correlations indicated that OT was unrelated to demographic variables, including parent age, height, weight, smoking, use of medications, and time of last meal. In addition, maternal OT was not related to menstrual cycle phase, contra-

<table>
<thead>
<tr>
<th>n</th>
<th>OT (pg/mL)</th>
<th>Means (SD)</th>
<th>Maximum (pg/mL)</th>
<th>Minimum (pg/mL)</th>
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<tbody>
<tr>
<td>76</td>
<td>Mothers (time 1)</td>
<td>337.35 (195.64)</td>
<td>1351</td>
<td>147.8</td>
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<tr>
<td>76</td>
<td>Fathers (time 1)</td>
<td>401.98 (360.28)</td>
<td>2752.3</td>
<td>51.4</td>
</tr>
<tr>
<td>59</td>
<td>Mothers (time 2)</td>
<td>357.79 (207.72)</td>
<td>1351</td>
<td>125.2</td>
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<tr>
<td>56</td>
<td>Fathers (time 2)</td>
<td>434.12 (401.88)</td>
<td>2233.8</td>
<td>184</td>
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OT, oxytocin.
Parenting Behavior

Mean proportions of affectionate play was .66 (SE = .05) and the frequency was 4.79 (SE = .20). Mean proportions of stimulatory play behavior was .37 (SE = .02) and the frequency was 2.65 (SE = .15). Pearson correlations showed that among both fathers and mothers the proportion of affectionate behavior and stimulatory play was negatively related (r = −.51, p < .005, and r = −.41, p < .005 for fathers and mothers, respectively). To examine the differences between mothers and fathers in the distributions of parenting behavior, paired sample t tests were performed. No mean-level differences were found in the proportion of time mothers and fathers engaged in affectionate and stimulatory parenting behaviors. However, maternal OT correlated with the amount of time mothers spent in affectionate parenting behavior, r = .33, p < .05, but not with the time mothers engaged in stimulatory parenting behaviour, r = −.22, p > .10. On the other hand, paternal OT levels were related to the amount of time fathers spent in stimulatory parenting behavior, r = .30, p < .05, but not with the proportions of paternal affectionate parenting behavior, r = .08, p > .10. Figures 2A and 2B present the scatter plots for these correlations.

Discussion

Results of the present study provide the first normative data on the distributions of OT in human mothers and fathers across the first months of parenthood. The data point to similarities between the OT levels of mothers and fathers and show that during the early phases of parenthood, peripheral OT levels in cohabitating parents are interrelated. Finally, the findings point to gender-specific associations between parental OT and parenting behaviors during dyadic interactions in the first postpartum weeks: affectionate parenting behavior was associated with maternal OT and stimulatory parenting behavior was related to paternal OT.

Although OT has typically been considered a maternal hormone associated with birth and lactation (3,36), our findings show similar basal concentrations of OT in maternal and paternal plasma. The present findings are consistent with recent research assessing plasma (30) and cerebrospinal fluid OT (37), which showed similar concentrations of OT in men and women. These gender similarities are also consistent with studies on the intra-nasal effects of OT (18,24,38).

The high level of stability found in basal OT levels may suggest that baseline OT levels are relatively stable during the postpartum period, except for moments of specific physiological processes such as breastfeeding or sexual intercourse that lead to considerable rise in OT but are short in duration (26,39–41).

### Table 2. Correlations Between Maternal and Paternal OT in the First and Second Assessments

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<tr>
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<th>Fathers</th>
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<tr>
<td></td>
<td>Postpartum</td>
<td>6 Months</td>
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<tr>
<td>Fathers</td>
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<tr>
<td>Postpartum</td>
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<td>.790&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>6 months</td>
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<td>Mothers</td>
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<tr>
<td>Postpartum</td>
<td>.372&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.423&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>6 months</td>
<td>.317&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.345&lt;sup&gt;a&lt;/sup&gt;</td>
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OT, oxytocin.  
<sup>a</sup>p < .05.  
<sup>b</sup>p < .01.
When longitudinal changes in basal OT concentrations have been reported, such changes appear to be relatively small in magnitude (27,42). Future research is required to assess whether breastfeeding has a prolonged effect on basal OT levels and whether such effect may explain the rise in OT levels from the second to the sixth postpartum month.

The significant rise in OT during the first 6 months of parenting may suggest that OT increases in parents as their relationship with the infant evolves. Parents derive a greater reward from interacting with an infant who is a more active and object-oriented play, a style that is typical of the human parental bonding. As the functioning of the OT system is underlay by distinct genetic and hormonal constellations. For instance, two parenting styles—social and didactic—have been described in the interactions of mothers and their infants, which were stable over time and unrelated to each other (56). It is also possible that OT is related to the type of behaviors from which mothers and fathers derive the most reward. Infants tend to prefer fathers as playmates when they are positive and choose mothers for comfort when distressed (52,53,57). The infant’s preference may be of high reward value for the parent, and thus, although mothers and fathers displayed similar levels of affectionate and stimulatory play, OT may be linked to the behaviors each parent found the most rewarding. These findings are consistent with the associations reported between central OT functioning and the mesolimbic dopamine reward pathways in animals (7,58–61). Future research is thus needed to follow the parent’s interactive style in relation to hormonal levels and the developing attachment across the first years of life.

The present study is the first to demonstrate associations between OT levels in cohabitating partners; yet, due to the study design, it is not possible to determine the mechanisms through which such hormonal synchronization occurs. Similar interdependence between attachment partners has been reported for hormones such as cortisol, vasopressin, epinephrine, adrenocorticotropic hormone, growth hormones, and prolactin (62–64). Similarly, a couples’ intervention program including warm and affectionate touch was found to induce an “endocrine fit” between partners (65). Further longitudinal research is required to follow individuals throughout adulthood and examine changes in OT levels during periods of falling in love with a romantic partner or during the first months of pregnancy to assess whether the correlation in OT levels described here is specific to the postpartum period or represents a more general trend.

Among the limitations of the study is the reliance on basal and peripheral OT without the inclusion of central or reactive measures. Although the relationship between central and peripheral OT levels is not fully understood, both animal (29,66) and recent human (39) studies suggest that central and peripheral activity of the oxytocinergic system is coordinated. The high stability in OT levels across a period of several months and the links reported between plasma OT with socioemotional and behavioral indicators of affiliation (27,28,30,39,67–69) support the validity of peripheral OT as a biomarker of affiliation processes. In addition to the actual level of OT in the periphery, the distribution and density of central OT receptors may be another key factor in understanding the role of OT and related neuropeptides in affiliative behavior (70,71). For example, in rodents there is a major shift in the location and density of OT receptors following parturition in the dams and after weaning in the pups (72,73). Future studies may incorporate measures of OT reactivity to the study of the transition to parenthood.

Our findings highlight the involvement of OT in adaptive human parental bonding. As the functioning of the OT system is disrupted in a variety of psychopathological conditions, including depression and schizophrenia (68,74), assessing the transition to parenthood under risk conditions for the development of parenting is required to provide a broader perspective on the biological underpinning of healthy and high-risk parenting.

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tute of Psycho-Analyse.
3. Carter CS (1998): Neuroendocrine perspectives on social attachment and
4. Donaldson ZR, Young LJ (2008): Oxytocin, vasopressin, and the neuro-
5. Insel TR (1997): A neurobiological basis of social attachment. Am J Psy-
chiatry 154:726–735.
6. Insel TR, Fernald RD (2004): How the brain processes social information:
prairie voles (but not in males). Horm Behav 41:456.
9. Holman SD, Goy RW (1995): Experiential and hormonal correlates of
care-giving in rhesus macaques. In: Pycke CR, Martin RD, Skuse D, edi-
tors. Motherhood in Human and Nonhuman Primates: Biosocial Determi-
oxytocin stimulates maternal behaviour in the sheep. Neuroendocrinol-
ting variations in maternal behavior in the rat are associated with differ-
ences in estrogen-inducible central oxytocin receptors. Proc Natl Acad
14. champagne FA (2008): Epigenetic mechanisms and the transgenera-
psychopathology. Biol Psychiatry 51:27–43.
16. Leckman JF, Carter CS, Hennessy MB, Hrdy SB, Keverne EB, Klann-Delius
Carter CS, Ahnert L, editors. Dahlien Workshop Report. Cambridge, MA:
MIT Press, 303–349.
The effect of intranasal oxytocin administration on endocrine and sex-
18. Steinbrecher MC, Fernald RD (2004): How the brain processes social infor-
20. Leckman JF, Goodman WK, North WG, Chappell PB, Price LH, Pauls DL,
et al. (1994): Elevated cerebrospinal fluid levels of oxytocin in obsessive-
compulsive disorder. Comparison with Tourette’s syndrome and healthy
controls. Arch Gen Psychiatry 51:782–792.
port and oxytocin interact to suppress cortisol and subjective responses
effects of intranasal oxytocin administration on endocrine and sexual func-
Ehlert U, et al. (2001): Effects of suckling on hypothalamic-pituitary-adre-
nal axis responses to psychosocial stress in postpartum lactating
traits in women 4 days post partum and their correlation with plasma levels
(2000): Relation of plasma oxytocin and prolactin concentrations to milk
Endocrinol Metab 85:3661–3668.
shared timing; physiological precursors, developmental outcomes, and
27. Haith MM, Bergman T, Moore MJ (1977): Eye contact and face scanning
29. Stern DN (1977): The First Relationship: Infant and Mother. Cambridge,
MA: Harvard University Press.
behavior are associated with differences in oxytocin receptor levels in
32. Neumann ID (2008): Brain oxytocin: A key regulator of emotional and
865.
33. Uvnas-Moberg K, Pettersson M (2005): [Oxytocin, a mediator of anti-
stress, well-being, social interaction, growth and healing. J Psychosom
34. Feldman R (2003): Infant-mother and infant-father synchrony: The co-
35. Lam ME (1977): A 25-year review of the infant social world. Hum Dev 20:
65–85.

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