Effects of oxytocin on recollections of maternal care and closeness

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Although the infant–caregiver attachment bond is critical to survival, little is known about the biological mechanisms supporting attachment representations in humans. Oxytocin plays a key role in attachment bond formation and maintenance in animals and thus could be expected to affect attachment representations in humans. To investigate this possibility, we administered 24 IU intranasal oxytocin to healthy male adults in a double-blind, placebo-controlled, crossover designed study and then assessed memories of childhood maternal care and closeness—two features of the attachment bond. We found that the effects of oxytocin were moderated by the attachment representations people possess, with less anxiously attached individuals remembering their mother as more caring and close after oxytocin (vs. placebo) but more anxiously attached individuals remembering their mother as less caring and close after oxytocin (vs. placebo). These data contrast with the popular notion that oxytocin has broad positive effects on social perception and are more consistent with the animal literature, which emphasizes oxytocin's role in encoding social memories and linking those memories to the reward value of the social stimulus.

neurohypophyseal hormones | social cognition | social memory | individual differences | Syntocinon

According to attachment theory (1–3), infants develop affective bonds with their caregivers, which arise from an attachment behavioral system that promotes the infant's survival by facilitating caregiver closeness and protection. A core feature of the attachment system is the notion of *internal working models*, which are thought to contain information about close others' reliability and availability to meet one's needs for security, as well as affective and motivational information about regulating the self in relation to significant others. These attachment representations are formed in the infant–caregiver relationship but continue to operate throughout the lifespan and are adjusted to incorporate new close relationship experiences. The attachment behavioral system plays an important role in guiding interpersonal perceptions, expectations, and behaviors, but it is also significant from an evolutionary perspective—the attachment bond is thought to be essential for species survival because it fosters caregiver protection, thereby allowing the infant to survive to maturity and reproduce (2). Although critical to survival, little is known about the biological mechanisms supporting attachment representations in humans.

One candidate suggested by animal research is oxytocin, a mammalian hormone that acts as a neuromodulator in the brain. Oxytocin is produced in the hypothalamus and released into the circulatory system, where it is involved in facilitating uterine contractions during parturition and milk ejection during lactation (4). Oxytocin also is released directly into the brain, where it has been shown to play a critical role in attachment bond formation and maintenance in animals (5–8). A working hypothesis is that social contact triggers the release of oxytocin; oxytocin then orients attention to social stimuli and facilitates the encoding of social memories along with the hedonic value of the social stimulus (via interactions with the dopamine system) so that attachment bonds are formed with social but not nonsocial objects (6, 9). On the basis of the physiological role oxytocin plays in childbirth and animal attachment data, it often is assumed that oxytocin is involved in human attachment representations. This idea has not been tested empirically, however.

We investigated whether oxytocin is involved in human attachment representations by manipulating the availability of oxytocin in the brain and assessing the effects of oxytocin on recollections of childhood maternal care and closeness—two key features of the attachment bond. Although it is popularly thought that oxytocin has broad positive effects on social perception and function in humans (e.g., refs. 10–12), we theorized that if oxytocin is involved in linking social stimuli (mother) and hedonic information (warm, affectionate, "makes me feel better," close), the effects of oxytocin on recollections of maternal care and closeness should depend on the attachment representations people possess. Rather than positively biasing maternal recollections for everyone, oxytocin should bias these recollections in a positive or negative direction, depending on the nature of one's attachment style.

One critical factor then that should moderate the effects of oxytocin on maternal recollections is chronic concerns about the availability of close others, or attachment anxiety (1, 2). Attachment anxiety is theorized to be rooted in early experiences with a caregiver who inconsistently responds to the infant's bids for protection and nurturance; in response, the infant becomes anxious, preoccupied with securing the caregiver's love and attention, and fearful of abandonment. The attachment representation formed as a function of the infant–caregiver relationship then becomes an "interpretative filter" through which new relationships are meaningfully understood and construed (2, 3, 13), although it is clear that subsequent interpersonal experiences can modify people's attachment representations. [Indeed, a recent meta-analysis found that infant and adult attachment styles are typically only moderately correlated (Pearson $r = 0.27$), indicating that there is both stability and change in attachment representations over time (14).] In this way, attachment anxiety becomes a more general interpersonal orientation characterized by worry, hypervigilance to attachment-related cues, and chronic feelings of unmet attachment needs. This pattern of attachment can be contrasted with that of more securely attached individuals who, through repeated experiences with a responsive caregiver, come to expect that close others can generally be relied upon in times of need.

We hypothesized that oxytocin would positively bias recollections of maternal care and closeness for less anxiously attached individuals because it should bring to mind their positive caregiving experiences and expectancies—that is, feelings of adequate caregiver responsivity and closeness. By contrast, oxytocin should negatively bias recollections of maternal care and closeness for

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more anxiously attached individuals because it should bring to mind the caregiver's inconsistencies and unpredictability, consistent with their chronic concerns about separation and abandonment.

To investigate the effects of oxytocin on recollections of maternal care and closeness in childhood, and to test whether attachment anxiety moderates those effects, we conducted a randomized, double-blind, placebo-controlled, crossover trial in which adult male participants received 24 IU intranasal oxytocin or a matching placebo on two occasions (3–5 wk apart). Individual differences in attachment anxiety and avoidance were assessed at baseline, and recollections of maternal care and closeness in childhood were assessed at both testing sessions after oxytocin/placebo administration (*Materials and Methods*). We then calculated the change in maternal recollections as a function of drug by subtracting placebo day ratings from oxytocin day ratings on the measures of maternal care and closeness; thus, positive values on these change indices indicate increased perceptions of care and closeness for oxytocin vs. placebo, and negative values indicate decreased perceptions of care and closeness for oxytocin vs. placebo.

Results

Our primary dependent variables were change (oxytocin minus placebo) in (*i*) maternal care ratings and (*ii*) maternal closeness ratings. To test our hypotheses we conducted regression analyses with mean-centered attachment anxiety, mean-centered avoidance, the anxiety × avoidance interaction, and drug administration order (coded: placebo first = −0.5; oxytocin first = +0.5) as predictors of each change score. With the regression model set up in this way, the intercept estimates the main effect of drug for the typical person. Results showed no main effect of oxytocin on change in maternal care ratings [$b = 0.02$, $t(26) = 0.22$, nonsignificant (ns)] or change in maternal closeness ratings [$b = -0.03$, $t(26) = -0.17$, ns]. This suggests that in contrast to the prediction that would be made on the basis of one popular view, oxytocin did not positively bias recollections of maternal care and closeness in childhood for the typical person.

However, as hypothesized, attachment anxiety interacted with oxytocin administration. Specifically, attachment anxiety significantly predicted change in maternal care ratings for oxytocin vs. placebo [$b = -0.12$, $t(26) = -2.16$, $P < 0.05$] and change in maternal closeness ratings for oxytocin vs. placebo [$b = -0.45$, $t(26) = -2.95$, $P < 0.01$]. As depicted in Figs. 1 and 2, less anxiously attached individuals remembered their mother as more caring (Fig. 1, left side) and remembered being closer to their mother (Fig. 2, left side) when they received oxytocin compared with when they received placebo, whereas the opposite was true for more anxiously attached individuals, who remembered their mother as less caring (Fig. 1, right side) and remembered being less close to their mother (Fig. 2, right side) after oxytocin vs. placebo. Neither avoidance nor the anxiety × avoidance interaction predicted change in maternal care (all ts < 1.7) or change in maternal closeness (all ts < 1.4) ratings.[†]

Additional analyses indicate that oxytocin did not simply bias participants' current beliefs about themselves and/or their close relationships more generally. Regression analyses like those described above revealed no effects of drug, attachment anxiety, attachment avoidance, or the anxiety × avoidance interaction on change in self-esteem (all ts < 1), current attachment (all ts ≤ 1), or perceptions of closeness to participants' closest current relationship partner (all ts < 1). Moreover, these observations

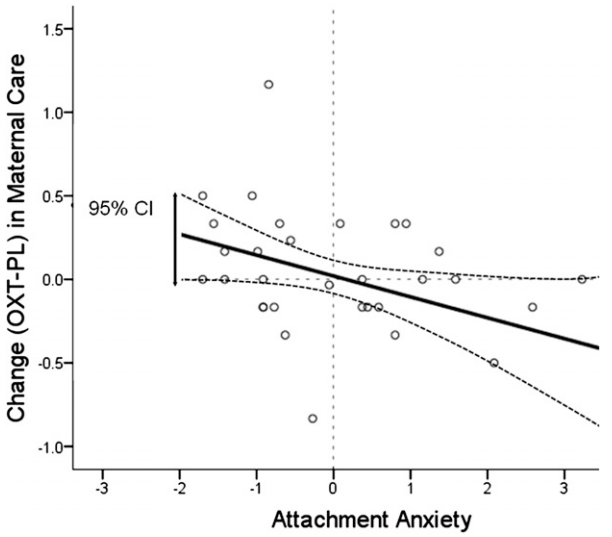

Fig. 1. Scatter plot displaying the association between participants' attachment anxiety score (mean-centered) and change in recollections of maternal care after oxytocin (OXT) [vs. placebo (PL)], with predicted regression line. The dotted curves indicate 95% confidence intervals (CIs). Higher numbers on the care change index (*y* axis) indicate an increase in care recollections in the oxytocin condition; lower numbers on the care change index indicate a decrease in care recollections in the oxytocin condition; a change score of zero indicates no change in recollections of maternal care across drug conditions. Higher numbers on the attachment anxiety scale (*x* axis) indicate greater attachment anxiety. Predicted values are shown only for observed levels of attachment anxiety. The predictive equation when other variables are set to their mean value is as follows: change in maternal care = 0.02 − 0.125 (mean-centered attachment anxiety). The effect of attachment anxiety predicting change in maternal care ratings was significant at $P < 0.05$, two-tailed.

cannot be explained by the nonspecific effects of oxytocin on state mood: paired-samples t tests comparing change in state mood (i.e., postoxytocin/placebo mood ratings vs. baseline mood ratings) in the oxytocin and placebo conditions showed no effects of drug on change in anxiety, anger, depression, confusion, fatigue, or vigor (all ts < 1, ns). Finally, the percentage of participants guessing they received oxytocin did not differ by drug condition [54.84% receiving placebo and 45.16% receiving oxytocin; $c^2(2, n = 62) = 1.42$, *ns*], indicating that participants were unaware of whether they had received oxytocin or placebo.

Discussion

Little is known about the biological mechanisms supporting attachment representations in humans. One potential candidate is the neuromodulator oxytocin, which regulates attachment bond formation and maintenance in animals. We investigated oxytocin's involvement in human attachment representations by manipulating the availability of oxytocin and measuring recollections of maternal care and closeness in childhood—two key features of the attachment bond. In contrast to the popular view that oxytocin exerts broad positive effects on social perception and behavior in humans (10–12, 15), we did not find that oxytocin positively biased maternal recollections in all cases. Rather, we found that the effects of oxytocin on maternal recollections were critically moderated by individual differences in attachment anxiety. Specifically, less anxiously attached individuals remembered their mother as more caring and remembered being closer to their mother in childhood after oxytocin (vs. placebo) administration, whereas more anxiously attached individuals remembered their mother as less caring and remembered being less close to their mother in childhood after oxytocin (vs. placebo) administration. These observations are

[†]There was a significant effect of drug administration order on change in maternal closeness ratings [$b = -0.79$, $t(26) = -2.29$, $P < 0.05$] but not on change in maternal care ratings ($t < 0.5$). Importantly, additional analyses showed no order × attachment anxiety interaction ($t < 0.5$), indicating that the effect of attachment anxiety on change in maternal closeness ratings does not depend on drug administration order.

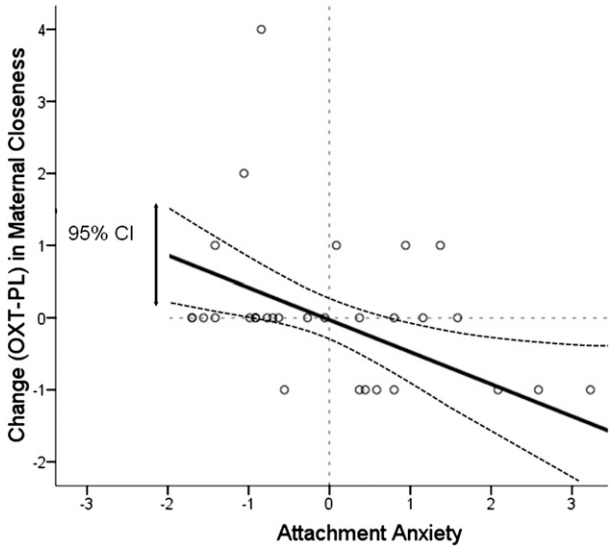

Fig. 2. Scatter plot displaying the association between participants' attachment anxiety score (mean-centered) and change in recollections of maternal closeness after oxytocin (OXT) [vs. placebo (PL)], with predicted regression line. The dotted curves indicate 95% confidence intervals (CIs). Higher numbers on the closeness change index (*y* axis) indicate an increase in closeness recollections in the oxytocin condition; lower numbers on the closeness change index indicate a decrease in closeness recollections in the oxytocin condition; a change score of zero indicates no change in recollections of maternal closeness across drug conditions. Higher numbers on the attachment anxiety scale (*x* axis) indicate greater attachment anxiety. Predicted values are shown only for observed levels of attachment anxiety. The predictive equation when other variables are set to their mean value is as follows: change in maternal closeness = −0.03 − 0.446 (mean-centered attachment anxiety). The effect of attachment anxiety predicting change in maternal closeness ratings was significant at $P < 0.05$, two-tailed.

striking given that maternal recollections like those assessed here are thought to be fairly stable (16). Importantly, oxytocin biased neither peoples' current beliefs about themselves or their mood, ruling out the possibility that such effects on participants' current state could have distorted their childhood memories. The fact that oxytocin had a polarizing rather than a main effect on maternal recollections suggests that oxytocin plays a more nuanced role in attachment representations than previously thought. Indeed, these findings are more consistent with the animal literature, in which it has been suggested that oxytocin is involved in encoding social memories and linking those memories to the reward value of social stimuli (6, 9).

One question is whether oxytocin increases people's ability to accurately recollect their relationship with their mother during childhood. Although there is some evidence that oxytocin facilitates accurate memory for faces in humans (17–19), we cannot conclusively say whether oxytocin increases people's accuracy here because we do not have information about participants' attachment style to their mother in childhood, which would be needed for a true index of accuracy.

An alternative possibility is that oxytocin triggers a motivated recall, setting in motion a biased search for information that is congruent with people's current chronic interpersonal beliefs and expectations (20). In contrast to the social memory studies referred to above, which focused on relatively "cold" aspects of cognition (stranger's faces) (21), we asked participants to recollect one of the most significant relationships in their life—their relationship with their mother. Moreover, attachment representations contain information about the identity of the caregiver but, more significantly, cognitive, affective, and motivational information related to the caregiver's ability to meet one's most basic needs for security. Given that we are tapping these "hot" aspects of cognition, there is more opportunity for chronic affective and/or motivational interpersonal biases to come into play as people recollect on these early experiences (22, 23). We suspect that oxytocin may work in the brain in ways that increase activation of the attachment system and the reward centers associated with attachment, so that it produces an attachment-congruent memory search in which participants selectively remember information about their mother that is consistent with their current chronic attachment style, in this way biasing recollections. Future research will be needed to fully answer the bias vs. accuracy question because both mechanisms are consistent with the data.

Another point worth discussing is that oxytocin did not change participants' current attachment level. Although it is possible that measurement issues (e.g., assessing general rather than mother-specific attachment after oxytocin/placebo) may have undermined our ability to detect an effect of oxytocin on change in current attachment, this null effect is in fact consistent with the activation hypothesis. Consider an analogy to cognitive priming of an attitude like "politicians are untrustworthy." Such an attitude is available in memory (for those who hold the attitude), but it can also be primed—for example, by showing people a picture of former US President Nixon, a notoriously untrustworthy politician. Priming does not typically alter the extremity of the attitude; rather, priming activates the attitude so that it is more readily applied in a situation involving the attitude object, in the example above biasing people's evaluation of an unknown politician (see ref. 24 for further discussion about attitude extremity vs. strength). Similarly, oxytocin may serve as a prime that increases the activation of chronic attachment representations so that they more readily guide people's memory search about their early experiences of maternal care and closeness. Future research incorporating implicit measures of attachment accessibility could explore this hypothesis.

One last question is whether attachment in general, or mother-specific attachment, moderates the effects of oxytocin on maternal recollections. As noted, attachment representations are rooted in the infant–caregiver relationship but are revised over the lifespan to incorporate other significant relationships (2, 3). Attachment in adulthood is thus complex, reflecting one's past and current relationship with parents, as well as those with romantic partners, and even close friends. Although a detailed discussion is beyond the scope of this article, theory (3) and empirical work (25) suggest that attachment representations are hierarchically organized, with episodic memories of specific attachment interactions at the bottom, representations of relationship "kinds" in the middle, and more general attachment representations at the top. Given the complexity of attachment in adulthood, it is standard to measure a person's global attachment style (3) as we did, and data suggest that global and relationship-specific measures tap distinguishable constructs that are modestly correlated (26). Given the small correlations between explicit measures of global attachment and mother-specific attachment, it would seem unlikely that our significant effect for global attachment anxiety was due solely to chronic mother-specific representations.

Finally, it should be noted that participants in this study were men. Future research is needed to confirm whether these findings generalize to women.

In closing, these data suggest caution when hypothesizing about the effects of oxytocin for different individuals or as an intervention. On one hand, we found that oxytocin exacerbated chronic concerns about closeness and the reliability of close others that characterize attachment anxiety. On the other hand, less anxious participants clearly showed a beneficial response to oxytocin, remembering their relationship with their mother in childhood in a more positive light. Oxytocin is popularly dubbed the "hormone of love," but these data suggest that oxytocin is not an all-purpose attachment panacea.

Materials and Methods

Participants. Participants were 31 men aged 19–45 y (mean, 27.06 y; SD, 7.05 y; median, 25 y) who were medication free and confirmed to be mentally and physically healthy by a study psychiatrist. We focused on men only in this study because of possible risks associated with administering oxytocin to women (i.e., inducing labor and unknown effects on a developing fetus). The study was approved by the Mount Sinai School of Medicine Institutional Review Board, and all participants gave informed consent before participation. Participants were compensated $120.

Procedures. Participants first underwent a brief interview with a study psychiatrist to confirm eligibility. Eligible participants completed a series of self-report questionnaires including the Experience in Close Relationships scale (ECR) (27), a widely used and highly reliable self-report measure of adult attachment. Baseline mood was also assessed at this point with the Profile of Mood States (POMS) (28).

Participants then self-administered 24 IU intranasal oxytocin [Syntocinon (Novartis), imported from Switzerland] or a matching placebo under the supervision of study personnel. The placebo was custom-designed by a commercial compounding pharmacy to match drug minus the active ingredient. To maintain the blind, drug and placebo were transferred to generic bottles. Drug/placebo administration order was counterbalanced, and participants and experimenters were blind to drug condition (the Mount Sinai School of Medicine pharmacy oversaw packaging, storage, and dispensation of study drug and placebo, maintained drug accountability, and assigned randomization codes to study participants). As described in *Results*, participants were unable to discern whether they had taken active drug or placebo when queried at the end of each testing session.

Approximately 90 min after oxytocin/placebo administration, and after completing the POMS again and another measure unrelated to this study (see ref. 29 for a detailed description of this measure), we assessed recollections of maternal care with the Parental Bonding Instrument (PBI) (30) and recollections of maternal closeness with the Inclusion of Other in the Self scale (IOS) (31). To address the specificity of the effects of oxytocin, we also assessed self-esteem (32), current attachment (33), and IOS for "closest current relationship." Finally, at the end of the testing session, participants were asked to guess whether they had received oxytocin or placebo that day. Participants returned 3–5 wk later, received the alternate compound, and underwent identical procedures (with the exception of the psychiatric interview and baseline questionnaires).

Materials. The ECR (27), which was modified from 36 to 29 items to reduce item redundancy, assesses attachment anxiety (i.e., sensitivity to and anxiety about rejection/abandonment) and attachment avoidance (i.e., discomfort with and desire to avoid closeness). Participants indicate on a seven-point scale how much they agree or disagree with each item in terms of how they "generally feel in important close relationships in [their] life" (e.g., family members, romantic partners, and close friends). After reverse scoring items for which lower numbers reflected greater attachment anxiety or avoidance, we computed attachment anxiety and avoidance scores for each participant by taking the mean response on the 14 anxiety items ($\alpha = 0.95$) and 15 avoidance items ($\alpha = 0.87$). Anxiety and avoidance scores were not correlated [$r(29) = 0.28$, ns].

The PBI (30) is a widely used retrospective measure of parenting styles as perceived by the child. Specifically, the PBI lists various attitudes and behaviors of the mother (e.g., "spoke to me in a warm and friendly voice"). The standard format is to ask respondents to rate how well each statement describes their mother "as you remember your mother in your first 16 years"; ratings are made on a 4-point scale (1 = very like; 2 = moderately like; 3 = moderately unlike; 4 = very unlike; the scale was reverse scored so that higher numbers reflect greater maternal care recollections). Although the PBI has been shown to have good reliability and validity (16), there is evidence that responders have difficulty interpreting and responding to the negatively framed "indifference" items, likely because of the double-negative involved (34); moreover, factor analyses indicate that the indifference items lack specificity (35). For these reasons, we included only the positively framed PBI care items in our maternal care composite.

The IOS (31) is also a widely used single-item pictorial scale that assesses relationship closeness; scores range from 1 to 7, with higher numbers reflecting greater closeness. To be consistent with the PBI, the IOS was similarly framed in terms of how participants remember their relationship with their mother during their first 16 y.

The Rosenberg Self-Esteem Scale (32) is a widely used self-report measure of self-esteem.

The Relationship Questionnaire (33) consists of four paragraphs describing the secure, preoccupied, avoidant-dismissive, and avoidant-fearful attachment styles. Participants rate the extent to which they resembled each of the four styles in their close relationships on a scale from 0 ("not at all") to 4 ("completely"). Scores for attachment anxiety and avoidance can be calculated by subtracting dismissive from preoccupied ratings and subtracting secure from fearful ratings, respectively (36). We elected to use this alternative attachment measure after oxytocin/placebo administration because we thought consistency demands would make it unlikely that we would observe a change in current attachment within a 3-h period if we assessed attachment using identical attachment measures before vs. after oxytocin.

The POMS (28) is a commonly used self-report instrument assessing state anxiety, anger, depression, confusion, fatigue, and vigor. Participants rate the extent to which each item describes "how they feel right now" on a scale from 0 (not at all) to 4 (extremely).

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