Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

Research Report

Oxytocin and vasopressin support distinct configurations of social synchrony

*Yael Apter-Levi, Orna Zagoory-Sharon, Ruth Feldman**

Department of Psychology, Gonda Brain Sciences Center, Bar-Ilan University, Ramat-Gan 52900, Israel

ARTICLE INFO

Article history:
Accepted 27 October 2013
Available online 1 November 2013

Keywords:
Oxyctocin
Vasopressin
Parenting
Synchrony
Social behavior

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.

This article is part of a Special Issue entitled Oxytocin and Social Behav.

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

*Corresponding author. Fax: +972 3 535 0267.
E-mail address: feldman@mail.biu.ac.il (R. Feldman).

0006-8993/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.brainres.2013.10.052

observed in hormonal systems (Feldman, 2012). These neurohormonal 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