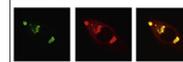


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Research Report

Oxytocin and vasopressin support distinct configurations of social synchrony

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ABSTRACT

Social synchrony – the coordination of behavior between interacting partners during social contact – is learned within the parent-infant bond and appears in a unique form in mothers and fathers. In this study, we examined hormonal effects of OT and AVP on maternal and paternal behavioral patterns and detail the processes of parent-infant social synchrony as they combine with hormonal activity. Participants included 119 mothers and fathers (not couples) and their 4–6 month-old infants. Baseline OT and AVP were collected from parents and a 10-minute face-to-face interaction with the infant was filmed. Interactions were micro-coded for parent-child contact, social signals, and social- versus-object focused play. Proportions and lag-sequential patterns of social behaviors were computed. Mothers provided more affectionate contact, while fathers provided more stimulatory contact. Parents with high OT levels displayed significantly more affectionate contact compared to parents with low OT and constructed the interaction towards readiness for social engagement by increasing social salience in response to infant social gaze. In contrast, parents with high AVP engaged in stimulatory contact and tended to increase object-salience when infants showed bids for social engagement. OT levels were independently predicted by the amount of affectionate contact and the durations of gaze synchrony, whereas AVP levels were predicted by stimulatory contact, joint attention to objects, and the parent increasing object salience following infant social gaze. Results further specify how synchronous bio-behavioral processes with mother and father support the human infant's entry into the family unit and prepare the child for joining the larger social world.

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1. Introduction

The nature of the affiliative bond between infants and their parents is crucial for understanding human relationships and the developmental psychopathologies that result from its malfunction (Douglas, 2010). Across mammalian species, the transition to parenthood involves a major neuro-hormonal reorganization that is essential for the provision

of adequate caregiving and the formation of the parent-infant bond (Curley and Keverne, 2005). Thus, pregnancy and child-birth occur in the context of marked changes in maternal and paternal brain areas implicated in motivation, nurturance, and attention (Atzil et al., 2011; Kinsley and Amory-Meyer, 2011; Mosek-Eilon et al., 2013; Swain et al., 2007). Mothers' and fathers' brains undergo changes and become sensitive to their infants' cues (Kim et al., 2010), and similar changes are

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observed in hormonal systems (Feldman, 2012). These neuro-hormonal changes support the expression of the species-typical behavioral repertoire in mothers and fathers that prompt the parent-infant affiliative attachment (Feldman et al., 2007). A basic concept in the understanding of this affiliative bond is that of *bio-behavioral synchrony* (Feldman, 2007, 2012; Feldman et al., 2012). Human studies have shown that parent-infant social synchrony – the coordination of parental behavior with the infant's social signals – describes a distinct and stable behavior constellation that is uniquely expressed in mothers and fathers (Feldman, 2007, 2012; Feldman et al., 2012). The human maternal behavioral repertoire is largely based on eye contact with the infant, “motherese” vocalizations, affectionate touch, and the appropriate and synchronous adaptation of these behaviors to infant responsiveness (Feldman and Eidelman, 2004, 2007). The human paternal constellation, on the other hand, involves redirection of infant attention to the environment, stimulatory contact, and joint attention in the exploration of objects (Feldman et al., 2013; Feldman et al., 2013; Parke, 1996), although mothers and fathers both employ the “maternal” and “paternal” repertoire during social play. These behaviors parallel those described in the classical animal literature, mainly in rodents, that link maternal behavior to motivational and affective neural systems (Champagne et al., 2008).

There is currently much support for the notion that human attachment develops within the matrix of biological attunement and close behavioral synchrony (Atzil et al., 2013; Feldman, 2012; Feldman et al., 2011, 2012). An important area of research in the neurobiology of attachment has been the hormonal system, in particular the posterior hypophysial peptides oxytocin (OT) and vasopressin (AVP). Accumulating evidence has shown in both animals and humans that these hormones are indispensable elements in the developing formation of relationships, affecting individual differences in parenting behavior, social recognition, and affiliative behaviors (for review, Feldman, 2012; Ishak et al., 2011; Skuse and Gallagher, 2011). Studies in rodents (prairie voles) indicate that variations in maternal behavior based on distinct patterns of mothering correlate with a specific bio-behavioral profile and greater OT receptor densities in both mother and child (Olazábal and Young, 2006). In humans, OT levels in parent and child are inter-related and depend on the degree of interactive synchrony (Feldman et al., 2010a, 2011), including gaze synchrony and the matching of affective expression. Mothers who engaged in more synchronous interactions showed more coherent activations of the amygdala and nucleus accumbens (NAcc) to their infant's stimuli, and these activations correlated with maternal plasma OT (Atzil et al., 2011). Parallel to research in mice pointing to associations between mothers' and fathers' physiological and behavioral responses in the context of infant cues (Franssen et al., 2011), we found correlations between OT levels in human mothers, fathers, and infants (Feldman et al., 2013) as well as synchrony between mothers' and fathers' brain response to their own infant's stimuli (Atzil et al., 2012).

In contrast to OT, very little is known about the effects of AVP on human parenting. In rodents, AVP has been associated with male bonding and defensive and territorial behavior in rodents (Bielsky et al., 2005), and recent research

has shown that AVP promotes social recognition in both animals, especially rodents, (Caldwell et al., 2008), and human males (Guastella et al., 2010). Regions characterized as part of the AVP circuitry are implicated in socio-cognitive processes in both humans and rodents (Goodson and Thompson, 2010). This AVP-brain associations may represent elevated AVP-dependent vigilance, which supports the father's ability to read the intention of others in order to defend mother and young (Atzil et al., 2012; Thompson et al., 2006). In contrast, in women, AVP was found to support the mother's ability to befriend with others. Thus, AVP may prompt differential social strategies in social contexts in women and men (Thompson et al., 2006).

OT effects on human social functioning, however, are not uniform and depend on the individual's attachment history and social skills (Bartz and Hollander, 2006; Weisman et al., 2013b). The influence of OT on social emotion processing in humans appears to depend, at least in part, on gender (Gamer et al., 2010), and OT significantly increased activations in brain areas involved with emotion encoding and empathy in females and not in males (Decety, 2010). This may imply that OT influences prompts different parental behaviors in mothers and fathers. Interestingly, in mothers, but not in fathers, plasma OT correlated with limbic activations (Zink et al., 2011). It thus appears that maternal instinctual care may originate from a limbic OT-sensitive motivational circuit, while fathering is acquired by experience, influenced by social-cognitive processes and AVP.

Brain activity–OT correlations provide additional support to the notion that mothering is guided by greater motivational-emotional focus whereas fathering by a more socio-cognitive executive focus. We found that plasma OT levels may reflect enhanced maternal but not paternal brain activity in limbic-emotional brain areas. In contrast, father OT correlated with higher activations in socio-cognitive circuits, whereas AVP was linked with fathers' amygdala activations (Atzil et al., 2012). It has further been reported that when fathers received exogenous OT, their infants' showed a comparative increased levels of salivary OT and both partners engaged in greater toy exploration (Weisman et al., 2012). Furthermore, infant OT response correlated with the behavioral repertoire typical of the father–infant bond, including paternal stimulation and joint object exploration (Feldman et al., 2010b). Similarly, Naber et al. (2010), showed that OT administration increased fathers' stimulatory and exploratory play with their toddlers.

The aforementioned synchronous bio-behavioral processes allow the human infant to enter the social world of the family unit and to prepare for joining the larger social group. The *bio-behavioral synchrony* conceptual model (Feldman, 2012; Feldman et al., 2012) postulates that the formation of human attachment includes a finely-tuned adaptation of the parent and infant's neural function. Still, there are some major gaps in the literature that require attention. The vast majority of studies have focused on maternal behavior and there is a relative lack of studies on fathers. Furthermore, most studies have not differentiated between the effects of the two “bonding” hormones, OT and AVP, on patterns of parental–infant bonding. Research on AVP is predominantly male oriented as AVP has been mostly

studied in the context of autism and aggression. There is a paucity of AVP research in humans, with no prior study testing the links between AVP and parenting behavior. Finally, there is a lack of understanding of how OT and AVP differentially structure the behavioral repertoire involved in social interactive processes.

As such, the goals of the present study were to compare the hormonal effects of OT and AVP on both maternal and paternal parenting behaviors and to detail the processes of parent-infant interaction as they synchronize with hormonal activity.

Our major hypothesis was that both OT and AVP levels would be associated with the social behaviors that form the basis of parental care. We also hypothesized that hormonal levels would correlate with the specific ways parents synchronize and structure social interaction with their offspring and that this would differ between OT and AVP. Finally, based on research showing that OT administration increases peripheral AVP (Weisman et al., 2013a), suggesting inter-relatedness between the two hormones, we expected correlations between maternal and paternal OT and AVP.

119 parents (not couples) and their 4–6 month-old infants participated in the study. Parental plasma OT and AVP levels were measured. Parent infant interaction was coded systematically from video recordings focusing on Affectionate and Stimulatory Contact, Joint Attention, and Gaze Synchrony. In addition behavioral sequences of the parent's reaction to the infant's gaze, parent increase social or object salience were assessed.

2. Statistical analysis

In the first section, ANOVAs examined differences between maternal and paternal OT and AVP. Next, three MANOVAs examined differences between mothers and fathers in: (a) touch behavior; (b) synchrony variables, and (c) lag-sequential patterns. In the second section, similar three MANOVAs were computed twice: once for parents with high versus low OT and once for parents with high versus low AVP. In the third section, Pearson's correlations tested inter-relationships between hormones and behavior. Finally, two hierarchical regression models were computed predicting parents' OT and AVP from touch behavior, synchrony variables, and lag-sequential patterns.

3. Results

3.1. Differences in OT, AVP, and social behavior between mothers and fathers

As a first step, we examined whether plasma OT and AVP levels differ between mothers and father. No differences were found in baseline OT and AVP, confirming our previous findings (Atzil et al., 2012; Feldman et al., 2010a, 2011). Levels of OT for mothers were 388.05 ($SD=205.95$) and for fathers 391.18 ($SD=159.72$), $F(1, 118) = .010$, NS. Levels of AVP for mothers were 223.29 ($SD=85.93$) and for fathers 201.37 ($SD=86.37$), $F(1, 118) = 1.855$, NS. OT and AVP were each divided into high and low groups based on the median split (OT median = 332.8 pM, AVP median = 200.2 pM). Consistent with our hypothesis, parents' OT and AVP were inter-related, $r = .21$, $p = .024$.

Three MANOVAs examined differences between mothers and fathers in (a) proportions of touch patterns (*affectionate touch, stimulatory touch*), (b) synchrony variables (*social gaze synchrony, joint attention*), and (c) lag-sequential patterns (*Infant gaze at parent-parent increase social salience: Infant gaze at parent-parent increase object salience: Infant gaze at parent-parent affectionate touch, and Infant gaze at parent-parent stimulatory touch*).

MANOVA for proportions of touch showed an overall effect for parent gender; Wilks' $F(2, 116) = 35.24$, $p < .000$, Effect Size (ES) = .37. Mothers provided significantly more affectionate touch than fathers, Univariate $F(1, 116) = 19.80$, $p < .000$, ES = .145, while fathers exhibited substantially more stimulatory touch, $F(116) = 47.78$, $p < .000$, ES = .29.

MANOVA for the synchrony variables showed no effect of parent gender, Wilks' $F(2, 116) = 1.02$, $p = .38$, NS. Similarly, MANOVA for lag-sequential patterns showed no parent gender effect, Wilks' $F(4, 114) = .49$, $p = .73$, NS. These findings suggest that while mothers and fathers provide different types of touch, the sequential organization of their social behavior during play with their infant does not differ.

3.2. Differences in social behavior between parents of high and low OT and AVP

Next, similar three MANOVAs examined differences between parents high and low in OT, and, following, the same three MANOVAs tested those high and low in AVP.

Table 1 – Social Behavior in parents with high and low oxytocin.

Social Behavior	High OT		Low OT		F
	Mean	SEM	Mean	SEM	
Affectionate contact	56.82	2.6	42.93	3.07	11.86**
Stimulatory contact	27.88	1.77	28.38	1.52	.05
Gaze synchrony	6.75	.85	5.35	.76	1.51
Joint attention	3.51	.33	4.37	.4	2.72
Increasing social salience	1.14	.16	.73	.11	4.447*
Increasing object salience	.46	.11	.37	.09	.42

* $p < .05$.

** $p < .01$.

3.2.1. High and low oxytocin

Means and SD for all variables according to parental OT appear in Tables 1 and 2.

Parental touch – MANOVA revealed a significant effect for OT in parental touch; $F(2, 116) = 5.94, p = .003, ES = .093$. Univariate tests showed that parents with high OT provided

Table 2 – Social behavior in parents with high and low vasopressin.

Social Behavior	High AVP		Low AVP		F
	Mean	SEM	Mean	SEM	
Affectionate contact	53.28	3.06	46.41	2.85	2.7
Stimulatory contact	30.5	1.53	25.77	1.7	4.3*
Gaze synchrony	6.02	.83	6.97	.79	.002
Joint attention	3.5	.33	4.37	.4	2.72
Increasing social salience	.96	.16	.92	.11	.03
Increasing object salience	.56	.12	.27	.57	4.45*

Differences between parents' high and low OT levels in means and SEM of social measures in child-parent interaction. * $p < .05$.

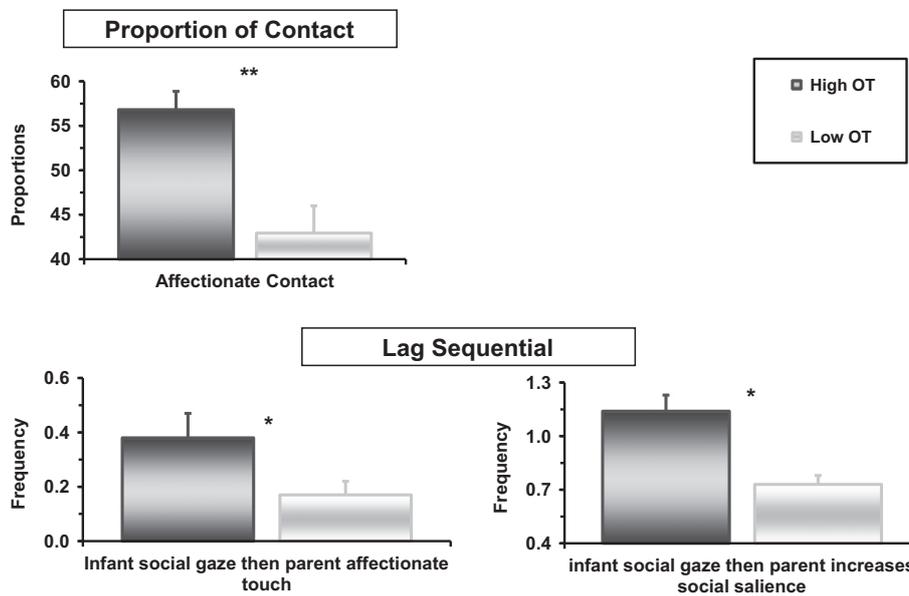


Fig. 1 – Parent-child contact and sequential patterns in parents with high and low oxytocin footer: * $p < .05$, ** $p < .01$.

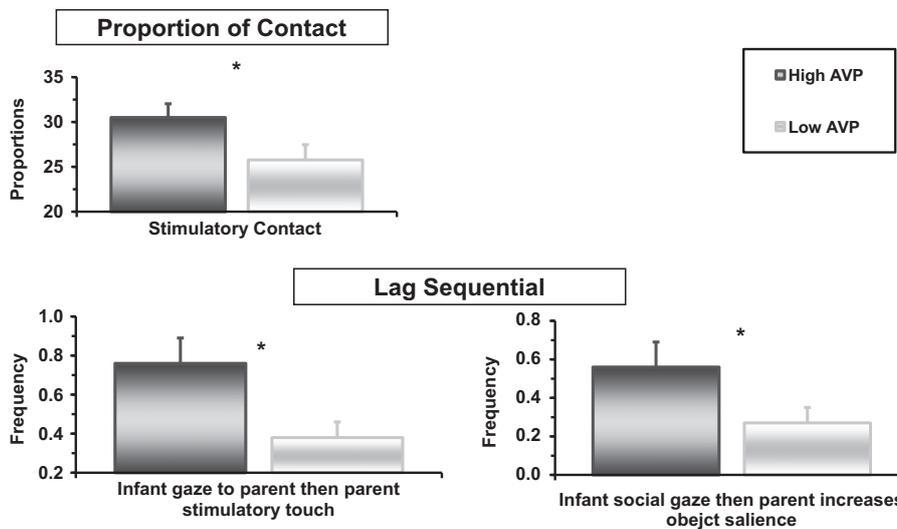


Fig. 2 – Parent-child contact and sequential patterns in parents with high and low vasopressin footer: * $p < .05$.

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Table 3 – Correlations of hormones and social behavior.

Social Behavior	OT	AVP	Affectionate contact	Stimulatory contact	Gaze synchrony	Joint attention	Increasing social salience	Increasing object salience
Increasing object salience	.06	.192*	-.094	.001	-.159*	.03	~.15	1
Increasing social salience	.191*	.02	.004	-.045	-.008	-.084	1	
Joint attention	-.04	.15	-.15**	.18*	.03	1		
Gaze synchrony	.11	-.004	.074	.04	1			
Stimulatory contact	-.02	.19*	-.163*	1				
Affectionate contact	.303*	.15	1					
AVP	-.04	1						
OT	1							

* $p < .05$.** $p = .051$.

substantially more affectionate touch to their infants, $F(1116) = 11.86$, $p = .001$, $ES = .092$, and no differences emerged in stimulatory touch (Fig. 1).

Synchrony variables – no overall difference was found for OT.

Sequential patterns – MANOVA revealed a significant OT effect for sequential patterns; $F(2, 116) = 2.685$, $p = .042$, $ES = .082$. Univariate tests showed that interactions of parents with high OT included higher frequencies of the sequence: infant social gaze then parent affectionate touch, $F(1116) = 4.43$, $p = .037$, $ES = .037$, and infant social gaze then parent increase social salience, $F(1, 116) = 3.81$, $p = .05$, $ES = .033$ (Fig. 1).

3.2.2. High and low vasopressin

Parental touch – MANOVA indicated significant main effect for AVP, $F(2, 116) = 4.29$, $p = .016$, $ES = .069$. Univariate tests showed that parents with high OT provided more stimulatory touch, $F(1116) = 4.29$, $p = .04$, $ES = .035$, and no differences were found for affectionate touch (Fig. 2).

Synchrony variables – no overall effects were found for AVP.

Sequential patterns – MANOVA revealed a significant AVP effect for sequential patterns; $F(2, 116) = 2.372$, $p = .05$, $ES = .078$. Univariate tests showed that parents with high AVP tended to respond to infant social bids with increasing object salience and stimulatory touch. Differences were for: infant social gaze then parent stimulatory touch, $F(1, 116) = 5.73$, $p = .018$, $ES = .048$, and infant social gaze then parent increase object salience, $F(1, 116) = 3.88$, $p = .05$, $ES = .033$ (Fig. 2).

3.3. Correlations between OT, AVP, and parental social behavior and synchronous sequential patterns

Pearson's correlations (Table 3) indicate that parental OT was associated with greater affectionate contact and greater frequency of the sequence *infant social gaze-parent increasing social salience*. Parents' AVP correlated with more stimulatory contact and longer durations of joint attention. Stimulatory contact correlated with joint attention, and gaze synchrony with less parental increasing object salience following infant social gaze.

3.4. Predicting parental OT and AVP

Finally, two regression equations were computed predicting parents' OT and AVP from social behavior. Predictors were entered in seven theoretically-determined steps. Parent-gender was entered in the first step to partial out gender affect. Following, the two touch patterns, two synchrony variables, and two lag-sequential patterns were entered (Table 4). Both models were significant explaining 20% and 31% of the variability in OT and AVP respectively.

OT levels were independently predicted by the amount of affectionate contact, and the durations of gaze synchrony. AVP levels were uniquely predicted by the parent's stimulatory contact, the duration of parent-infant joint attention to object, and the parent responding to infant social gaze by increasing object salience.

4. Discussion

This study provides further evidence for the essential role of the pituitary hormones in parenting and for the complex and intricate relationship between the OT and AVP systems and both mothering and fathering. To our knowledge, this is the first study to examine plasma AVP in human mothers and fathers in comparison to plasma OT and parenting behavior. We found that each hormone is associated with both maternal and paternal behavior but in distinct, sometimes overlapping ways. It may thus be concluded that each hormone promotes a cascade of specific sequential behaviors which form the basic elements of parenting. Specifically, our central hypothesis – that hormonal levels would correlate with the ways in which parents structure social interactions with their offspring and that these correlations would differ for OT and AVP – was, in the main, supported by the findings.

Not surprisingly, our behavioral observations showed how affectionate contact was more characteristic of mothers, while fathers showed more stimulatory contact. This is consistent with studies in both rodents and humans (Szyf et al., 2007; Feldman et al., 2010b). It thus appears that paternal bonding and maternal bonding differ in their basic

Table 4 – Predicting parent oxytocin (OT) and vasopressin (AVP).

Social Behavior	Parental OT			Parental AVP		
	Beta	R ² change	F change	Beta	R ² change	F change
Parent gender	-.07	.00	.43	.09	.02	1.85
Affectionate contact	.36**	.12	16.39***	.07	.00	.96
Stimulatory contact	.15	.02	2.57	.52***	.21	22.92***
Gaze synchrony	.22*	.05	5.81*	.09	.00	.87
Joint attention	.04	.00	.005	.20*	.04	5.79**
Increasing social salience	.03	.00	.31	.07	.00	1.39
Increasing object salience	.08	.00	.98	.19*	.03	3.41*
R ² total=	.20, F (7, 110)=3.81, p < .001			.31 F (7, 110)=7.13, p < .001		

* p < .05.

** p < .001.

*** p < .0001.

behavioral structure. Importantly, irrespective of gender, high levels of OT correlated with affectionate contact, response to infant gaze, and behaviors of high social salience. In contrast, high AVP levels correlated with joint attention to inanimate objects and to behaviors with more object salience. Furthermore, specific behaviors were shown to predict hormonal levels. Affectionate warm contact and duration of gaze synchrony predicted OT levels, emphasizing that the parent's ability to react to their infants synchronously related to OT. Predictors of AVP, on the other hand, were more related to stimulatory contact, durations of joint attention, and the parent responding to infant social gaze by increasing object salience in both mothers and fathers. These findings are supportive of those reported in previous research both in bi-parental rodents (e.g. Woller et al., 2012; Veenema, 2012) and humans (e.g. Feldman et al., 2012; Atzil et al., 2012; Gordon et al., 2010b, 2011; Skuse and Gallagher, 2011). The major novel aspects of this study, however, are the findings that OT and AVP effects are important for both fathers and mothers and to the way they sequentially segment parental behavior to direct infants to the social context or to features of the environment.

Fatherhood in itself can bring about hormonal changes in the father, particularly when fathers become increasingly involved in parenting. In the context of evolving cultural and social values that underscore father involvement in childcare (Lamb, 2010), understanding these processes in the context of the *bio-behavioral synchrony* conceptual model becomes increasingly relevant (Feldman, 2012; Feldman et al., 2012). Our results are consistent with perspectives that suggest a common neuroendocrine pathway in the development of fathering and mothering in nonhuman primate's biparental species and men (Wynne-Edwards, 2001). Whereas in the past, maternal sensitivity has been stressed as vital for infant development, sensitivity of both spouses is becoming recognized as critical for optimal growth and longitudinal studies specify the unique contributions of sensitive mothering and fathering to child social development (Feldman and Masalha, 2010; Feldman et al., 2013). Our study provides a biological justification for stressing both maternal and paternal sensitive responsiveness and show that the link between OT and AVP with the unique constellations of parenting behavior appears in both maternal and paternal play.

Research supports the important role of AVP in parenting. In humans, the lowest levels of maternal sensitivity were found among mothers who had a combination of high levels of early adversity and a variant of AVPR1A gene (Bisceglia et al., 2012). Fathers who had histories of adversity also showed hyper excretion of AVP that was related to differential activation of the amygdala, which in itself has shown to be a marker for parental attunement to the infant's emotional state (Seifritz et al., 2003). Similarly, AVP was found to be a component of prairie vole paternal care (Ross et al., 2009) and in rats, males with a higher density of V1aRs in the lateral septum are more likely to provide paternal behavior. Furthermore, AVP has the capacity to bind not only to AVP receptors but also to the OXTR, indicating that it has the potential to modulate the activity of various receptor subtypes (Kinsley and Amory-Meyer, 2011). Similar co-activation of the OT and AVP systems has recently been shown in our lab, with the administration of OT reliably increasing salivary AVP levels across the first hour after administration (Weisman et al., 2013a). However, apart from an earlier study by our group which showed a correlation between social cognitive circuits in fathers and serum AVP, the current study is the first to show a relationship between AVP and fathering in humans.

Oxytocin has been repeatedly implicated in the expression of human maternal behavior with higher OT associated with sensitive and adaptive maternal care (Feldman et al., 2010; Gordon et al., 2010a, b; Levine et al., 2007), and the current results are consistent with these studies. Our findings extend previous research by showing how OT is associated with some of the more complex elements of human parenting. In a previous study we tested differences between OT and prolactin in fathers and there is an interesting similarity in the relative contribution of OT and AVP to the OT/PRL effects on paternal behavior (Gordon et al., 2010c). Thus both AVP and PRL were associated with a specific aspect of paternal behavior not covered by OT: PRL with father facilitation of the child's exploratory behavior and OT with the father-infant affect Synchrony. In this context, AVP seems to be more associated with the cognitive-stimulatory aspects of the interaction.

It appears that early parent-child relationships take place in the context of a network of bio-behavioral experiences that shape children's affiliative biology and social behavior across

multiple attachments (Feldman et al., 2013). Future research will naturally expand our understanding of this network. It is becoming increasingly evident that complex behaviors are rarely influenced by a single locus of main effect and are subject to the influence of multiple neurohormonal systems and environmental conditions (Petronis, 2010). Possible areas for future research are the dopamine (DA) and serotonergic (5HT) system. Evidence is emerging implicating dopamine-OT interactions in the modulation of neural circuits that influence affiliative behaviors in rats (Shahrokh et al., 2010). In humans, receptor binding sites of OT and of DA tend to coexist in several brain regions that are central for the expression of parental care (Skuse and Gallagher, 2011). There is also considerable evidence for the relations between OT and the serotonin system. Animals exposed to elevated serotonin during early development have reduced OT expression and loss of OT-containing cells in the paraventricular nucleus in adulthood. This reduction is associated with reduced maternal bonding and socially explorative behaviors found in rats (McNamara et al., 2008). As such, a more comprehensive assessment of affiliative hormones within the context of multiple hormonal systems may shed further light on the neuroendocrine foundation of maternal and paternal care.

4.1. Limitations

The major limitation of the study is that it is cross sectional and thus cause-effect relationships cannot be inferred. As such, it is unclear whether the hormonal changes result from the behavioral changes or vice versa and prospective follow up studies are required to address this issue. In addition, a single study can only include a limited number of hormones. It is clear that OT and AVP do not act in a vacuum and are only part of multiple hormones and neurotransmitters which act in as a network to support parental care. As such, any linear model must necessarily be limited in its ability to explain complex human behavior such as parenting. Nonetheless, we believe that this study provides information that may lead to further programmatic hypothesis-driven research and ultimately to a better understanding of the issues involved in human bonding and parenting. Such understanding may, in turn, lead to the development of therapies to help young mothers and fathers provide the carefully-synchronous parenting their infant requires for his or her physiological, social, and emotional growth.

5. Experimental procedures

5.1. Participants

Participants were 119 parents and their infants, including 71 mothers and 48 fathers (not couples) and their 4–6 month-old infants ($M=167.4$ days, $SD=12.3$). Parents were of middle-class SES, healthy, and with at least 12 years of education. Mothers' age was, $M=28.9$, $SD=5.22$ years, and education, $M=15.17$, $SD=2.47$ years, and 81.3% were breastfeeding. Fathers' age was, $M=29.3$, $SD=4.26$ years and education, $M=15.53$, $SD=2.71$ years. Infants were born at term (birthweight: $M=3319.4$ gr. $SD=452.1$), mainly (96.3%) by vaginal

delivery, received an Apgar score of 9.40 ($SD=1.56$), and 55% were firstborns. Infants were healthy since birth, parents were screened for depression and anxiety, and all parents reported sharing childcare responsibilities. The study was approved by the Institutional Review Board and all parents signed an informed consent.

5.2. Procedure

Parents and infants arrived at the lab during the early afternoon (1–4 PM) and following an acquainting period plasma samples were collected. Following, parent and child entered an observation room with an infant-seat mounted on a table and were filmed from an adjoined room by two cameras that were integrated into single frame using a split-screen generator. Parents were asked to engage in a fifteen-minute interaction that would include any type of touch they typically use. Parents were then interviewed and completed self-report measures.

5.3. Hormone collection and analysis

Blood was drawn from the antecubital-vein of the parents into 9 mL chilled vacutainer tubes containing lithium-heparin that were supplemented with 400 KIU of Trasylol (Bayer, Leverkusen, Germany) per 1 mL blood. Samples were kept ice-chilled for up to 2 h before centrifuged at 4 °C at 1000 g for 15 min. Supernatants were collected and stored at –70 °C until assayed. Parents were asked to refrain from food intake 30-minutes before blood draw. Maternal blood was drawn at least 30 min after nursing and 30 min before nursing. Previous studies (Feldman et al., 2007, 2010b, Gordon et al., 2010a) showed no differences between plasma OT levels in breastfeeding and non-breastfeeding mothers when OT is not measured around breastfeeding. Determinations of hormones were performed using a commercial oxytocin and vasopressin enzyme-linked-immunosorbent-assay (ELISA) kit (Assay Design, Ann Arbor, Michigan) as described in ours and others' research on plasma oxytocin and vasopressin (Carter et al., 2007; Feldman et al., 2007, 2010, 2011; Weisman et al., 2013a). Measurements were performed in duplicate and the concentrations of samples were calculated by MATLAB-7 according to relevant standard curves. The intra-assay and inter-assay coefficients for oxytocin were less than 7% and 15.8%, respectively. The intra-assay and inter-assay coefficients for Vasopressin were less than 3.9% and 16.9%, respectively.

5.4. Coding of parent-infant interaction

Interactions were micro-coded on a computerized system in 01-second frame using our well-validated micro-coding scheme (Atzil et al., 2012; Feldman and Eidelman, 2004, 2007; Feldman et al., 2011; Feldman et al., 2010b), which has shown associations with multiple parental hormones and patterns of brain activations. Four categories of parent and infant's behavior were: Gaze, Affect, Vocalization, and Touch, each containing a set of mutually-exclusive codes. Codes included: *Gaze*: social gaze to partner, gaze to object (parent or child looking at object other than the focus of the partner's gaze), joint attention (parent and child looking at same object), gaze aversion. *Affect*: parent – positive, neutral,

negative-withdrawn, negative-angry; infant- positive neutral, fuss-cry. *Vocalizations*: parent – “motherese” high-pitched vocalizations, adult speech, none; infant – positive vocalizations, fuss-cry, none. *Touch*: parent: affectionate, cradle, functional, stimulatory, proprioceptive, parent stands child on his/her knees and moves infant around, touch with object, and none; infant: intentional, accidental, none. Inter-rater reliability was computed for 15 interactions and reliability *kappas* averaged .84 (range=.76-.93).

The following variables were used in the current study as sum proportions:

Affectionate contact – was the sum proportions of parent affectionate touch and cradle. *Stimulatory contact* – was the sum proportions of stimulatory, proprioceptive, child on knees, and touch-with-object.

The following “synchrony” variables were used as conditional probabilities that index the co-occurrence of social behavior bin parent and infant and were computed as mean durations.

Joint attention – parent and child are attending to the same object. *Gaze synchrony* – parent and child are simultaneously engaged in social gaze (parent gaze at infant while infant gaze at parent).

The following variables were computed by lag-sequential analysis and index the frequencies in which a specific parent behavior follows the infant's social gaze to the parent as the behavior that signals infant initiation of social bid (i.e., infant gaze to parent then parent in behavior Y). *Infant gaze at parent-parent increase social salience* – number of times parent responds by social gaze, “motherese” vocalization, or positive affect to infant social gaze. *Infant gaze at parent-parent increase object salience* – number of times parent responds by gaze at object or joint attention to infant social gaze. *Infant gaze at parent-parent affectionate touch* – number of times parent responds by affectionate touch to infant social gaze. *Infant social gaze – parent stimulatory touch* – number of times parents responds by stimulatory touch to infant social gaze.

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