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Witte, A.M.; de Moor, M.H.M.; Majdandžić, M.; Verhees, M.W.F.T.; van IJzendoorn, M.H.; Bakermans-Kranenburg, M.J.

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Effects of oxytocin and vasopressin administration on human fathers' sensitive and challenging parenting: A randomized within-subject controlled trial

Annemieke M. Witte [a,*], Marleen H.M. de Moor [a], Mirjana Majdandžić [b], Martine W.F.T. Verhees [c], Marinus H. van IJzendoorn [d,e], Marian J. Bakermans-Kranenburg [a,f]

[a] Clinical Child & Family Studies, Faculty of Behavioral and Movement Sciences, Vrije Universiteit, Amsterdam, the Netherlands
[b] Research Institute of Child Development and Education, University of Amsterdam, Amsterdam, the Netherlands
[c] Quantitative Psychology and Individual Differences, KU Leuven, Leuven, Belgium
[d] Department of Psychology, Education, and Child Studies, Erasmus University Rotterdam, Rotterdam, the Netherlands
[e] Research Department of Clinical, Education and Health Psychology, Faculty of Brain Sciences, UCL, London, UK
[f] Leiden Institute for Brain and Cognition, Leiden University Medical Center, Leiden, the Netherlands

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ABSTRACT

This randomized, double-blind, placebo-controlled within-subject study examined the effects of intranasal administration of oxytocin and vasopressin on fathers' sensitive and challenging parenting behaviors. Furthermore, we examined the moderating role of fathers' early childhood experiences. The sample consisted of 70 fathers with their 2- to 12-month-old infants. All fathers were assigned to each of the three experimental sessions (oxytocin, vasopressin, and placebo), on three separate days, with random order and intervening periods of one to two weeks. Sensitive and challenging parenting behaviors (CPB) were observed during a 10-minute free play task. Results showed no effects of vasopressin administration on paternal sensitivity. Fathers in the oxytocin condition were less sensitive than fathers in the placebo condition, and this effect was moderated by fathers' own childhood experiences: Fathers who reported higher levels of experienced parental love withdrawal were less sensitive in the oxytocin condition as compared to the placebo condition, whereas fathers with less experienced parental love withdrawal showed no difference in sensitivity between the oxytocin and placebo condition. No effects were found of oxytocin and vasopressin administration on fathers' CPB. Our results, although partly unexpected, are largely in line with previous literature showing that oxytocin administration can exert negative effects in individuals with adverse childhood experiences.

1. Introduction

Several studies have identified oxytocin and vasopressin as key hormones implicated in parenting behavior (Apter-Levi et al., 2014; Lonstein et al., 2015; Rilling, 2013). Whereas most studies have devoted attention to the hormonal underpinnings of maternal behavior, there is an increasing body of research pointing to the involvement of hormones in fathering behaviors (Feldman and Bakermans-Kranenburg, 2017; Grumi et al., 2021). However, many of these studies are correlational in nature, and only a few experimental studies have examined the effects of intranasal administration of oxytocin (Naber et al., 2010; Naber et al., 2013; Weisman et al., 2012) and vasopressin (Li et al., 2017) on fathering behaviors in the postnatal period. To gain more insight into the hormonal underpinnings of paternal behavior, we conducted a randomized double-blind, placebo-controlled within-subject experiment to study the effects of intranasal administration of oxytocin and vasopressin on fathers' sensitive and challenging parenting behaviors in the first year of fatherhood.

Sensitive parenting behavior refers to the ability to correctly perceive and interpret infant signals and to respond to these signals in an appropriate and prompt manner (Ainsworth et al., 1974). Sensitive parents provide a secure base from which infants can explore their physical and social environment (Bowlby, 1973). Paternal sensitivity is positively associated with children's cognitive development and emotion regulation (Rodrigues et al., 2021). Moreover, sensitive parenting predicts infant attachment security to mothers (De Wolff and

* Corresponding author:
E-mail address: a.m.witte@vu.nl (A.M. Witte).

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van IJzendoorn, 1997) and fathers (Lucassen et al., 2011). Challenging parenting behavior (CPB; Majdandžić et al., 2016) is defined as the extent to which parents physically and verbally encourage the child to push their limits, or to engage in behaviors outside their comfort zone (Majdandžić et al., 2016). CPB includes physical components (e.g., rough-and-tumble play or letting the infant 'fly') as well as verbal/socio-emotionally components (e.g., encouragements to do something difficult, or excitement-inducing sounds). CPB is an important aspect of father's parenting behaviors, possibly because CPB promotes exploration as well as physical and social risk-taking, which is considered an important dimension of the father-child relationship (Bögels and Phares, 2008; Feldman and Shaw, 2021; Paquette, 2004). Moreover, paternal CPB has been associated with less anxiety in infancy and early childhood (Majdandžić et al., 2018; Möller et al., 2015). No associations were found between paternal CPB and paternal self-reported warmth at 4 months postpartum, however, small to moderate associations were present when the children were 1 year and 2.5 years old (Majdandžić et al., 2016). In sum, sensitive and challenging behaviors are important dimensions of parenting. Yet, few studies have examined how fathers' sensitive and challenging behaviors are affected by oxytocin and vasopressin levels.

Previous literature showed that oxytocin and vasopressin levels are related both to different and similar parenting behaviors in mothers versus fathers. For instance, a correlational study, including mothers and fathers (not couples) and their 4- to 6-month-old infants, showed that maternal plasma and salivary baseline oxytocin levels were positively associated with affectionate touch, whereas paternal plasma and salivary baseline oxytocin levels were positively associated with stimulatory touch (Feldman et al., 2010). Furthermore, mothers who engaged in high levels of affectionate touch and fathers who engaged in high levels of stimulatory touch showed an increase in oxytocin levels from pre- to post- parent-infant contact (Feldman et al., 2010). In addition, fathers with higher oxytocin levels showed more affect synchrony with their 6-month old child during play (Gordon et al., 2010). Moreover, mothers and fathers with higher oxytocin levels exhibited more sensitive parenting behaviors towards their 4- to 6-month old infants, including increased responsiveness to infant social cues (Apter-Levi et al., 2014). However, it should be noted that these previous described studies were all from the same laboratory (see Grumi et al., 2021). A study from a different laboratory found that fathers who engaged in higher levels of playful touch (e.g., throwing the infant in the air) during a free play interaction with their 6-month old infant showed higher post-free play oxytocin levels (Morris et al., 2021). Other research reported no association between paternal oxytocin levels and the quality of father-toddler interactions (Miura et al., 2015).

Experimental studies showed that fathers who received intranasal administration of oxytocin showed more sensitive structuring (i.e., supporting exploration and autonomy) and less hostility during play with their child (age range 1.5 to 6 years) as compared to the placebo condition (Naber et al., 2010; Naber et al., 2013). Moreover, after receiving intranasal oxytocin administration, fathers engaged in more positive parenting behaviors during interactions with their 5-month-old infant, including longer episodes of touch and social reciprocity as compared to the placebo condition (Weisman et al., 2012). These findings indicate that intranasal administration of oxytocin affect specific paternal behaviors. Yet, the effects of oxytocin adminsitration on fathers' sensitive and challenging behaviors have not yet been examined in an experimental setting with fathers in the early postnatal period.

Vasopressin is structurally similar to oxytocin and differs by only two amino acids (Insel, 2010). In marmosets, fatherhood is associated with higher vasopressin receptor density in the prefrontal cortex (Kozorovitskiy et al., 2006), and injections of vasopressin into the lateral septum facilitate caregiving behavior in male prairie voles (Wang et al., 1994). There is also evidence for a potential role for vasopressin in promoting human fathering behaviors. For instance, parents with higher vasopressin levels showed more object focused play and engaged in more stimulatory contact with their 4- to 6-month-old infant (Apter-Levi et al., 2014). Moreover, after administration of intranasal vasopressin, expectant fathers (compared to non-expectant men) spend more time looking at baby-related avatars (Cohen-Bendahan et al., 2015). On a neural level, administration of vasopressin increased neural activation in response to infant cry sounds accompanied by emotional (versus neutral) contextual information (Thijssen et al., 2018). In a different sample, administration of vasopressin had no effects on neural responses to infant cry sounds in fathers in the postnatal period (Li et al., 2017). In the same sample as Thijssen et al. (2018), expectant fathers used more handgrip force after vasopressin administration (as compared to placebo) in reaction to viewing an image of an unknown infant versus viewing an image of their own infant, possibly indicating that vasopressin administration reduces empathy for an unknown crying infant (Alyousefi-van Dijk et al., 2019). How intranasal administration of vasopressin affects father-infant interactions in the early postnatal phase of fatherhood remains to be investigated.

An important factor to consider when examining the effects of oxytocin and vasopressin administration on paternal behaviors is individual differences in fathers' own early caregiving experiences. Meta-analytic evidence showed that individuals who grew up in positive family environments are more susceptible to the prosocial effects of oxytocin administration while individuals with negative family environments are more likely to not show a prosocial response after oxytocin administration, or to display a negative response (Ellis et al., 2021). Early caregiving experiences may alter oxytocinergic functioning, which may help individuals growing up in negative family environments to adapt to a harsh and unpredictable future, whereas the oxytocinergic system of individuals growing up in a positive family may become adapted to stable and predictable environments (Ellis et al., 2021). A previous study found that the effects of intranasal vasopressin administration on neural responses to infant cry sounds were stronger in expectant fathers from a more supportive (relative to less supportive) familial background (Thijssen et al., 2018), whereas another study found that fathers' early life experiences did not moderate the effects of intranasal vasopressin administration on neural responses to infant cry sounds (Li et al., 2017). In another study, administration of intranasal vasopressin increased empathic concern among a sample of students, but only among students who reported higher levels of paternal warmth (Tabak et al., 2015). Although cautiously, because neural findings have been mixed, available evidence suggests that fathers' own early caregiving experiences moderate the effects of oxytocin and vasopressin administration on fathering behaviors.

In sum, the aim of the present study was to investigate the effects of intranasal administration of oxytocin and vasopressin on fathers' observed sensitive and challenging parenting behaviors in the first year of fatherhood. We also examined whether behavioral effects are moderated by fathers' own early caregiving experiences. In line with correlational results (Apter-Levi et al., 2014; Feldman et al., 2010; but see also Grumi et al., 2021) and experimental findings (Naber et al., 2010; Naber et al., 2013; Weisman et al., 2012), we hypothesized that fathers show more sensitive and challenging parenting behaviors in the oxytocin and vasopressin condition than in the placebo condition. Moreover, based on theories and findings indicating that individuals with more positive childhood experiences are more susceptible to the prosocial effects of oxytocin and vasopressin administration than individuals with more negative childhood experiences (Ellis et al., 2021; Tabak et al., 2015; Thijssen et al., 2018), we hypothesized that behavioral effects of oxytocin and vasopressin administration would be stronger in fathers reporting more positive (relative to more negative) early caregiving experiences.

2. Method

2.1. Sample

The study was registered in the Dutch Trial Register (ID: NL8124), and the study protocol was published prior to the start of the data collection (Witte et al., 2019). The sample consisted of 70 first-time fathers with a healthy single-born infant. Fathers were recruited through an information letter sent by the municipality of Amsterdam. Fathers who were interested in participation received an additional information letter with a detailed description of the study procedures. To be eligible for participation, fathers had to meet the following inclusion criteria: fluent in speaking and writing Dutch and living in the same house as the infant and the mother. Both parents needed to have parental authority and infants had to be healthy and born full-term (i.e., born after 37 weeks of gestation). Exclusion criteria for fathers were: neurological disorders, endocrine diseases, psychiatric disorders, cardiovascular diseases, use of psychoactive medications, nose injuries and disorders, magnetic resonance imaging contraindications (relevant for other research questions), regular use of soft drugs, hard drug use within the past three months, or excessive alcohol intake. Fathers were on average 35.56 years old (SD = 4.60, range 22–49). Most fathers were born in the Netherlands (99%) and father's educational level was fairly high; 67% had a university master's degree, 24% had a university bachelor's degree, and 9% had completed secondary vocational education. Infants (46% girls) were between 2 and 12 months old (M = 6.70, SD = 2.16). Prior to participation, both parents signed an informed consent. Fathers received a financial compensation for their participation after each research visit (to a maximum of €130), travel expenses were covered, and the infant received an age appropriate gift after the final research visit. The study was approved by the Ethics Committees of the Leiden University Medical Centre and was carried out in accordance with national legislation and The Code of Ethics of the World Medical Association (Declaration of Helsinki). See Fig. S1 for a CONSORT flow diagram of the study.

2.2. Procedure

Participants were randomized to each of the three experimental conditions (oxytocin, vasopressin, and placebo) on three separate days in counterbalanced order, with intervening periods of one to two weeks. Thus, fathers participated once in the oxytocin condition, once in the vasopressin condition and once in the placebo condition. Mean number of days between the first and second research visit was 10.18 (SD = 10.36). Mean number of days between the second and third research visit was 11.11 (SD = 9.50). Given the study entails hormonal measures, we tried to schedule individual research visits at the same time of day (46%) or within in a 2-hour time difference from each other (28%). Due to scheduling difficulties, 26% of the participants had research visits that deviated more than 2 h from another research visit.

An independent researcher conducted randomization of administration prior to the start of the study using a computer-generated randomization sequence, and communicated the randomization results to the pharmacy. The pharmacy prepared the nasal sprays and omitted all information that could identify condition assignment. Participants, researchers, and coders were blind to condition assignment. Participants were instructed to not consume caffeine on the day of the research visit, and to not smoke, chew gum, eat or drink (except water) 30 min before the start of the research visit, and to abstain from alcohol intake and excessive physical exercise during the 24 h preceding the research visit.

Upon arrival, baseline saliva samples of oxytocin and vasopressin were collected using a cotton swab (Salivettes, Sarstedt). Subsequently, participants self-administered a nasal spray containing either oxytocin (Syntocinon®, 24 IU, registered in the Netherlands as RVG 03716), vasopressin (Vasostrict®, 20 IU), or a placebo (see supplemental materials for more details). Comparable doses of oxytocin and vasopressin have been previously used in studies examining the effects of oxytocin and vasopressin on behavioral outcomes (e.g., Naber et al., 2010; Naber et al., 2013; Tabak et al., 2015). Following intranasal administration, a 40-minute waiting period was included, which is in line with previous research showing that plasma oxytocin levels were elevated 30–40 min after intranasal oxytocin administration of similar doses (Burri et al., 2008; Gossen et al., 2012), and previous recommendations to start sampling data 40–45 min after intranasal administration of oxytocin 24 IU (Born et al., 2002). For vasopressin, a 40-minute waiting period is consistent with previous studies assessing the effects of vasopressin administration 20 IU (Rilling et al., 2012; Thompson et al., 2004).

During the 40-minute waiting period, fathers completed several questionnaires and received verbal instructions about further study procedures. Thereafter, fathers engaged in a 10-minute free play task with their infant. The free play was videotaped for coding purposes. No toys were provided during the first 5 min of play ("free play *without* toys"). After 5 min, a researcher handed the father a bag of toys ("free play *with* toys"). Fathers were instructed to play with their infant as they would normally do. Immediately after the free play, participants provided another saliva sample to measure oxytocin and vasopressin levels. After the first research visit, fathers completed several online questionnaires at home. After completion of each research visit, participants guessed their assignment of condition. Participants were allowed to guess the same condition more than once. A guess was considered correct when it was both specific and selective. Thus, we considered a guess correct when the participant guessed the condition correct and did not guess this specific condition also for another research visit. Fathers did not guess above chance level the correct assignment to the oxytocin (n = 13, p = .38) or vasopressin (n = 14, p = .22) conditions. However, participants did guess the correct assignment to the placebo condition above chance level (n = 18, p = .01). We also examined the proportion of correct guesses for each research visit. Binomial tests showed that participants did not guess above chance level the correct condition assignment at research visit 1 (p = .41), neither at research visit 2 (p = .38), nor at session 3 (p = .31). These findings indicate no learning process of hormonal administration.

2.3. Measures

2.3.1. Paternal sensitivity

Parental sensitivity during the free play task was coded using the Ainsworth scales for Sensitivity and Cooperation (Ainsworth et al., 1974). Coding of sensitivity involved the entire free play task, including 5 min without toys and 5 min with toys. The Sensitivity scale assesses the caregiver's ability to accurately perceive and interpret infant signals and to respond to them appropriately and promptly. The Cooperation scale assesses the extent to which the caregiver shows physical cooperation and absence of interference with the infant's activity. Coders gave an overall score for the 10-minute interaction and scores ranged from 1 = highly insensitive or highly interfering to 9 = highly sensitive or highly cooperative. Examples of highly sensitive behaviors are noticing infant signals accurately (e.g., over-excitement), responding to them appropriately (e.g., decreasing the intensity of the interaction), and engaging in smooth and complete interaction patterns (Ainsworth et al., 1974). Examples of highly insensitive behaviors are inappropriate, fragmented or incomplete responses, and lacking understanding, empathy or ignoring infant signals (e.g., not picking the infant up when the infant stretches out his arms) (Ainsworth et al., 1974).

Examples of highly cooperative behaviors are showing respect for the infant's autonomy and following the infant's activities (e.g., the infant plays with a toy and the parent involves himself in the play) instead of interrupting or controlling the infant's activities. Indicators of highly interfering behaviors are not respecting the infant's wishes, mood or ongoing activities, or imposing physical force (e.g., forcefully taking away a toy from the infant's hands in order to show how it should be used) in situations in which a cooperative approach is appropriate.

Three coders were extensively trained by the last author (expert coder). The four coders, blind to the experimental condition, coded the videotaped interactions for paternal sensitivity and cooperation. Each coder coded no more than one research visit from the same participant. The average Intraclass Correlation Coefficient (ICC) (single measures, absolute agreement) between the expert coder and trained observers was 0.75 for sensitivity and 0.78 for cooperation. Observers coding paternal sensitivity were not involved in the coding of challenging parenting behavior CPB. The sensitivity and cooperation scales were strongly correlated across research visits and experimental conditions (range r = 0.59–0.83, $p < .001$). Therefore, for each research visit, scores on the sensitivity and cooperation scales were averaged into an overall score indicating paternal sensitivity.

2.3.2. Challenging parenting behavior

The free play task was also coded for challenging parenting behavior (CPB; see Majdandžić et al., 2016 for a detailed description of the coding system). Coding was done in 1 min-intervals and scores ranged from 1 = low frequency and/or intensity of CPB to 5 = high frequency and/or intensity of CPB (see also Mahoney et al., 1998 for the rating method). Separate scores were assigned for (1) *physical* CPB during free play *without* toys, (2) *verbal* CPB during free play *without* toys, (3) *physical* CPB during free play *with* toys, and (4) *verbal* CPB during free play *with* toys. For each CPB measure, scores for the 1-min intervals were averaged. Lower CPB scores are given when the father shows no physical/verbal stimulation (score = 1) or when, e.g., the father gently moves the infant's feet around or says "whoeee" in a quiet tone of voice or (score = 2). Examples of moderate scores (i.e., 3) are tickling the infant with moderate intensity/verbal encouragements with moderate intensity (e.g., "1, 2, 3… are you ready?"). Examples of higher CPB score are letting the infant fly through the air/verbally challenging the infant to practice a difficult physical skill (e.g., "yes, there you go, sit up") (score = 4). Indicators of high CPB scores are throwing the infant wildly in the air/verbally challenging the infant to push their limits (e.g., "yes, show me that you can roll over to the other side!") (score = 5) (Majdandžić et al., 2016). Age of the infant was taken into account, so that behaviors such as putting an infant into a sitting position was coded as CPB when the infant was 4 months old but not when the infant was 9 months old. Five coders were extensively trained by the first author who was previously trained and supervised by the expert coder (second author). The average ICC (single measures, absolute agreement) between the first author and trained observers was 0.66 for physical CPB *without* toys, 0.81 for verbal CPB *without* toys, 0.70 for physical CPB *with* toys, and 0.83 for verbal CPB *with* toys. Coders were blind to the experimental condition and coded no more than one research visit from the same participant for CPB. Observers coding CPB were not involved in the coding of paternal sensitivity.

Based on strong correlations across research visits and experimental conditions between physical and verbal CPB *without* toys (range r = 0.50–0.69, $p < .001$) and physical and verbal CPB *with* toys (range r = 0.66–0.73, $p < .001$), we computed composite scores for CPB *without* toys and CPB *with* toys by averaging scores on the physical and verbal scales. A principal component analysis (PCA) identified two factors (CPB *without* toys and CPB *with* toys) which explained 82% of the total variance, supporting the creation of composite scores for CPB *without* toys and CPB *with* toys.

2.3.3. Experienced parental harsh discipline

Fathers completed at home the Conflict Tactics Scale – Parent Child (CTS; Straus et al., 1998), which measures experiences of harsh discipline. A total of 18 items from the subscales Psychological aggression, Minor physical assault, Severe physical assault, and Neglect were included. Items (e.g., "My mother or father said she/he would send me away or kick me out of the house") were scored on a 7-point rating scale (0 = 'never', 1 = 'once', 2 = 'twice', 3 = '3–5 times', 4 = '6–10 times', 5 = '11–20 times', 6 = 'more than 20 times'). Similar to Thijssen et al. (2018) and Alyousefi-van Dijk et al. (2019), we calculated a CTS total score using the following procedure. First, we calculated a Physical assault score by averaging scores on the Minor and Severe physical assault scales. Second, we calculated an Abuse score by averaging scores on the Psychological aggression and Physical assault scales. A CTS total score (M = 0.64, SD = 0.57) was computed by averaging scores on the Abuse and Neglect scales. Internal consistency of the items comprising the CTS total score was high (α = 0.81).

2.3.4. Experienced parental love withdrawal

Fathers also completed at home seven items from the Withdrawal of Relations subscale of the Children's Report of Parental Behavior Inventory (CRPBI, Beyers and Goossens, 2003; Schludermann and Schludermann, 1983). Four items from the Parental Discipline Questionnaire (PDQ; (Patrick and Gibbs, 2007) and see (Huffmeijer et al., 2011) were added to obtain a more comprehensive measure of experienced parental love withdrawal. Parental love withdrawal involves withholding love and affection when a child disobeys or fails to meet parental expectations (Van IJzendoorn et al., 2011). Parental love withdrawal is a component of insensitive caregiving, which is suggested to predict insecure infant-parent attachment (Bowlby, 1973). Participants indicated whether the items were representative of their mother and father (e.g., "My mother was a person who, when I disappointed her, told me how sad I made her") on a 5-point rating scale ranging from 1 (not at all) to 5 (very well). Maternal and paternal love withdrawal scores were correlated (r = 0.58, $p < .001$). A total parental love withdrawal score (M = 1.66, SD = 0.60) was computed by averaging maternal and paternal scores. Internal consistency of the items comprising the parental love withdrawal total score was excellent (α =0.91). The parental love withdrawal total score was moderately correlated with the CTS total score (r = 0.39, $p < .001$).

2.3.5. Oxytocin and vasopressin levels

For baseline levels and manipulation checks, saliva samples were collected before nasal administration and on average 60 min (SD = 4.00, range 47–71) after nasal administration. Participants were instructed to softly chew on the cotton swab for 60 s and to move the cotton swab around in their mouth to stimulate saliva collection. Oxytocin and vasopressin levels were analyzed at RIAgnosis (Sinzing, Germany), and were quantified using radioimmunoassay. Salivettes were centrifuged at 4 degrees Celsius for 30 min with ca. 5000 *g* centrifugal force. Subsequently, 0.3 ml of saliva for the analysis of oxytocin and 0.3 ml saliva for the analysis of vasopressin was pipetted into a vial. The detection limit for oxytocin and vasopressin was 0.1 pg/ml. Inter-assay and intra-assay variability was <10%. Oxytocin and vasopressin levels are reported in pg/ml. Paired sample *t*-tests indicated a significant increase in oxytocin levels (but not vasopressin levels) following intranasal administration of oxytocin ($p < .001$) (see Supplementary Table 1). Furthermore, results indicated a significant increase in vasopressin levels (but not oxytocin levels) following intranasal administration of vasopressin ($p < .001$). Intranasal administration of placebo did not result in a significant increase in oxytocin or vasopressin levels. These findings thus suggest that hormonal manipulation was effective. It is unclear to what extent the increase in oxytocin and vasopressin levels can be explained by the dripping back of nasal fluids. Yet, prior evidence showed that salivary oxytocin levels remained elevated for more than 7 h after intranasal administration of 16 IU as well as 24 IU oxytocin (Van IJzendoorn et al., 2012). As such, it is unlikely that increases in salivary oxytocin levels only result from the dripping back of nasal fluids.

2.4. Data analytic strategy

We performed Linear Mixed Models (LMM) with restricted maximum likelihood (REML) as the estimator in IBM SPSS Statistics version 26. An advantage of LMM is that all available data points are included in the analyses (Hesser, 2015). First, separate LMMs for each dependent

variable were fitted to examine the effects of condition on paternal sensitivity, paternal CPB *without* toys and paternal CPB *with* toys, respectively. Next, we tested whether experienced harsh discipline (CTS) and parental love withdrawal (CRPBI) moderated potential effects of oxytocin and vasopressin administration on paternal sensitivity and CPB *without* toys and CPB *with* toys. For the moderation analyses, we fitted an LMM and included condition as within-subject factor (oxytocin, vasopressin, placebo), experienced harsh discipline (mean centered) and experienced parental love withdrawal (mean centered) as between-subject factors and added the interaction terms between condition × experienced harsh discipline (mean centered) and condition × experienced parental love withdrawal (mean centered) to the model. We ran similar LMMs with standardized instead of mean centered dependent and moderator variables to obtain the standardized estimates of the models, which are presented in text and the unstandardized estimates are presented in the tables. A priori computed power analysis indicated that we had sufficient power (>80%) to detect medium effects of condition (see our study protocol, Witte et al., 2019).

We had to temporarily stop data collection due to the COVID-19 outbreak, resulting in missing data on the second ($n = 6$), or second and third ($n = 3$) research visit. A small number of participants dropped out of the study after the first research visit (drop out not COVID-19 related), resulting in missing data on the second and third research visit ($n = 4$). In total, 57 fathers completed all three research visits. One participant had missing data on the verbal scales of CPB, due to speaking a different language with his infant. For this participant, only scores on the physical CPB scales were included. For one participant, recording stopped prematurely and CPB *with* toys was not recorded. Due to technical problems, three videos could not be coded for CPB and paternal sensitivity. Four participants did not complete the questionnaires, resulting in missing data on experienced harsh discipline (CTS) and parental love withdrawal (CRPBI). In total 11.5% of the data was missing across the variables of interest (range 0%–14.3%). Missing value analysis showed that Little MCAR (Little, 1988) was not significant, $\chi 2(112) = 126.19$, $p = .17$, indicating that data were missing completely at random. Missing data were handled using restricted maximum likelihood (REML) as the estimator.

3. Results

3.1. Descriptive statistics

Descriptive analyses were performed to examine variable distributions and to identify potential outliers. All variables approached normality. Inspection of boxplots with corresponding *z*-values indicated no outliers (defined as *z*-values >3.29 or <−3.29). Table 1 shows the means and correlations between all study variables for each experimental condition. LMMs indicated no effect of visit period (prior to COVID-19 lockdown compared to during the COVID-19 lockdown) on CPB *without toys* or CPB *with* toys. There was however an effect of visit period on paternal sensitivity, indicating that fathers visiting prior to COVID-19 lockdown ($M = 4.64$, $SD = 1.81$) were less sensitive compared to fathers visiting during COVID-19 lockdown ($M = 5.30$, $SD = 1.26$), $t(65) = -2.26$, B = −0.71, SE = 0.32, $p = .027$.

Correlations were examined between background characteristics (age of infant, age of father, gender infant) and the dependent variables (paternal sensitivity, CPB *without* toys, and CPB *with* toys). Age of infant was significantly correlated to CPB *without* toys ($r = 0.30$, $p = .002$, adjusted for repeated measures), indicating that fathers engaged in more CPB during play without toys when children were older. No significant correlations were found between the other background characteristics and the dependent variables. LMMs were used to examine the effects of number of lab session (1,2,3) on paternal sensitivity, CPB *without* toys and CPB *with* toys. No significant effects were found.

Table 1
Means and correlations between the study variables in the oxytocin, vasopressin and placebo condition.

		N (%)	*M* (*SD*)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Condition																
OXT	1. CPB without toys	62	2.85 (0.64)													
	2. CPB with toys	62	2.17 (0.57)	0.18												
	3. Paternal sensitivity	62	4.92 (1.44)	**−0.31***	−0.03											
AVP	4. CPB without toys	61	2.71 (0.70)	**0.34***	0.20	−0.12										
	5. CPB with toys	60	2.06 (0.60)	0.16	**0.47****	−0.10	**0.44****									
	6. Paternal sensitivity	61	5.23 (1.35)	−0.06	0.10	0.22	−0.12	−0.05								
PLC	7. CPB without toys	61	2.78 (0.62)	**0.46****	0.18	−0.21	**0.37****	0.13	−0.09							
	8. CPB with toys	61	2.10 (0.53)	−0.08	**0.35****	−0.20	0.22	**0.49****	−0.16	0.23						
	9. Paternal sensitivity	60	5.27 (1.52)	−0.25	−0.07	**0.44****	−0.14	0.04	**0.51****	−0.16	−0.04					
	10. Experienced parental harsh discipline	66	1.66 (0.60)	0.02	0.03	0.11	0.05	−0.08	−0.05	0.17	−0.16	−0.08				
	11. Experienced parental love withdrawal	66	0.64 (0.57)	**−0.27***	−0.04	−0.08	−0.02	0.15	−0.11	−0.14	0.00	0.08	**0.39****			
	12. Age infant	70	6.70 (2.16)	0.23	−0.07	−0.01	0.16	−0.05	0.00	0.25	0.03	−0.04	0.21	−0.12		
	13. Age father	70	35.56 (4.60)	−0.06	0.05	−0.07	−0.04	0.02	−0.07	0.13	−0.05	0.05	0.04	0.10	0.20	
	14. Infant sex	70		0.09	0.10	−0.06	0.25	0.06	−0.03	0.08	−0.12	−0.14	0.09	−0.07	0.13	0.13
	Girls	32 (46%)														
	Boy	38 (54%)														

Note. OXT = oxytocin; AVP = vasopressin; PLC = placebo. Range of the CPB scales 1–5, range of paternal sensitivity 1–9.
** $p < .001$.
* $p < .05$.

3.1.1. Effects of oxytocin and vasopressin administration on paternal sensitivity

LMM analyses showed a significant main effect of oxytocin administration on paternal sensitivity, $t(104) = -2.10$, $\beta = -0.28$, $p = .038$, indicating that fathers were less sensitive in the oxytocin condition than in the placebo condition (see Table 2). Results remained significant after controlling for timing of observation, $t(105) = -2.14$, $\beta = -0.28$, $p = .035$ (before COVID-19 pandemic or during COVID-19 pandemic). Moreover, the effect of oxytocin administration on paternal sensitivity remained significant when including only those fathers who completed all three research visits, $t(95) = -2.25$, $\beta = -0.31$, $p = .026$. There was no significant main effect of vasopressin administration on paternal sensitivity, $t(95) = 0.49$, $\beta = 0.06$, $p = .628$.

3.1.2. Early childhood experiences as a moderator of the effects of hormonal administration on paternal sensitivity

The LMM for paternal sensitivity with interaction terms condition × experienced harsh discipline and condition × experienced parental love withdrawal indicated that effects of oxytocin administration on paternal sensitivity were not moderated by experienced harsh discipline, $t(104) = 1.70$, $\beta = 0.29$, $p = .092$. There was however a significant interaction effect of oxytocin × experienced parental love withdrawal, $t(94) = -2.03$, $\beta = -0.31$, $p = .045$ (see Table 2 and Fig. 1). Fathers with higher levels of experienced parental love withdrawal were less sensitive in the oxytocin condition compared to the placebo condition, whereas fathers with lower levels of experienced parental love withdrawal showed similar levels of paternal sensitivity in the oxytocin and placebo condition. The interaction effect (oxytocin × experienced parental love withdrawal) remained significant after controlling for timing of observation (before COVID-19 pandemic or during COVID-19 pandemic), $t(94) = -2.06$, $\beta = -0.31$, $p = .042$. Furthermore, the interaction effect remained significant when including only those fathers who completed all three research visits, $t(89) = -0.33$, $\beta = -0.56$, $p = .032$. Effects of vasopressin administration on paternal sensitivity were not moderated by experienced harsh discipline, $t(115) = 0.73$, $\beta = 0.12$, $p = .467$, neither by experienced parental love withdrawal, $t(111) = -1.54$, $\beta = -0.24$, $p = .127$.

3.1.3. Effects of oxytocin and vasopressin administration on paternal CPB

No significant main effects were found of oxytocin administration ($t(95) = 0.95$, $\beta = 0.12$, $p = .347$) and vasopressin administration ($t(98) = -1.03$, $\beta = -0.14$, $p = .305$) on CPB *without* toys (see Table 3). Inclusion of age of infant as a covariate did not alter the results for CPB *without* toys. Similarly, no significant main effects were found for oxytocin administration ($t(110) = 0.89$, $\beta = 0.12$, $p = .374$) and vasopressin administration ($t(96) = -0.30$, $\beta = -0.04$, $p = .766$) on CPB *with* toys (see Table 4).

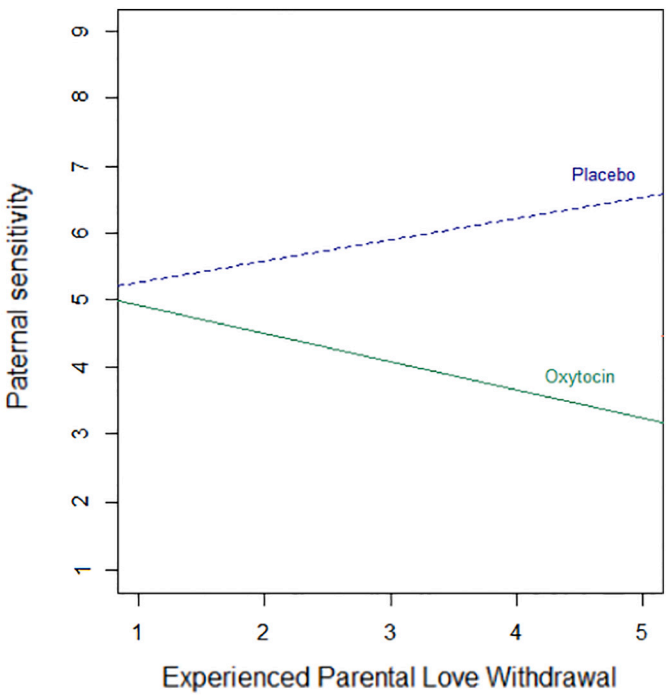

Fig. 1. Experiences of parental love withdrawal moderating the effects of oxytocin administration on paternal sensitivity.
Note. Figure displays the unstandardized moderation effects for experienced parental love withdrawal. Mean experienced parental love withdrawal = 1.66 ($SD = 0.60$). Fathers with higher levels of experienced parental love withdrawal were less sensitive in the oxytocin condition compared to the placebo condition, whereas fathers with lower levels of experienced parental love withdrawal showed similar levels of paternal sensitivity in the oxytocin and placebo condition.

3.1.4. Moderating effects of early childhood experiences on the relation between hormonal administration and paternal CPB

The effect of oxytocin administration on CPB *without* toys was not moderated by experienced harsh discipline ($t(92) = -0.41$, $\beta = -0.07$, $p = .680$), nor by experienced parental love withdrawal ($t(78) = -0.90$, $\beta = -0.13$, $p = .371$). Similarly, the effect of vasopressin administration on CPB *without* toys was not moderated by experienced harsh discipline ($t(104) = -1.81$, $\beta = -0.30$, $p = .073$), nor by experienced parental love withdrawal ($t(105) = 0.81$, $\beta = 0.12$, $p = .423$). For CPB *with* toys, also no moderating effects of experienced harsh discipline ($t(108) = 1.59$, $\beta = 0.27$, $p = .115$) or experienced parental love withdrawal ($t(104) = -0.96$, $\beta = -0.15$, $p = .339$) on the effect of oxytocin administration were found. Neither did experienced harsh discipline ($t(118) = -0.40$, $\beta = 0.07$, $p = .690$) or experienced parental love withdrawal ($t(104) =$

Table 2
Main effects of oxytocin and vasopressin administration on paternal sensitivity (Model 1) and moderation effects of fathers' early childhood experiences (Model 2).[a]

	Paternal sensitivity									
	Model 1					Model 2				
	B (SE)	df	*t*	*p*	95% CI	B (SE)	df	*t*	*p*	95% CI
Intercept	5.26 (0.18)	130	28.94	<0.001	[4.90, 5.62]	5.26 (0.18)	129	29.47	<0.001	[4.91, 5.62]
OXT	−0.40 (0.19)	104	−2.10	0.038	[−0.78, −0.02]	−0.36 (0.20)	103	−1.87	0.065	[−0.75, 0.02]
AVP	0.09 (0.19)	95	0.49	0.628	[−0.29, 0.48]	0.11 (0.20)	97	0.50	0.584	[−0.28, 0.50]
Experienced harsh discipline						−0.33 (0.390	143	−0.84	0.400	[−1.10, 0.44]
Experienced harsh discipline × OXT						0.73 (0.43)	104	1.70	0.092	[−0.12, 1.58]
Experienced harsh discipline × AVP						0.31 (0.43)	115	0.73	0.467	[−0.54, 1.17]
Experienced love withdrawal						0.32 (0.34)	133	0.93	0.353	[−0.36, 0.99]
Experienced love withdrawal × OXT						−0.74 (0.36)	94	−2.03	0.045	[−1.46, −0.02]
Experienced love withdrawal × AVP						−0.58 (0.38)	111	−1.54	0.127	[−1.33, 0.17]

[a] Unstandardized Linear Mixed Model effects. OXT = oxytocin; AVP = vasopressin. Parameters of the placebo condition are set to zero because this condition is used as the reference group; its parameters are therefore not displayed.

Table 3
Main effects of oxytocin and vasopressin administration on challenging parenting behavior without toys (Model 1) and moderation effects of fathers' early childhood experiences (Model 2).[a]

	Challenging parenting behavior without toys									
	Model 1					Model 2				
	B (SE)	df	*t*	*p*	95% CI	B (SE)	df	*t*	*p*	95% CI
Intercept	2.79 (0.08)	139	34.11	<0.001	[2.62, 2.95]	2.80 (0.08)	125	33.88	<0.001	[2.64, 2.96]
OXT	0.08 (0.09)	95	0.95	0.347	[−0.09, 0.25]	0.09 (0.09)	89	1.08	0.283	[−0.08, 0.27]
AVP	−0.09 (0.09)	98	−1.03	0.305	[−0.27, 0.08]	−0.12 (0.09)	89	1.35	0.180	[−0.30, 0.06]
Experienced harsh discipline						0.33 (0.18)	140	1.89	0.061	[−0.02, 0.69]
Experienced harsh discipline × OXT						−0.08 (0.19)	92	−0.41	0.680	[−0.46, 0.30]
Experienced harsh discipline × AVP						−0.35 (0.19)	104	−1.81	0.073	[−0.74, 0.03]
Experienced love withdrawal						−0.24 (0.16)	129	−1.50	0.135	[−0.55, 0.07]
Experienced love withdrawal × OXT						−0.14 (0.16)	78	−0.90	0.371	[−0.46, 0.17]
Experienced love withdrawal × AVP						0.14 (0.17)	106	0.81	0.423	[−0.20, 0.47]

[a] Unstandardized Linear Mixed Model effects. OXT = oxytocin; AVP = vasopressin. Parameters of the placebo condition are set to zero because this condition is used as the reference group; its parameters are therefore not displayed.

Table 4
Main effects of oxytocin and vasopressin administration on challenging parenting behavior with toys (Model 1) and moderation effects of fathers' early childhood experiences (Model 2).[a]

	Challenging parenting behavior with toys									
	Model 1					Model 2				
	B (SE)	df	*t*	*p*	95% CI	B (SE)	df	*t*	*p*	95% CI
Intercept	2.08 (0.70)	133	29.53	<0.001	[1.94, 2.22]	2.06 (0.07)	122	28.59	<0.001	[1.92, 2.20]
OXT	0.07 (0.08)	110	0.892	0.374	[−0.08, 0.22]	0.11 (0.08)	106	1.40	0.165	[−0.05, 0.26]
AVP	−0.02 (0.08)	96	−0.30	0.766	[0.17, 0.13]	−0.01 (0.08)	99	−0.11	0.914	[0.16, 0.14]
Experienced harsh discipline						−0.21 (0.16)	143	−1.32	0.189	[−0.52, 0.10]
Experienced harsh discipline × OXT						−0.27 (0.17)	108	1.59	0.115	[−0.07, 0.61]
Experienced harsh discipline × AVP						0.07 (0.17)	118	0.40	0.690	[−0.27, 0.41]
Experienced love withdrawal						0.11 (0.14)	129	0.77	0.443	[−0.17, 0.38]
Experienced love withdrawal × OXT						−0.14 (0.15)	104	−0.96	0.339	[−0.44, 0.15]
Experienced love withdrawal × AVP						0.01 (0.15)	104	0.07	0.946	[−0.28, 0.30]

[a] Unstandardized Linear Mixed Model effects. OXT = oxytocin; AVP = vasopressin. Parameters of the placebo condition are set to zero because this condition is used as the reference group; its parameters are therefore not displayed.

0.07, $\beta = -0.01$, $p = .946$) moderate the effects of vasopressin administration on CPB *with* toys.

4. Discussion

This study was the first randomized, double-blind, placebo-controlled within-subject trial to examine the effects of intranasal administration of oxytocin and vasopressin on fathers' sensitive and challenging parenting behaviors during the first year of parenthood. In addition, we examined the moderating role of fathers' own childhood experiences. Against our expectations, fathers were less sensitive during play with their infant in the oxytocin condition as compared to the placebo condition, but moderation analyses showed that this decrease in sensitivity was only present in fathers reporting higher levels of experienced parental love withdrawal. Fathers reporting lower levels of experienced parental love withdrawal showed similar levels of sensitivity in the placebo and oxytocin condition. We found no effects of vasopressin administration on paternal sensitivity, nor of oxytocin and vasopressin administration on fathers' CPB, and these effects were not moderated by fathers' early childhood experiences.

Oxytocin is well known for its role in promoting prosocial behaviors (Van IJzendoorn and Bakermans-Kranenburg, 2012; Yang et al., 2021). Moreover, experimental studies reported that after oxytocin administration, fathers' showed more sensitive structuring and less hostility during play with their child (Naber et al., 2010; Naber et al., 2013). We therefore expected that oxytocin administration would enhance fathers' sensitive interactions with their infant. Surprisingly, our findings showed that fathers were less sensitive in the oxytocin condition. Yet, we found a moderating effect of fathers' early childhood experiences, such that this decrease in sensitivity was observed in fathers with more experiences of parental love withdrawal in their childhood but not in fathers with less experiences of parental love withdrawal. These results are largely consistent with meta-analytic findings demonstrating null or negative effects of oxytocin administration in individuals with adverse childhood experiences, however, our results contradict findings showing positive effects of oxytocin administration in individuals who report lower levels of childhood adversity (Ellis et al., 2021). Moreover, correlational research indicates that higher oxytocin levels in mothers with a history of childhood adversity are associated with lower levels of positive parenting behaviors (Julian et al., 2018). Furthermore, previous studies showed that oxytocin administration can promote negative behavioral outcomes in adults with borderline personality disorder (Bartz et al., 2011), adults with opioid dependence (Woolley et al., 2016), mothers with postnatal depression (Mah et al., 2013), men with major depressive disorder (MacDonald et al., 2013), and men with anxious attachments (Bartz et al., 2015). Thus, this study adds to previous evidence showing that the effects of oxytocin administration seem to depend on individual characteristics, and can have negative effects in individuals at risk.

An explanation for these findings is that adverse events in early childhood induce changes in the oxytocin system, including down-regulation of oxytocinergic functioning (e.g., higher methylation of the oxytocin receptor) (Ellis et al., 2021). These changes are assumed to be adaptive, and are associated with a broad range of psychological behaviors which may help individuals to navigate through future environments that are harsh and unpredictable (Ellis et al., 2021). Indeed, evidence shows that adverse childhood experiences have been associated with alterations in the recognition and processing of facial

expressions (Doretto and Scivoletto, 2018). For instance, children and adults with experiences of childhood adversity showed an attentional bias to negative facial expressions (Curtis and Cicchetti, 2011; Dannlowski et al., 2013; Feeser et al., 2014), which suggests the enhanced identification of potential threat. Interestingly, experimental studies found that oxytocin administration to adults with childhood adversity enhanced emotion perception abilities (Riem et al., 2014), in particular recognition of angry and fearful facial expressions (Schwaiger et al., 2019). Possibly, oxytocin administration to fathers with higher levels of experienced parental love withdrawal enhanced their attention to negative infant signals which may have affected their ability to provide a sensitive response.

For fathers reporting lower levels of parental love withdrawal we expected to find higher levels of sensitivity in the oxytocin condition, in line with previous studies showing that oxytocin administration enhances sensitive fathering behaviors (Naber et al., 2010; Naber et al., 2013). However, these earlier studies focused on fathers with children of an older age (children 1.5 to 6 years old) and did not examine the moderating role of adverse childhood experiences. In the present study we found similar levels of sensitivity in the placebo and oxytocin condition for fathers reporting lower levels of experienced love withdrawal. Positive effects of oxytocin administration have been reported for attention orientation towards social stimuli (Eckstein et al., 2019; Hubble et al., 2017), and emotion recognition (Leppanen et al., 2017). While attention to and recognition of infant emotional signals are prerequisites for parental sensitivity, they do not necessarily prompt a sensitive caregiving response. Future studies may examine whether oxytocin administration affects attention to and perception of infant signals and whether these effects are related to actual fathering behaviors.

It should be further noted that our measure of paternal sensitivity did not capture the frequency or intensity of paternal touch. Correlational studies have linked higher oxytocin levels to more affectionate touch (e.g., hugging, kissing) in mothers but not in fathers (for a systematic review, see Scatliffe et al., 2019). Yet, a more recent study showed that fathers with higher unextracted (but not extracted) oxytocin levels displayed more gentle affectionate touch during interactions with their 6-month-old infant (Morris et al., 2021). Future experimental studies may incorporate measures of paternal affectionate touch to generate a better understanding of the effects of oxytocin administration on fathers' affectionate caregiving behaviors.

The present study reported no effects of vasopressin administration on paternal sensitivity, neither were effects of vasopressin administration on paternal sensitivity moderated by fathers' early childhood experiences. Research in animals pointed to the involvement of vasopressin in paternal caregiving (Kozorovitskiy et al., 2006; Wang et al., 1994). To our knowledge, this is the first study examining the effects of vasopressin administration on human fathering behaviors in the first year of parenthood. Previous studies have suggested that vasopressin plays a significant role in defensive and territorially behaviors (van Anders et al., 2011). Moreover, fathers' vasopressin levels were associated with lower neural activation in brain regions associated with social-cognition and empathy when watching own infant stimuli versus unknown infant stimuli (Atzil et al., 2012). Also, after vasopressin administration, expectant fathers showed enhanced handgrip force in response to bouts of infant crying while viewing an image of an unknown versus own infant face (Alyousefi-van Dijk et al., 2019), and showed increased neural activation in response to infant cry sounds coupled with emotional contextual information (e.g., this infant is sick/bored) (Thijssen et al., 2018). These results in combination with findings of the present study indicating no effects of vasopressin administration on fathers' sensitive behaviors, point to the possibility that vasopressin is more strongly implicated in processes of social cognition and responding to infant threat and distress than in paternal sensitivity (Alyousefi-van Dijk et al., 2019; Atzil et al., 2012; Bakermans-Kranenburg et al., 2019).

Findings regarding fathers' CPB were not in line with our expectations: we found no effect of oxytocin and vasopressin administration on fathers' CPB, neither during play without toys, nor during play with toys. Previous experimental results showed that fathers engaged in longer episodes of touch and social reciprocity with their 5-month-old infant after oxytocin administration (Weisman et al., 2012). Furthermore, correlational research showed that fathers with higher vasopressin levels engaged in more stimulatory play with their 4- to 6-month-old infant (Apter-Levi et al., 2014). Yet, CPB includes physical and verbal components and is therefore a broader construct than 'touch' or 'stimulatory play'. As such, conceptual differences in observed behaviors might explain why we found no effect of oxytocin and vasopressin administration on fathers' CPB. Moreover, as previously noted, effects of vasopressin on fathers' CPB may be absent because vasopressin is suggested to be more strongly involved in social-cognitive processes and in responding to infant threat and distress (Alyousefi-van Dijk et al., 2019; Atzil et al., 2012; Bakermans-Kranenburg et al., 2019).

Another explanation for the absence of effects for CPB may be the age of the children. Possibly, hormones exert a stronger influence on fathers' CPB when children become older. It has been suggested that fathers' parenting role changes across childhood (e.g., Bögels and Phares, 2008), and it may be that CPB becomes a more salient characteristic of the fathering role after infancy and is then more strongly influenced by hormones. A literature review found support for positive associations between child age and the frequency of paternal rough-and-tumble play/CPB, with a peak in these behaviors after the first year of life, but also reported negative and non-significant associations between child age and frequency of paternal rough-and-tumble play/CPB (Feldman and Shaw, 2021). The present study found a positive association between CPB and child age. Moreover, although not statistically tested, fathers' observed CPB slightly increased from 4 to 12 months old, after which lower levels of CPB were observed at 2.5 years old (Majdandžić et al., 2016). Future research is warranted to examine whether oxytocin and vasopressin administration exert stronger effects on fathers' CPB in a later age stage (i.e., in early toddlerhood). Additionally, prior research showed that fathers' social anxiety disorder symptoms were associated with lower levels of CPB (Möller et al., 2015). Considering the anxiolytic effects of oxytocin (Heinrichs and Domes, 2008), future work might explore whether administration of oxytocin promotes CPB by reducing feelings of anxiety in fathers with symptoms of social anxiety.

The absence of an effect of oxytocin and vasopressin administration on fathers' challenging behaviors may also be due to a relative lack of variation in the context in which CPB was observed. For instance, previous studies assessed CPB across a range of different contexts (Majdandžić et al., 2016; Majdandžić et al., 2018). More specifically, CPB was observed in various structured movement tasks (e.g., a dancing task) as well as in free play tasks (play *with* and *without* toys). In the present study, we observed challenging parenting behavior during a 5-minute free play setting *without* toys followed by 5 min of free play *with* toys. Perhaps the assessment of CPB across more and different types of contexts is needed to obtain a reliable measure of fathers' CPB, and to observe effects of hormonal administration on fathers' challenging behaviors.

The most important strength of this study was the inclusion of a randomized, double-blind, placebo-controlled within-subject design. Moreover, we included a hormonal manipulation check and measured hormonal levels at baseline and post-administration, as recommended by Grumi et al. (2021) in a recent review. However, the results of the present study should be interpreted in light of the following limitations. First, the sample consisted predominantly of highly educated fathers who were born in the Netherlands and experienced relatively low levels of childhood adversity. Further research is needed to examine whether our findings can be generalized to samples with different socio-economic backgrounds and nationalities and to samples with higher levels of adverse childhood experiences. Second, fathers were observed in a controlled laboratory setting and future studies could examine the effects of oxytocin and vasopressin administration on fathers' sensitive

and challenging behaviors in more ecologically valid contexts, such as the home. Third, there are many other individual factors (e.g., attachment security) and contextual factors (e.g., presence of unfamiliar people) that might influence the effects of oxytocin and vasopressin administration on parenting outcomes (see also Szymanska et al., 2017). Fourth, the validity of retrospective reports of adverse childhood experiences has been questioned (Hardt and Rutter, 2004). However, recent work suggests that the impact of subjective, retrospective reports of childhood adversities (such as used in our study) may have more impact on later development than objective, archival reports (Danese and Widom, 2020). Fifth, dosage of administered oxytocin and vasopressin might modulate the effects and establishing optimal dosages for both hormones in specific populations is still is an outstanding question (Borland et al., 2019; Kosaka et al., 2016; Price et al., 2017). Finally, fathers were able to correctly guess above chance level assignment to the placebo condition. These findings underscore the importance of careful evaluation of the placebo solution in future research. Previous experimental studies have used two distinct placebo solutions, which were matched to either the oxytocin or vasopressin solution (Li et al., 2017; Rilling et al., 2012). However, in contrast to the present study, participants in these studies were not assigned to each experimental condition. In the present study, we include a randomized double-blind placebo-controlled within-subject design which allowed for comparing the effects of hormonal administration within participants.

5. Conclusion

The present study was the first randomized, double-blind, placebo-controlled within-subject trial to examine the effects of oxytocin as well as vasopressin administration on fathers' sensitive and challenging parenting behaviors in the first year of parenthood. Findings of the present study showed that fathers who reported higher levels of experienced love withdrawal were less sensitive in the oxytocin condition as compared to the placebo condition, whereas fathers with lower levels of experienced love withdrawal showed similar levels of paternal sensitivity in the oxytocin and placebo condition. We found no effects of vasopressin administration on paternal sensitivity, neither did oxytocin and vasopressin administration affect fathers' CPB. Although oxytocin is well-known for promoting prosocial behaviors, our findings showed that oxytocin administration can negatively affect paternal sensitivity, depending on fathers' own childhood experiences. Importantly, oxytocin administration, which has been proposed as a promising therapeutic intervention, may not be effective for individuals with adverse childhood experiences.

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Declaration of competing interest

None.

Data availability

Data will be made available upon reasonable request

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.yhbeh.2022.105175.

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