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Oxytocin and Romantic Relationships: A Functional Perspective

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ABSTRACT

Despite a large body of evidence implicating oxytocin (OT) in various classes of social relationships, researchers have only recently investigated how OT might function within human romantic relationships. I contribute to the growing literature on OT and romantic relationships with the current study, which investigated relationship features that promote OT secretion in a sample of 75 romantic couples. Partners in separate rooms were asked to write (for 10 minutes) about ways their partner did or did not support them. OT was assayed before and after this writing task, and also at a follow-up session one week later. Mixed model analyses showed that participants' OT increased across the task with multiple dimensions of relationship involvement/investment. However, increases in participants' OT also corresponded to their partners reporting *lower* relationship involvement. OT increases, then reflected *discrepancies* between own and partner's relationship assessments. These findings may importantly speak to its function in sexual relationships.

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Introduction

Overview

Oxytocin (OT) is a mammalian neuropeptide hormone, produced in the hypothalamus and secreted by the posterior pituitary gland. While only mammals produce OT, the –tocin family of molecules (e.g., vasotocin, mesotocin) is found in some form across fishes, birds, and invertebrates (Gwee et al., 2008). OT is released in the central nervous system as well as peripheral tissues, where it can act as both a hormone and a neurotransmitter. OT possesses diverse functions, both within and across animal species. Biologists, psychologists, and anthropologists alike have shown neuropeptides, and OT in particular, to be versatile molecules, as new findings continually suggest their involvement in widespread aspects of physiology and behavior (Carter 2014). OT has recently gained much attention for its involvement in human social behavior. Still, psychological OT research is in its infancy. While comparative work suggests OT and other –tocin peptides may have important functions for mating and social bonding in many species, including humans, little work has explored the role of OT in romantic relationships. Furthermore, conflicting findings and methodological issues have hindered the development of a theoretical framework for the role of OT in human social relationships.

Functions of OT

The earliest function of OT was identified from discoveries showing that mammalian pituitary gland extracts could help stimulate uterine contractions during labor (Dale, 1906; Bell, 1909)—hence the name oxytocin, which comes from the Greek for

‘quick birth’. Shortly after, researchers also discovered these extracts could stimulate the milk letdown reflex in both humans and other animals (Schafer & Mackenzie, 1911; Mackenzie, 1911). du Vigneaud et al. (1953) won the 1955 Nobel Prize in chemistry after being the first to synthesize pure OT, paving the way for its extensive use within the field of obstetrics to induce labor and prevent postpartum hemorrhage (see den Hertog et al., 2001).

A closely related line of OT research has focused on its roles in sexual functioning. Similar to the smooth muscle contractions of the uterus during labor, OT is involved in muscle contractions during orgasm in both men and women (Borrow & Cameron, 2012). OT administration also induces erections in several mammal species (Argiolas, 1992). In an early review, Carter (1992) suggests that OT is responsible for both the initiation and cessation of sexual responses in rats. While the causal directions are less clear in humans (e.g., whether OT causes or is a response to sexual arousal), many studies clearly implicate OT in human sexual functioning as well (reviewed in Borrow & Cameron, 2012).

A recent study in *Caenorhabditis elegans*, a nematode about 1 mm in length, provides compelling evidence for the importance of –tocin neuropeptides in mating. Garrison et al. (2012) discovered two genes in *C. elegans* coding for a previously unknown peptide. Called nematocin for its structural similarity to neuropeptides such as OT, the molecule proved crucial to the process of reproduction. Nematocin-knockout *C. elegans*, compared to wild-type individuals, made contact with mating partners less quickly, took more time to locate the vulva of mating partners, and were less likely to transfer sperm successfully. By demonstrating a conserved function between distantly

related nematodes and mammals, Garrison et al. argue that –tocin neuropeptides are fundamental to sexual reproduction.

Expanding beyond the physiological aspects of reproduction, researchers in the last few decades have utilized animal models to investigate the role of OT in social bonds. Early work focused on the mother-infant bond. In rats, OT appears to function for both mother and offspring. Female virgin rats, which normally attack or ignore foreign pups, instead demonstrate maternal behavior when given OT (Pedersen et al., 1982); for their part, pups given OT are more likely to elicit maternal attention through isolation calls (Insel & Winslow, 1991). Female sheep similarly treat strange offspring aggressively, but not when administered OT (Keverne & Kendrick, 1992). A seminal finding in OT research came from Williams et al. (1994), who first demonstrated the importance of OT in forming mating bonds. In the monogamous prairie vole, females typically form preferences for males after mating with them, preferring to spend time with them over unfamiliar males. However, administration of OT into the cerebrospinal fluid caused females to form preferences for cohabiting males without the need for mating. Furthermore, this phenomenon did not occur in voles given an OT antagonist. Animal studies in this vein became the theoretical foundation for human OT studies on social bonding.

OT is often referenced in popular science literature as a ‘trust’ (Zak, 2008) or ‘love’ molecule (Carter & Porges, 2013). These characterizations stem from a number of human studies performed in the last ten years suggesting that OT facilitates human bonding and closeness. The advent of non-invasive techniques for manipulating (e.g. nasal sprays of an OT solution) and measuring (e.g. fMRI, salivary assays) OT was

crucial in this new wave of psychological studies (Bos et al., 2012). Drawing upon classic animal studies, one line of research has focused on the bond between mother and child. OT levels in the mother have been associated with maternal attachment and neural responses to infant cues in the hypothalamus (Bos et al., 2012)—among other bonding behaviors—and OT responses in infants also appear to be crucially related to the development of secure mother-infant bonds (Fries et al., 2005). Other studies have investigated social relationships more generally. Zak, Kurzban, and Matzner (2005) report higher OT levels among players in a dyadic 'trust game' when participants receive or reciprocate an offer that signals trust in the other member. Kosfeld et al. (2005), in one of the earliest intranasal OT administration studies, reported increased interpersonal trust in a similar economic game after OT administration. Expanding upon this result, Baumgartner et al. (2008) found participants given OT are more likely to forgive breaches of trust in the same game used by Kosfeld et al. Domes et al. (2007; 2013a; 2013b) found improvements in 'mind reading' ability (i.e. inferring intentions and emotions of others) in a series of OT administration studies. While not all findings point to a positive role for OT in affiliative bonds (see below), the vast majority do (see Bos et al., 2012 for a review of OT administration studies).

Past research on OT covers many different phenomena, but a common thread runs between several areas. Specifically, many findings relate to important elements of mating systems (e.g., giving birth, nursing, forming close bonds, copulating, caring for offspring), and they point to OT being necessary for normal functioning. Given this, one might expect that OT is important for multiple aspects of human mating. And indeed, some of the work noted above—on mother-infant bonds, obstetrics, and sexual

functioning, for example—speaks to this point. Human romantic relationships, however, have been neglected until very recently. Given the centrality of the romantic pair-bond to human mating (and the explicit labeling of OT as a 'love molecule'), research investigating the role of OT in romantic relationships is crucial. Some fundamental questions remain open: Is OT beneficial for romantic relationships, as it appears to be for other types of bonds? Can OT levels predict certain features of relationships, in either men or women? In general, given the intersection of sexual and social behavior in romantic relationships, how might OT function within them?

OT and Mating Pair-Bonds

As expected, OT is implicated in many prosocial, positive elements of human romantic bonds. OT administration leads to more engaged, constructive communication about relationship conflicts (Ditzen et al., 2009), and more intense orgasms and greater contentment after intercourse with a partner (Behnia et al., 2014). Success of emotional support relationship interventions is related to OT levels (Holt-Lunstad et al., 2008), as is overall relationship satisfaction (Holt-Lunstad, Birmingham, & Light, 2014; but see Smith et al., 2013). Schneiderman et al. (2012) measured OT levels at the beginning of a romantic relationship, finding that new lovers had elevated OT compared to singles. In addition, OT levels at the outset of the relationship predicted relationship success six months later. Studies in other pair-bonding primates provide comparative evidence consistent with human findings. In male common marmosets, a comparison of OT levels during isolation to levels after reunion with a mating partner showed higher levels in the latter condition (Seltzer & Ziegler, 2007). Black-tufted marmoset pairs engaged in increased rates of huddling and partner-seeking behavior after OT administration (Smith

et al., 2010). Collectively, these results suggest that OT facilitates the process of pair-bond formation in primates, just as it does in rodents.

However, a number of psychological studies also support a role for OT in relationship features that are perhaps less socially desirable. Taylor et al. (2010) presented evidence that high OT levels in women are a marker of 'distressed pair bonds'; similarly, Marazziti et al. (2006) associated OT levels with greater attachment anxiety in pair bonds. Weisman et al. (2013) also found a positive association between baseline OT and attachment anxiety in a sample of 277 women. Schneiderman et al. (2012), in the same study associating OT with relationship success, also found that high OT correlates with worries about the partner and relationship. These findings among romantic partners parallel several studies involving social relationships more generally. Various studies have suggested a possible 'dark side' of oxytocin, showing that OT administration can lead to greater ethnocentrism (De Dreu et al., 2011), envy (Shamay-Tsoory et al., 2009), and perceptions of others as less healthy (Declerck, Lambert, & Boone, 2014); in addition, OT increases in response to an imagined transgression associates with less forgiveness of that transgression (Tabak et al., 2011).

Effects of OT Administration

This body of conflicting findings was recently summed up by a group of researchers as the "oxytocin paradox" (Bethlehem et al., 2014). One part of the paradox focuses on contradictory effects, which Bethlehem et al. attempt to address. They offer several possible conceptualizations: perhaps OT is an anxiolytic substance; or it increases the salience of social cues in general; or it modulates the perceived rewards from

engaging in social behaviors. Each of these perspectives receives some support from the literature. OT's apparent anxiolytic effects are well known from animal studies (e.g., Ring et al., 2006; Ebitz et al., 2013), and in a review, Churchland and Winkielman (2012) argue that many findings on OT and social behavior can be explained in terms of the hormone acting upon general dispositions, such as overall anxiety level. Several findings showing that OT administration improves 'mind-reading' and eye contact (Domes et al., 2007, 2013; Guastella, Mitchell, & Dadds, 2008) support an important role for OT in awareness of social cues. Bethlehem et al. favor the hypothesis that OT modulates the perceived rewards of social behaviors, as they argue it can best explain both pro-social and anti-social effects of OT (for example, if humans are already predisposed to favor interaction with ingroup over outgroup members, then OT will reinforce this process, possibly leading to ethnocentric attitudes; Bethlehem et al., 2014). As a general state of the field, however, Bethlehem et al. admit that no perspective can entirely explain all of OT's apparent effects.

The methodological approaches of OT studies might also contribute to the paradox. As noted earlier, OT nasal sprays are extensively used as a non-invasive method for manipulating OT. However, while there is some evidence for their capacity to raise OT levels in the blood and cerebrospinal fluid (Born et al., 2002), the mechanism and strength of this increase is unknown (Striepens et al., 2013), making it unclear how much of the hormone actually acts upon oxytocinergic pathways in administration studies. It is also unknown if these sprays only affect OT, and not other hormones or neurotransmitters as well. Twenty years ago, Williams et al. (1994) acknowledged the possibility of ovarian hormones interfering with OT administration, and more recent

work supports potential interactions. Estrogen stimulates the synthesis of OT in mice (Nomura et al., 2002), as well as its binding affinity to OT receptors (Gimpl & Fahrenholz, 2001) Ochedalski et al. (2007) show that the influence of OT on the hypothalamic-pituitary-adrenal (HPA) axis depends on circulating estrogen levels in rats. Grazzini et al. (1998) present direct evidence of progesterone actually binding to OT receptors *in vitro*. These findings raise the possibility, for instance, that OT administration also alters ovarian hormones via feedback mechanisms. It is unknown if these hormones—whether in addition to OT or instead of OT—contribute to observed behavioral changes following OT administration.

Causes of OT Production

Another limitation, not addressed by Bethlehem et al., concerns the theoretical power of the method itself. OT administration studies can only speak to the effects of OT. While an understanding of effects is certainly important, perspectives that seek to address the *causes* of natural OT production are also necessary; given their superior ecological validity, they may even provide greater insights towards an integrated functional perspective. Many OT administration studies introduce a large dose of the hormone in a situation where it is unclear whether the organism would produce it naturally. Perhaps unsurprisingly, given the diverse functions and interactions OT possesses, many such studies induce behavioral changes. However, it is unclear whether these behaviors reflect OT-dependent behavioral adaptations, or if they are by-products that have little to do with the functional design of OT. To take just one example, there is little theoretical background arguing that OT is important for assessing the health of other faces. What,

then, should one make of a finding showing that OT decreases healthiness ratings of faces (Declerck, Lambert, & Boone, 2014)?

Research on OT production within romantic relationships, then, carries a substantial advantage: it represents a realistic and theoretically supported context for functionalities of OT. Still, one must reconcile paradoxical findings that also exist within these types of studies. Smith et al. (2013), in an empirical study of OT levels among romantic couples, summarized the two dominant perspectives in this regard. The first ("calm and connect"; e.g. Carter, 1998), inverts the "anxiolytic effect" argument—in this model, warm, secure social interactions (e.g., within a romantic relationship) lead to heightened oxytocinergic activity, and thus greater circulation of OT. The second ("tend and befriend"; e.g., Taylor, 2006) focuses on OT's 'dark side'. Here, OT rises in response to relationship distress. In turn, increased OT leads to an increased motivation for affiliative bonding.

In their attempt to test these models (and therefore speak to the paradox), Smith et al. (2013) found support for neither model. One reason for this might be limited and inconsistent measures for assessing relationship quality or involvement. Smith et al. (and others; e.g. Holt-Lunstad et al., 2008, 2014) have operationalized 'relationship quality' via questionnaire measures that largely concern self-reports of overall satisfaction and conflict levels. More nuanced dimensions of relationships (e.g. sexual responsiveness, emotional support), and their associations with OT, are left unmeasured. Others assessed different features of relationships (e.g., Taylor et al., 2010), but omit measures of overall quality or involvement. There is a clear need within the OT literature to consider a wide variety of relationship qualities.

The Discrepancy Hypothesis

Alternative perspectives on the causes of OT production can reconcile past findings, while also aiding in the development of testable hypotheses. I aim to test one such alternative, which I label the "Discrepancy Hypothesis". This hypothesis argues that cues of relationship vulnerability, paired with an emotional engagement to the relationship, drive increases in OT. In turn, OT may function to orient attention toward that relationship, perhaps via modulating the social rewards an individual experiences from pair-bonding behaviors (Bethlehem et al., 2014). There are multiple advantages to this perspective. First, it fits with multiple types of close relationships. Mother-infant relationships, for example, represent an extremely vulnerable pair-bond, where the mother is almost entirely responsible for the survival of her offspring. As predicted, OT increases when breast-feeding (White-Traut et al., 2009), or responding to an infant's solicitations for attention (Feldman et al., 2010). New or distressed romantic relationships—where special attention or investment are necessary for their success—act as other examples of relationship conditions that appear to lead to greater OT. This perspective also helps reconcile paradoxical effects. Rather than predicting OT to be a response to either strong feelings of bonding with a new partner (e.g., Schneiderman et al., 2012) *or* a partner's perceived disengagement (e.g., Taylor et al., 2010), the Discrepancy Hypothesis predicts the hormone would be produced in *both* scenarios. Finally, the Discrepancy Hypothesis provides a generalizable theoretical framework. It argues that OT, like many other hormones, functions as a distributed communication system that allocates energy to certain types of activities (Ketterson & Nolan, 1992). For example, one theoretical perspective on testosterone argues that it functions across animal

species to dedicate energetic resources towards mating effort, and away from parenting effort (Bribiescas, 2001; Gettler et al., 2011). Perhaps OT, in a similar manner, functions to allocate psychological resources (e.g. emotional investment, sexual desire) towards a vulnerable relationship.

The Discrepancy Hypothesis possesses similarities to both the "calm and connect" and "tend and befriend" models—and in fact, Taylor (2006) comes remarkably close to advancing a version of the Discrepancy Hypothesis when she argues that OT is released in response to "gaps in positive social relationships" (p. 274). However, two crucial distinctions separate the hypotheses. First, despite conceptualizing that OT signals "gaps" in relationships, Taylor et al. (2006; 2010) only link OT with distress, and not with any positive assessments of relationship investment. For a gap or discrepancy to exist, two elements are equally necessary: one's own interest and investment in the relationship, as well as a lack of interest and investment from one's relationship partner. The Discrepancy Hypothesis predicts both. Second, Taylor (2006) conceptualizes OT as a modulator of "appetite" (Taylor, 2006; p. 273) for social affiliation in general, and Taylor et al. (2010) continue this argument, proposing that OT may lead individuals to seek affiliation with people other than the pair-bond partner. The Discrepancy Hypothesis argues the opposite: that the desire for affiliation is focused on the pair-bond partner, rather than social partners in general.

The Current Study and Predictions

I seek to contribute to the growing literature on OT and romantic relationships, while addressing some of the shortcomings of past OT research. Within the current study,

I investigate associations between naturally-occurring OT and numerous dimensions of romantic relationship involvement/investment via two salivary measures of OT: 1) the average of two separate baseline measurements; and 2) the short-term change across a thought-writing task, where participants are primed to think about their partner's support (or lack thereof) in the relationship (see Methods for a description of this task).

This study will attempt to answer several questions. One prediction concerns whether OT is associated with positive relationship qualities, negative relationship qualities, or a mixture of both. In line with past studies on romantic relationships (e.g., Holt-Lunstad et al., 2014; Schneiderman et al., 2012), I predict that *an individual's average OT levels and OT change during a thought-writing task will be positively associated with his or her reports of relationship involvement ("involvement" entailing factors such as general satisfaction, trust in one's partner, feelings of love and "bonded-ness", sexual responsiveness, and passion).*

However, in line with recent findings also tying OT to anxieties and preoccupations regarding relationships (e.g., Taylor et al., 2010), I also predict that *an individual's OT level and change across the task will be associated negatively with their partner's ratings of involvement (in terms of the same factors as described previously).* These first two predictions stem directly from the Discrepancy Hypothesis. Through priming participants to think about their relationship with their partner, these predictions jointly test whether OT functions to orient an invested individual towards a vulnerable relationship—a novel prediction that has not been addressed by previous research.

I also investigate whether the two predictions of the Discrepancy Hypothesis are moderated by sex—in particular, whether women's OT levels/changes are more

associated with a male partner's low ratings of relationship involvement, compared to the reverse. Some evidence argues for sex differences in the operation of OT within close relationships. Early OT administration studies in voles found that while OT was the crucial hormone for pair-bond formation in female voles (Williams et al., 1994), in male voles, vasopressin (a structurally similar neuropeptide) was instead the mediating factor (Cho et al., 1999). Supporting this sex difference in humans, a single nucleotide polymorphism on a vasopressin receptor gene predicted scores on a scale of romantic bonding (measuring affection, proximity-seeking, and perceptions of stability) in men, but not women (Walum et al., 2008). Taylor (2006) was among the first to explicitly suggest that OT influences women, more than men, to seek affiliative bonds in response to stressors (though, importantly, she presented no empirical evidence for this claim). And indeed, some empirical findings are consistent with this suggestion: in women, but not men, OT correlates with attachment anxiety (Weisman et al., 2013) and distress within a romantic relationship (Taylor et al., 2010). The effect of OT administration on the processing of fearful or angry faces in the amygdala contrasted between the sexes, with women showing greater reactivity (Domes et al., 2010; cf. Domes et al., 2007). Still, no clear prediction emerges. While effects may well be restricted to females, other studies on romantic relationships find no interactions between sex and OT (Schneiderman et al., 2012), or present evidence that OT plays a role in regulating emotional behavior in both sexes (Neumann, 2008). Given conflicting past findings, I explore interactions between sex and OT with regard to relationship features.

Related to sex x OT interactions, OT might specifically interact with the ovarian hormones estrogen and progesterone to either strengthen or weaken associations between

OT and the aforementioned relationship factors. As previously mentioned, molecular research suggests positive feedback between estrogen and OT: estrogen stimulates the synthesis of OT (Nomura et al., 2002), and also increases its binding affinity to OT receptors (Gimpl & Fahrenholz, 2001). Progesterone perhaps has opposing molecular effects, as Gimpl and Fahrenholz (2001) and Grazzini et al. (1998) show that progesterone decreases the number of available OT receptor binding sites. It is unknown, however, whether these interactions have any implications for romantic relationships. I therefore explore whether such interactions occur in normally ovulating women, and if they exist, the direction of the interactions. As this study was designed to test the Discrepancy Hypothesis in the largest sample possible, participant recruitment was not restricted to couples where the woman was normally ovulating. Therefore, exploratory analyses of estrogen/progesterone interactions will be limited by low statistical power. However, I will also examine whether the use of hormonal contraceptives (as a proxy for altered levels of estrogen, progesterone, or both) moderates the predicted effects of relationship discrepancies.

Methods

Overview of Procedure

75 heterosexual couples (mean age = 21.27, SD = 5.37) participated in the experiment. Couples arrived together, but completed study procedures in separate rooms. After completion of informed consent, participants were simultaneously given the first of two sets of questionnaires and materials to provide an initial saliva sample. After completion of both the first questionnaire and sample, participants were given ten minutes to perform a thought-writing task. Following the task, participants were given the second questionnaire set. Fifteen minutes into the second questionnaire set, a second saliva sample, and a first urine sample, were collected. Participants left the laboratory after completion of the second questionnaire, and returned one week later to drop off a third saliva sample and second urine sample, and to fill out a brief survey.

First Questionnaire Set

In the first set of questionnaires, participants provided a variety of demographic and health measures. Specific measures used in analyses include demographic information such as age, sex, and relationship length. These variables are necessary to include as covariates in statistical analyses. For instance, given the findings of Schneiderman et al. (2012), perhaps relationship length moderates any relationships between OT and relationship qualities. However, many questions in this first set were included to address other questions not relevant to the current study, and are therefore not listed here.

Thought-writing Task

The thought-writing task, designed to elicit OT secretion in individuals, was developed for this study. Participants were given a piece of paper with the following instructions:

"Please spend a few minutes thinking about your relationship with your partner. Then write about ways that your partner responds to you in ways that show that your partner *truly accepts and connects* with you, or how you *wish* your partner would respond to you in ways that show that your partner truly accepts and connects with you.

In total, you'll have about *10 minutes* for this task. So you have a few minutes to gather your thoughts before writing."

Measures of Romantic Relationship Involvement

Participants were given a wide variety of questionnaires regarding their relationship with their partner in the second questionnaire set. To prevent these questions from interfering with the measure of OT change, they were given only in the second set of questionnaires, after the thought-writing task. Specific measures used in analyses (with subscales listed as abbreviations) include: a measure of Relationship Attachment (Simpson et al., 1996) assessing attachment anxiety and avoidance in romantic relationships; the Relationship-Specific Investment Inventory (Ellis, 1998) consisting of self and partner reports of relationship investment on the subscales of emotional nurturance (EN), antagonism (ANT), commitment (COMMIT2), sexualizing others (SEXO), giving of time (TIME), social neglect (SOCNEG), dishonesty (DISHON), and sexual responsiveness (SEXRES); the Perceived Relationship Quality Components Inventory (Fletcher, Simpson, & Thomas, 2000) containing measures of overall satisfaction (SAT), commitment (COMMIT), trust (TRUST), passion (PASN), and love

(LOVE); a measure of infatuation with the partner (INFAT; adapted from an unpublished measure by Fisher); Tancredy & Fraley's (2006) Attachment Bond Strength questionnaire (BOND). Appendix 1 contains all relationship involvement measures.

Participants also filled out personality inventories within the second questionnaire set. Included in subsequent analyses is the NEO Five Factor Inventory (NEO-FFI; Costa & McCrae, 1992).

Factors of romantic relationship "involvement" were created through a factor analysis on all relationship scales. Oblimin rotation was used with principal component extraction to allow factors to correlate with one another. Three factors emerged (i.e., the scree plot showed three factors before the 'elbow' in the curve). All factor loadings from the pattern matrix are available in Table 1. The first factor contained strong loadings (>.45) for LOVE, COMMIT, BOND, WANT, EN, and TIME (labeled Love/Bonding in Results). The second factor loaded strongly on SAT, TRUST, and ANT (Trust/Satisfaction). The final factor loaded strongly on PASN, SOCNEG, and SEXRES (Sexual Passion/Responsiveness). All scores on relationship composites were formed using the regression method, in which measured variables are transformed into standardized *z* scores and multiplied by regression-based weights. The regression method also facilitates calculation of 'higher order' factors (Thompson, 2004); therefore, the moderately inter-correlated composites were summed (after reversing two factors so that all factors were positively correlated; see Table 2) to create a 'general' index of relationship involvement (General).

Table 1. Factor loadings (pattern matrix) for factor analysis of relationship involvement measures.

	Factor		
	1	**2**	**3**
COMMIT	**.809**	-.145	-.045
LOVE	**.880**	-.050	.050
BOND	**.812**	.011	.040
WANT	**.675**	.090	.063
EN	**.576**	-.310	-.115
COMMIT2	**.750**	-.017	.024
TIME	**.668**	-.157	.027
SAT	.273	**.633**	-.132
TRUST	.194	**.766**	.157
ANT	.115	**-.696**	.041
PASN	-.152	-.406	**.550**
SOCNEG	-.254	-.146	**-.470**
SEXRES	-.109	-.011	**.707**
INFAT	.434	.190	-.341

Table 2. Correlations between relationship involvement factors.

Factor	L/B	T/S	SR/P
Love/Bonding	1	.368	.464
Trust/Satisfaction		1	.394
Sexual Responsiveness/Passion			1

In addition, three composites assessing relationship "investment" were created from the individual components of the Ellis (1998) questionnaire. These components were sums of Ellis' subscales based on a factor analysis of the entire questionnaire; I used simplified sums of subscales, rather than factor analysis scores, to make self and partner ratings directly comparable. The first investment composite combined EN, COMMIT2, and TIME; the second combined ANT (reverse-scored) and DISHON (reverse-scored); the third combined SEXRES, SEXO (reverse-scored), and SOCNEG (reverse-scored). These composites are somewhat similar to those from the relationship involvement factor analysis. However, use of these composites allowed for direct comparisons between self reports of investment and reports *of* a partner's investment—in contrast to relationship involvement factors, which only include self reports. Still, these investment composites do not consider the breadth of measures that are included within relationship involvement factors. Therefore, relationship investment composites act as an interesting comparison to self-reports, but provide less robust tests of the first two predictions.

Hormonal Assays

For each of the three saliva samples, participants were instructed to provide approximately 5mL of passive drool into two separate test tubes. For urine samples, participants were given similar instructions to provide samples in the restroom. However, only saliva samples were used for hormonal assays. The second saliva sample, collected 25 minutes after initiation of the writing task, was designed to capture any changes in OT that occurred during the writing task (the 25 minute delay reflects the time necessary for changes in endogenous OT to be reflected in saliva [e.g., White-Traut et al., 2009], plus the amount of time typically needed for a participant to produce 5mL of saliva). Samples given during the laboratory procedure were provided at various times in the day, and follow-up samples were all provided when the participant woke up the morning before the session. All samples were collected and immediately frozen at -20°C until the time of assay. Prior to assay, samples were thawed, mixed by vortexing, then centrifuged for 15 minutes to break up and precipitate mucins.

Salivary 17β estradiol (E) and progesterone (P) concentrations were determined with enzyme-linked immunosorbent assays (ELISA) manufactured by Salimetrics LLC (Carlsbad, CA), and OT concentrations were measured using an ELISA kit from Enzo Life Sciences (Farmington, NY). All assays were performed in duplicate. Salimetrics reports a 0.8 correlation of saliva to serum for estrogen and progesterone. Enzo does not report a correlation between saliva and serum for OT, though a previous study found a correlation of 0.59 in an earlier assay kit (Grewen, Davenport, & Light, 2010). E and P concentrations were only measured for normally ovulating women in this sample (N=32 and 31, respectively, after accounting for missing data). Mean intra-assay coefficients of

variation (CVs) for E and P were 6.58% and 14.52%, respectively, and inter-assay CVs were 2.68% and 4.83%. For OT, mean intra-assay CV was 8.66% for men, and 14.56% for women. The mean inter-assay CV was 14.5% for men, and 14.6% for women.

Skewness statistics indicated highly skewed distributions for average OT in both men and women (3.39 and 6.72, respectively). Therefore, log-transformed average OT values were used in all subsequent analyses.

During the process of performing OT assays on women's samples, the assay manufacturer changed the detection antibody used in the assay kits. As a result, 44 samples (all provided in the initial questionnaire session) were measured with a newer assay antibody (as were all men's samples), though the majority of the women's samples were measured with the old antibody. The two different antibodies yielded highly different means and standard deviations for women's initial OT measurements, $t(62) = 9.40$, $p < .001$. However, using these groups to compare OT measurements for women at other time points (i.e., when the same antibody was used) showed similar means (second sample: $t(71) = .21$, $p = .84$; third sample: $t(59) = .39$, $p = .70$), indicating a similar distribution of true values. Thus, the 44 values from the new antibody were transformed to match the scale of the initial OT measurements from the old antibody; that is, they were assigned the same mean and standard deviation as values from the first OT sample measured with the old antibody. These transformed values were used in all analyses. One consequence of this transformation, where men and women were effectively measured on different scales, is a very large sex difference in average OT values, $t(147) = 6.63$, $p < .001$; though some of this difference may be real, most of it is likely an artifact of the different assays. To prevent this from biasing subsequent analyses, both OT variables (the

baseline average and the change) were transformed into *z*-scores within sex, which eliminated the main effect for sex.

One plate using the new assay kit, containing only four measurements, yielded the three largest values for women's first OT measurements. The odds of this occurring by chance are approximately .0003 $\left({}^{3}/_{44}{}^{3} \times {}^{41}/_{44}\right)$. In addition, the strong correlation between the first and second OT measurements for these 40 samples, .52, was reduced to .20 after including these four measurements. Therefore, I elected to drop these four values, as there is strong evidence that this plate yielded unreliable measurements.

The assay instructions for OT recommend an extraction step, which is designed to eliminate interfering substances that might also react with the assay antibody and lead to biased measures of OT concentration. McCullough et al. (2013) argue that extraction is necessary, as unextracted samples can lead to OT measurements orders of magnitude higher than, and uncorrelated with, traditionally extracted samples. However, recent evidence indicates that the vast majority of OT in the bloodstream is bound to supposedly 'interfering' substances that are eliminated by extraction (Carter, 2014), perhaps making unextracted measurements a better estimate of circulating OT levels. The question of whether to extract or not extract is an unresolved issue within the field of OT research. To conform to traditional techniques for assaying OT, prior to participant assays, we performed a pilot assay on extracted samples from 4 individuals not participating in the study. Extracted samples led to unreliable results: CVs greatly exceeded 15%, and assays of control samples (containing a known concentration of OT) yielded invalid values. All assays for participants were thus performed on unextracted samples. Some past studies on

romantic relationships have similarly used unextracted samples (e.g. Taylor et al., 2010; Schneiderman et al., 2012). Samples were, however, concentrated up to 6x and reconstituted prior to assay, per the manufacturer's recommendations.

Statistical Analyses

The primary research questions concerned associations between OT and romantic relationship involvement. To test these relationships, I performed a series of mixed model analyses (SPSS 21.0) on individuals nested within couples, which allows for modeling of individual effects, while accounting for non-independence between members of a couple (Kenny, Kashy, & Cook, 2006). Two sets of analyses were performed: one with average OT as the dependent variable (the natural log of the mean of the first and third [i.e., baseline] measurements), and one using OT change (the difference between first and second OT measurements). I first performed an analysis using the General relationship factor (as this tested the main effect of interest), then subsequently performed separate mixed model analysis for each individual relationship factor (which acted as more exploratory analyses). Therefore, 8 total mixed models were analyzed in this step. Reports of relationship involvement from self and from the partner were entered as covariates, and acted as the main effect of interest. Initial analyses did not include relationship length as a covariate; however, I also assessed robustness of results by including relationship length, and elect to report analyses with relationship length included, given its potential to influence the functions of OT within relationships (e.g., Schneiderman et al., 2012). Exclusion of relationship length did not lead any effect to gain or lose significance. Sex was entered as a fixed factor, and sex x relationship factor interactions were tested in each analysis. Degrees of freedom for test statistics in mixed

model analyses were determined using Satterthwaite approximation, reported to the nearest whole number. Associations between participants' OT and reports of their own feelings of relationship involvement tested the first prediction (that OT is positively associated with one's own involvement in the relationship), whereas associations between participants' OT and their *partners'* report of their feelings in the relationship tested the second prediction (that OT also negatively correlates with a partner's involvement in the relationship). Sex x relationship factor interactions tested whether associations between OT and relationship factors differ between men and women.

A nearly identical set of analyses was performed for the Ellis (1998) relationship investment composites, designed to investigate associations between OT and self/partner relationship investment. In this set, however, one's report *of* their partner's investment was used in place of partners' self-reports of involvement. These analyses tested a variant of the second prediction: that OT is negatively associated with a partner's investment, *as perceived by the person whose OT is measured.*

Finally, I performed a last set of mixed model analyses (once again using sex as a fixed factor, and relationship length as a covariate) on individual subscales of relationship involvement/interest. These analyses were exploratory, and performed to assess which individual subscales were strong predictors of OT.

I also explore whether progesterone and estrogen moderate associations between OT and relationship features. I created 16 interaction variables: 2 (progesterone or estrogen) x 4 (relationship factors) x 2 (self or partner reports). Partial correlations were then calculated between the interaction variables and average OT or OT change,

controlling for relationship length and report from the other member of the relationship. Separately, hormonal contraceptive usage was also added as a fixed factor in mixed model analyses using the relationship involvement factors. This analysis tested whether contraceptive use moderated associations between measures of relationship involvement and OT.

As an additional set of exploratory analyses, I also performed mixed model analyses that assessed relationships between anxiety and OT. Associations between anxiety and OT were not hypothesized *a priori* for this study, and therefore participants did not give information regarding trait-level anxiety. However, attachment anxiety in romantic relationships (Simpson et al., 1996) and the Big Five dimension of neuroticism (a personality dimension partially measuring feelings of anxiety, worry, and fear) were both assessed, allowing for some exploratory comparisons to OT. Each of these measures of anxiety was added as a covariate in a separate analysis. Sex was entered as a fixed factor, and relationship length as a covariate, in both analyses. As with the main analyses, exclusion of relationship length did not cause any result to gain or lose significance. I elected to include relationship length as a covariate, as past research investigating attachment styles in relationships has done (e.g., Simpson, 1990).

Results

OT and Relationship Involvement General Factor

Within mixed model analyses, self-reports on the General factor strongly predicted OT change, $F(1,115) = 8.73$, $p = .004$, $\beta = .27$. In addition, partner responses on the General factor strongly negatively predicted self OT change, $F(1,115) = 7.38$, $p = .008$, $\beta = -.24$. There was no significant effect for either self or partner responses predicting average OT: $F(1,131) = 0.69$, $p = .407$, $\beta = .07$ for self responses; $F(1,131) = 0.01$, $p = .947$, $\beta = .01$ for partner responses. Neither sex x General factor interaction was significant ($F[1,103] = 1.82$, $p = .18$ for self reports; $F[1,100] = 1.25$, $p = .27$ for partner reports), indicating that neither the average nor the change in OT differed between men and women as a function of either self or partner reports of relationship involvement.

Individual Factors

Given robust effects for the General factor, I then examined effects for individual components of the general factor. Among individual composites, OT change was predicted by as self reports of Love/Bonding, $F(1,115) = 5.98$, $p = .016$, $\beta = .30$, and marginally by partner reports, $F(1,115) = 3.44$, $p = .066$, $\beta = -.20$. Self reports of sexual Passion/Responsiveness predicted OT change, $F(1,114) = 6.60$, $p = .012$, $\beta = .23$, as did partner responses, $F(1,114) = 10.76$, $p = .001$, $\beta = -.30$. Neither self nor partner reports of Trust/Satisfaction predicted OT change, $p > .05$. See table 3. As with the General factor, none of the individual factors predicted average OT, $p > .05$, and sex did not moderate the effects of self or partner reports of any individual factor.

Table 3. Effects of relationship involvement factors on OT change.

	General Factor	Love/Bonding	Trust/Satisfaction	Sexual Responsiveness/ Passion
Self Report	$F(1,115) = 8.73$† $\beta = .27$	$F(1,115) = 5.98$* $\beta = .30$	$F(1,106) = 1.27$ $\beta = .11$	$F(1,114) = 6.60$* $\beta = .23$
Partner Report	$F(1,115) = 7.38$† $\beta = -.24$	$F(1,116) = 3.44$ $\beta = -.20$	$F(1,106) = .24$ $\beta = -.05$	$F(1,114) = 10.76$† $\beta = -.30$

* = $p < .05$
† = $p < .01$

Simplified Model

In the mixed models examined thus far, self and partner reports on relationship measures receive non-zero and opposite weights in the statistical model predicting OT change. Therefore, one can reduce and simplify the statistical model by entering the self-partner discrepancy as a single variable. The effect for this difference on the General factor is highly significant, $F(1,63) = 12.09$, $p = .001$, $\beta = .30$.

For individual composites, the Love/Bonding difference is statistically significant, $F(1,67) = 5.04$, $p = .028$, $\beta = .22$, and the difference for Sexual Passion/Responsiveness is highly significant, $F(1,94) = 11.51$, $p = .001$, $\beta = .27$. The difference on Trust/Satisfaction fails to reach significance, $F(1,61) = .29$, $p = .590$, $\beta = .05$.

OT and Relationship Investment

When considering Ellis' investment composites, only one significant effect emerged. Self-reports on the third investment composite predicted OT change, $F(1,103) =$

6.45, p = .013, β = .30. Reports of a partner's investment on the same composite had a non-significant negative effect on OT change, $F(1,113) = 2.38$, p = .126, β = -.19). See Table 4. Just as with relationship involvement, analyses on average OT yielded no significant effects.

Table 4. Effects of relationship investment composites on OT change.

	Composite 1	**Composite 2**	**Composite 3**
Self Report	$F(1,121) = .26$ β = .08	$F(1,121) = .001$ β = -.003	$F(1,103) = 6.47$* β = .30
Partner Report	$F(1,121) = .01$ β = .01	$F(1,121) = .63$ β = .10	$F(1,113) = 2.38$ β = -.19

* = $p < .05$

Specific Components of Relationship Involvement

Follow-up analyses were performed to explore which individual components of relationship composites contributed most strongly to OT changes. The strongest associations with OT change were self reports of greater SEXRES ($F(1,118) = 6.51$, p = .012, β = .35) and COMMIT ($F(1,124) = 5.07$, p = .026, β = .26); OT change also associated significantly with partners' reports of greater SOCNEG ($F(1,122) = 4.04$, p = .047, β = .18).

Moderation by Estrogen or Progesterone

Tests of the estrogen/progesterone x relationship factor interaction were limited by small sample size: only 21-23 women were normally cycling, had full OT

measurements, and had full reports for a given relationship factor. Perhaps unsurprisingly, then, all of the computed interaction terms failed to reach statistical significance for either the OT change or the average, $p > .05$.

Current usage of hormonal contraceptives showed a trend towards moderating the effect of the General factor difference on OT change, $F(1,48) = 2.94$, $p = .093$, $\beta = -.21$. Women on hormonal contraceptives had a more positive relationship between the General involvement difference and OT changes. Differences on the three individual involvement factors were not moderated by contraceptive use, $p > .05$.

Anxiety

Analyses yielded a marginally significant sex x attachment anxiety interaction for the OT change, $F(1,122) = 3.12$, $p = .080$, $\beta = .16$; women showed a more negative relationship between attachment anxiety and the OT change. Analyzing sexes separately, attachment anxiety marginally predicted the OT change in women, $r(56) = -.22$, $p = .095$, but not men, $r(65) = .08$, $p = .534$.

There was an marginal main effect of anxiety for average OT, $F(1,139) = 2.72$, $p = .100$, $\beta = .14$, where in contrast greater attachment anxiety related to higher average OT. No sex x attachment anxiety emerged for average OT, $F(1,129) = 2.18$, $p = .142$, $\beta = -.12$.

There was no significant sex x neuroticism interaction for the OT change, $F(1,123) = .09$, $p = .771$, $\beta = -.03$, or average OT, $F(1,129) = .77$, $p = .432$, $\beta = .-07$. Neuroticism did not have a significant main effect on the OT change, $F(1,123) = .39$, $p = .533$, $\beta = .-06$, or average OT, $F(1,140) = .77$, $p = .196$, $\beta = .11$.

Discussion

Overview

In a sample of young romantically involved couples, I find robust associations between a short-term change in OT and a measure of overall relationship involvement from both partners. Two central predictions were supported: increases in OT across a thought-writing task correlated with self reports of high overall involvement, but also with partner reports of low overall involvement. As is implied by these individual effects, the *difference or discrepancy* between self and partner reports of overall involvement was highly significant. Exploratory analyses revealed strong effects of differences in couples' Love/Bonding and Sexual Responsiveness/Passion. Sex was not a significant moderating factor, indicating that findings did not differ significantly between men and women. Finally, neither estrogen nor progesterone showed interactive effects (though these analyses had low power to detect interactions).

Comparison to Previous OT Findings

Unlike the majority of published findings on OT and human social bonding, I did not find robust associations between average OT and the psychological variables of interest (here, romantic relationship involvement or investment). However, findings with respect to the OT change were robust and theoretically consistent. One factor accounting for the divergent findings between average OT and the OT change might be the number of potential confounds in each case. Average OT, composed of two measurements of 'baseline' OT (i.e., levels upon arriving at a laboratory session), could be influenced by many uncontrolled factors: participants may have engaged in a number of behaviors with

their partner just before the experiment (e.g., had sexual contact, argued about the relationship); they may have spent time with other close social partners; they may have needed to trust someone with a serious investment, etc. There is evidence for each of these behaviors influencing endogenous OT, but it is plausible that many other factors could also have an influence. In contrast, the only thing changing between the first and second OT measurements was the experimental thought-writing task. Any observable changes in OT that occur should therefore be a function of thinking about one's relationship with his/her partner. For this reason, the OT change arguably represents a stronger test of the current study's predictions.

Advantages of the Study

The main advantage of the current study is conceptual; together, the theoretical proposal and supporting empirical evidence provide a novel way to think about the role of romantic relationships in influencing OT. Specifically, I argue that OT functions to help orient individuals towards relationships that they subjectively perceive as important, especially when romantic partners do not share this assessment. I based this conceptualization on a review of past findings, and established frameworks for other hormones that emphasize their importance in allocating resources. From my conceptualization (i.e., the "Discrepancy Hypothesis"), two predictions followed: first, OT will increase with one's own reports of involvement (as this reflects interest in maintaining the relationship), and second, OT will increase with partners' ratings of lower relationship involvement (as this indicates a need for the invested partner to attend to the relationship). Both of these predictions were borne out using assessments of overall relationship involvement, and they extended to several more specific facets of

relationships. While preliminary, the empirical pattern of results strongly supports the proposed conceptualization. Nevertheless, replication is needed.

The conceptual foundation of this study also highlights two of its methodological innovations. First, the use of multiple relationship measures (reported by both the self and partner) allows for a detailed examination of OT within romantic pair bonds, and helps clarify past findings. Consider the seemingly straightforward question of whether OT is associated with greater relationship quality. Though this topic has already been examined previously in multiple papers, differing results have led to researchers advancing opposite conclusions. Holt-Lunstad et al. (2014) find a strong positive relationship between OT and romantic relationship quality, yet the authors believe their results appear to contradict Taylor et al. (2010), who find positive associations between relationship distress and OT. The results seem incompatible until one considers the different ways the two studies measure "relationship quality". Holt-Lunstad et al. assess relationship quality via the Dyadic Adjustment Scale (Spanier, 1976), a self-report questionnaire which largely focuses on conflict (e.g. 'How often do you and your partner quarrel?') and overall satisfaction (e.g., 'Do you ever regret that you married?'). Taylor et al. instead measure quality with the MIDUS scale of relationships (Schuster, Kessler, & Aseltine, 1990), which asks a person to report *on* their partner (e.g. "How much can you rely on them for help if you have a serious problem?", "How much do they really care about you?"). As my results show, both findings can be reconciled: OT might be associated with one's own feelings of relationship involvement, but also with a lack of involvement from the partner. Furthermore, 'relationship quality' is a multidimensional construct, which has led to a variety of measurement methods. It is hardly surprising that past findings,

measuring relationship quality in a narrow sense, have appeared inconsistent. The present results support the use of composites of relationship involvement, measuring multiple facets of relationships (e.g., sexuality, conflict, social companionship, love), in order to draw robust conclusions regarding the role of OT.

Second, the measurement of OT before and after the thought-writing task allows for the controlled elicitation of a natural OT response. Many studies (e.g., Marazziti, 2006; Taylor et al., 2010; Smith et al., 2013) have examined correlations between relationship qualities and basal OT levels, often averaging across multiple baselines. As already noted, baseline measurements of OT might be influenced by a number of factors outside the experimental setting, decreasing the power to detect an association of interest. Future studies on OT and romantic relationships could benefit from experimental designs that isolate OT changes—an approach that researchers who study OT in the contexts of nursing (e.g., White-Traut et al., 2009) and parent-child interaction (e.g., Feldman et al., 2010) have already adopted.

Limitations, Functional Interpretations, and Avenues for Future Research

The present study sought to test a particular type of framework for OT: that it, like other hormones, allocates psychological resources towards certain types of activities, and away from others. I present findings supporting the former, but not the latter. If OT allocates resources toward vulnerable relationships, what does it allocate resources against? This remains a major question for future research. Some previous findings in the literature are suggestive. One interesting administration study found that OT, compared to placebo, led men to prefer greater distance between themselves and an unfamiliar

attractive woman (Scheele et al., 2012). De Dreu et al. (2010, 2011) find that OT administration increases out-group derogation in a number of experimental tasks. Perhaps in humans, OT leads to a decreased interest in establishing and maintaining social relationships with those other than close social partners (cf. Taylor et al., 2010). Future administration studies could address this. But, considering the need to understand causes of OT as well its effects, might changes in OT alternatively reflect this decreased interest? Future research, examining OT changes after interactions with strangers versus close partners, could examine this possibility as well.

OT concentrations were measured by assaying unextracted saliva samples, which combines two methods that have been scrutinized by some OT researchers. Regarding the use of saliva samples, past evidence that saliva does not contain detectable levels of OT (Horvat-Gordon et al., 2005) has been challenged by later findings using newer, and perhaps more sensitive, assay kits (Grewen, Davenport, & Light, 2010). The manual for the newest OT assay from Enzo Life Sciences, used in the current study, lists a 90% recovery of OT from a spiked saliva sample. Saliva appears to be an acceptable medium for the measurement of OT.

Samples were not extracted prior to assay. Though this was done out of necessity, and not as part of the planned procedure, recent findings defend the use of unextracted samples (Carter, 2014). Furthermore, the assay manufacturer reports observed levels of cross-reactivity with other substances. There are only two other substances known to cross-react substantially with the OT assay: mesotocin (7%) and vasotocin (7.5%), two neuropeptides related to OT but not produced by humans. All other substances, many of which are active metabolites of OT (Carter, 2014; McCullough et al., 2013) have low

cross reactivity (<.02%). While the traditional method for assaying OT involves extraction, it is unclear what assays on unextracted samples are measuring, if not OT. McCullough et al. (2013) argue that unextracted samples yield nothing more than noise. Yet the reliable associations I find from unextracted samples (that others do as well; e.g., Taylor et al., 2010; Schneiderman et al., 2012) contradict this point.

The current study failed to find consistent interactions between estrogen/progesterone and OT. This aspect of the study was particularly limited by small sample size, and thus low statistical power. However, a larger sample may have detected an effect. In addition, some of the strongest OT associations in women were with assessments of sexual responsiveness and passion, consistent with the idea that OT is related to women's sexuality within a relationship. Finally, the effect of overall involvement discrepancy was stronger, though not significantly, in hormonal contraceptive users. The interactions between OT, ovarian hormones, and female sexuality remain an interesting topic for further research. While larger samples of normally ovulating women are ideal, future research might also consider estimating the bioactive levels of synthetic hormones within women based on the type of hormonal contraceptive used, and using these estimates as moderators of OT x relationship involvement interactions. Recent findings from a Norwegian sample, in which these estimated hormone levels interact with relationship features to predict sexual behavior, speak to the utility of such an approach (Grøntvedt et al., under review).

Bethlehem et al. (2014) discuss three different functional interpretations of mixed OT effects: 1) OT is an anxiolytic; 2) OT increases salience of social cues in general; 3) OT increases the rewards of engaging in social behaviors. My data do not speak to

psychological outcomes; rather, they examine the conditions giving rise to a natural OT response. As such, my findings cannot be directly compared to Bethlehem et al.'s interpretations. However, I do find a marginally significant sex x attachment anxiety interaction on the OT change; the negative association between anxiety and OT is stronger in women, and itself marginally significant. No such relationship exists in men. While not evidence of an anxiolytic effect, it does contribute to the literature on OT and anxiety, which examines OT as both a cause and an effect (Churchland & Winkielman, 2012). One possible interpretation of this finding is that OT increases most in women who possess a supportive, secure relationship; perhaps OT truly acts as an anxiolytic "physiological metaphor for safety" (Churchland & Winkielman, 2012). Furthermore, just as I argue above that OT changes more precisely reveal possible functions, one might argue that this association with anxiety represents strong evidence. However, such a straightforward interpretation quickly runs into difficulties. I also find that attachment anxiety associates positively with average OT. Despite this seemingly opposing finding, one could still draw a similar conclusion regarding function: for example, OT is highest in those prone to feeling worries about their relationship, because they have the greatest need for its anxiolytic effect. It is difficult to draw any strong conclusions from the present results, especially as they were not a designed aspect of the present study. More research is necessary to further investigate the relationships between OT and anxiety. For example, OT might help orient bonded individuals to their vulnerable romantic relationships, but a more proximate mechanism for this shift might be an increase or decrease in anxiety regarding the relationship. Alternatively, anxiety independent of romantic relationships might be a relatively weak predictor of an OT change. Future

research that compares OT increases from different types of tasks—for example, one that induces anxiety in a non-romantic context versus one that induces anxiety about a romantic relationship—would help address this issue.

Conclusions

Within the past decade, OT has become a hot topic for psychological research, and with good reason. An extensive body of findings across a number of species suggests that the hormone is part of the physiological scaffolding that makes close social relationships possible. However, excitement regarding the discovery of a potential 'love molecule' has been tempered by inconsistent findings and the struggle to integrate these results into a coherent theoretical framework. The current study investigates OT specifically within the context of human romantic relationships, and attempts to reconcile and build upon past findings. I show that OT is indeed important for maintaining romantic pair-bonds, but that this manifests in psychological investment from one partner that is not reciprocated by the partner. This novel conceptualization receives strong support from the current data, and yields future predictions to test. However, the current study is only one step toward developing a functional framework for OT and romantic relationships; the role of OT is still unclear in many aspects of human social bonding, and further empirical work is necessary to address these gaps in knowledge.

Appendix 1: Questionnaires on personal relationships and history

AAQ. Please indicate how you typically feel toward romantic (dating) partners *in general.* Keep in mind that there are no right or wrong answers. Use the 7-point scale provided below.

1	2	3	4	5	6	7
I strongly disagree						I strongly agree

___ 1. I find it relatively easy to get close to others.
___ 2. I'm not very comfortable having to depend on other people.
___ 3. I'm comfortable having others depend on me.
___ 4. I rarely worry about being abandoned by others.
___ 5. I don't like people getting too close to me.
___ 6. I'm somewhat uncomfortable being too close to others.
___ 7. I find it difficult to trust others completely.
___ 8. I'm nervous whenever anyone gets too close to me.
___ 9. Others often want me to be more intimate than I feel comfortable being.
___ 10. Others often are reluctant to get as close as I would like.
___ 11. I often worry that my partner(s) don't really love me.
___ 12. I rarely worry about my partner(s) leaving me.
___ 13. I often want to merge completely with others, and this desire sometimes scares them away.
___ 14. I'm confident others would never hurt me by suddenly ending our relationship.
___ 15. I usually want more closeness and intimacy than others do.
___ 16. The thought of being left by others rarely enters my mind.
___ 17. I'm confident that my partner(s) love me just as much as I love them.

How *emotionally supportive* was your mother to you when you were young (under 10)?

1	2	3	4	5	6	7
Not at all supportive						Very supportive

How *emotionally supportive* was your father to you when you were young (under 10)?

1	2	3	4	5	6	7
Not at all supportive						Very supportive

How *strict* was your mother of you when you were young?

1	2	3	4	5	6	7
Not at all strict						Very strict

How *strict* was your father of you when you were young?

1	2	3	4	5	6	7
Not at all strict						Very strict

How often did your parents fight when you were young?

1	2	3	4	5	6	7
They never fought						They fought all the time

Did your parents' relationship have a lot of problems when you were young?

1	2	3	4	5	6	7
Few or minor problems						Many and/or serious problems

For the following statements please write the number that portrays **you** the best in the space provided.

1 2 3 4 5 6 7
Strongly Disagree Strongly Agree

_____1. Members of the opposite sex notice me.
_____2. Members of the opposite sex are *not* very attracted to me.
_____3. Members of the opposite sex are attracted to me.
_____4. Members of the opposite sex are *not* very interested in me.
_____5. Members of the opposite sex are interested in me.
_____6. Relative to my peer group, I consider myself (1=much less, 7= more attractive).

For the following statements please write the number that portrays **your partner** the best in the space provided. (Use the same 1-7 scale as that above.)

_____1. Members of the opposite sex notice him/her.
_____2. Members of the opposite sex are *not* very attracted to him/her.
_____3. Members of the opposite sex are attracted to him/her.
_____4. Members of the opposite sex are *not* very interested in him/her.
_____5. Members of the opposite sex are interested in him/her.
_____6. Relative to his peer group, I consider him/her (1=much less, 7= more attractive).

Who is more passionate in your relationship? (Check one)
_____ I am more passionate about my partner than my partner is about me
_____ My partner is more passionate about me than I am about her
_____ We are equally passionate about each other

If one of you were to break off the relationship, who do you think is more likely to do so? (Check one)
_____ I am more likely to break off the relationship
_____ My partner is more likely to break off the relationship
_____ We are equally likely to break off the relationship

Are you currently infatuated with more than one person? (Circle one) Yes No

For the following questions, use this scale:

1 2 3 4 5 6 7
Not at all Very

_____ How <u>likely</u> do you think the possibility is that your partner is going to leave you for another person?
_____ How much do you <u>worry</u> about the possibility that your partner would leave you for another person?
_____ How <u>likely</u> do you think the possibility is that your partner would have a sexual relationship behind your back without ever telling you?
_____ How much do you <u>worry</u> about the possibility that your partner would have a sexual relationship behind your back without ever telling you?
_____ If your partner ever were sexually unfaithful to you, how important would it be to you to find out?

Do you do these things with your partner?

Instructions: Using the scale below, rate how often you perform each of the following behaviors. Think only of the last six months. (If your relationship has lasted less than six months, than rate how often you have behaved in each of the specified ways during the time you have been together.) If a question simply does not apply to you, then please mark N.A. (Not Applicable)

Use This Scale:
0 = Never
1 = Seldom
2 = Sometimes
3 = Fairly Often
4 = Very Often
NA = Not Applicable

How often do you do this?

_____ 1. I make and discuss plans for our future
_____ 2. I act rudely toward my partner
_____ 3. I avoid doing things with my partner's family
_____ 4. I want to have sex with my partner
_____ 5. I pay for our evening entertainment
_____ 6. I refer to my partner publicly as my boyfriend/girlfriend
_____ 7. I flirt with other men/women in front of my partner
_____ 8. I start arguments with my partner over trivial issues
_____ 9. I am sensitive to my partner's needs
_____ 10. I take my partner out to eat at restaurants
_____ 11. I bring my partner to my family gatherings
_____ 12. I talk about the attractiveness of other men/women in my partner's presence
_____ 13. I make sure my partner doesn't have to go out alone at night
_____ 14. I make a special effort to spend time with my partner
_____ 15. I desert my partner at parties
_____ 16. I ask for my partner's opinion about things
_____ 17. I lie to my partner about important things
_____ 18. I share my feelings with my partner
_____ 19. I comfort my partner when he/she is distressed
_____ 20. I break plans with my partner to go out with my friends
_____ 21. I display concern for my partner's problems
_____ 22. I tell my partner little lies then try to wiggle out of them
_____ 23. I try to please my partner sexually
_____ 24. I ignore my partner in social settings
_____ 25. I escort my partner in potentially dangerous situations (such as walking him/her home at night)
_____ 26. I try to deceive my partner
_____ 27. I trust my partner with secrets that I do not want anyone else to know
_____ 28. I am willing and able to express my thoughts to my partner
_____ 29. I buy my partner gifts
_____ 30. I have sexual intercourse with my partner
_____ 31. I call my partner at unexpected times to see who he/she is with
_____ 32. I expect my partner to change his/her habits to please me
_____ 33. I prefer to spend my free time with my friends rather than with my partner
_____ 34. I pretend in public that my partner and I are just friends
_____ 35. I talk in the inclusive "we"
_____ 36. I look at other men/women when we go out together
_____ 37. I cancel dates with my partner at the last minute
_____ 38. I don't pay attention to my partner when we are around my friends
_____ 39. I refuse to have sex with my partner

Instructions: Do these statements describe you? Using the scale below, indicate whether you agree or disagree with each one.

Use this scale:

1	2	3	4	5
Strongly disagree		Neutral (neither agree nor disagree)		Strongly agree

_____ 1. I respect what my partner has to say.
_____ 2. I spend a lot of time with my partner
_____ 3. I fail to show an interest in my partner's daily life
_____ 4. When I talk about my future, my partner is always in it.
_____ 5. I enjoy my partner's family gatherings
_____ 6. I don't like to pay for our dates
_____ 7. With my partner, I am a willing and enthusiastic sexual partner
_____ 8. I don't discuss the idea of commitment with my partner
_____ 9. When it comes to spending money on my partner, I am a cheapskate
_____ 10. It doesn't bother me if my partner socializes with other women/men
_____ 11. I cannot seem to find time for my partner
_____ 12. At parties I do not let my partner out of my sight
_____ 13. I don't like to hear about my partner's problems
_____ 14. I am intolerant of my partner's flaws
_____ 15. I am not sexually responsive to my partner
_____ 16. I don't talk about my feelings toward my partner
_____ 17. I don't trust my partner
_____ 18. When my partner is with me, he/she feels physically safe
_____ 19. I am warm and sympathetic in conversation with my partner
_____ 20. I do not become jealous when my partner spends his/her free time with other people
_____ 21. I won't discuss the future with my partner
_____ 22. I do not get along well with my partner's parents
_____ 23. I try to change my partner's personality

Does your partner do these things?

Instructions: Using the scale below, rate how often your partner performs each of the following behaviors. Think only of the last six months. (If your relationship has lasted less than six months, than rate how often your partner has behaved in each of the specified ways during the time you have been together.) If a question simply does not apply to you, then please mark N.A. (Not Applicable)

Use This Scale:
0 = Never
1 = Seldom
2 = Sometimes
3 = Fairly Often
4 = Very Often
NA = Not Applicable

How often does your partner do this?

_____ 1. He/she makes and discusses plans for our future
_____ 2. He/she acts rudely towards me
_____ 3. He/she avoids doing things with my family
_____ 4. He/she wants to have sex with me
_____ 5. He/she pays for our evening entertainment
_____ 6. He/she refers to me publicly as his girlfriend/boyfriend
_____ 7. He/she flirts with other women/men in front of me
_____ 8. He/she starts arguments with me over trivial issues
_____ 9. He/she is sensitive to my needs
_____ 10. He/she takes me out to eat at restaurants
_____ 11. He brings me to his family gatherings
_____ 12. He/she talks about the attractiveness of other women/men in my presence
_____ 13. He/she makes sure I don't have to go out alone at night
_____ 14. He/she makes a special effort to spend time with me
_____ 15. He/she deserts me at parties
_____ 16. He/she asks for my opinion about things
_____ 17. He/she lies to me about important things
_____ 18. He/she shares his feelings with me
_____ 19. He/she comforts me when I am distressed
_____ 20. He/she breaks plans with me to go out with his friends
_____ 21. He/she displays concern for my problems
_____ 22. He/she tells me little lies then tries to wiggle out of them
_____ 23. He/she tries to please me sexually
_____ 24. He/she ignores me in social settings
_____ 25. He/she escorts me in potentially dangerous situations (such as walking me home at night)
_____ 26. He/she tries to deceive me
_____ 27. He/she trusts me with secrets that he does not want anyone else to know
_____ 28. He/she is willing and able to express his thoughts to me
_____ 29. He/she buys me gifts
_____ 30. He/she has sexual intercourse with me
_____ 31. He/she calls me at unexpected times to see who I am with
_____ 32. He/she expects me to change my habits to please him
_____ 33. He/she prefers to spend his free time with his/her friends rather than with me
_____ 34. He/she pretends in public that we are just friends
_____ 35. He/she talks in the inclusive "we"
_____ 36. He/she looks at other women/men when we go out together
_____ 37. He/she cancels dates with me at the last minute
_____ 38. He/she doesn't pay attention to me when we are around his/her friends
_____ 39. He/she refuses to have sex with me

Instructions: Do these statements describe your partner? Using the scale below, indicate whether you agree or disagree with each one.

Use this scale:

1	2	3	4	5
Strongly disagree		Neutral (neither agree nor disagree)		Strongly agree

_____ 1. He/she respects what I have to say
_____ 2. He/she spends a lot of time with me
_____ 3. He/she fails to show an interest in my daily life
_____ 4. When he/she talks about his/her future, I am always in it.
_____ 5. He/she enjoys my family gatherings
_____ 6. He/she doesn't like to pay for our dates
_____ 7. With me, he/she is a willing and enthusiastic sexual partner
_____ 8. He/she doesn't discuss the idea of commitment with me
_____ 9. When it comes to spending money on me, he/she is a cheapskate
_____ 10. It doesn't bother him/her if I socialize with other men/women
_____ 11. He/she cannot seem to find time for me
_____ 12. At parties he/she does not let me out of his sight
_____ 13. He/she doesn't like to hear about my problems
_____ 14. He/she is intolerant of my flaws
_____ 15. He/she is not sexually responsive to me
_____ 16. He/she doesn't talk about his feelings towards me
_____ 17. He/she doesn't trust me
_____ 18. When I am with my partner, I feel physically safe
_____ 19. He/she is warm and sympathetic in conversation with me
_____ 20. He/she does not become jealous when I spend my free time with other people
_____ 21. He/she won't discuss the future with me
_____ 22. He/she does not get along well with my parents
_____ 23. He/she tries to change my personality

For the following questions, use the following scale:

1 2 3 4 5 6 7
Not at all extremely

_____1. How satisfied are you with your relationship?
_____2. How content are you with your relationship?
_____3. How happy are you with your relationship?
_____4. How committed are you to your relationship?
_____5. How dedicated are you to your relationship?
_____6. How devoted are you to your relationship?
_____7. How intimate is your relationship?
_____8. How close is your relationship?
_____9. How connected are you to your partner?
_____10. How much do you trust your partner?
_____11. How much can you count on your partner?
_____12. How dependable is your partner?
_____13. How passionate is your relationship?
_____14. How lustful is your relationship?
_____15. How sexually intense is your relationship?
_____16. How much do you love your partner?
_____17. How much do you adore your partner?
_____18. How much do you cherish your partner?

Given how you **currently** behave, rate how much you agree with the statement using the following scale:

1 2 3 4 5 6 7
Not at all extremely

___ 1. I have a hard time sleeping because I am thinking about my partner.
___ 2. When I am with my partner, my mind wanders to other loves I have had.
___ 3. My heart races when I hear my partner's voice on the phone.
___ 4. I feel preoccupied by my feelings for my partner.
___ 5. The last person I think of each day as I fall asleep is my partner.
___ 6. When I'm in class/at work my mind wanders to thoughts about my partner.
___ 7. I often wonder whether my partner is as passionate about me as I am about him/her.
___ 8. No matter where it starts, my mind always seems to end up thinking about my partner.
___ 9. My emotional state depends on how my partner feels about me.
___ 10. My partner's behavior has little effect on my emotional well-being.
___ 11. I remember trivial things my partner says and does.
___ 12. I spend a lot of time imagining romantic episodes with my partner.

Given how you or your partner **currently** behaves, rate how much you agree with the statement using the following scale:

1 2 3 4 5 6 7
Not at all extremely

_____ 1. I try to make my partner feel comfortable about himself/herself and how he/she feels
_____ 2. I try to make my partner feel valued as a person.
_____ 3. I try to be sensitive to my partner's feelings.
_____ 4. I really try to understand my partner's concerns.
_____ 5. I really listen to my partner when he/she talks.
_____ 6. I behave warmly toward my partner.
_____ 7. My partner tries to make me feel comfortable about myself and how I feel.

_____ 8. My partner tries to make me feel valued as a person.
_____ 9. My partner tries to be sensitive to my feelings.
_____ 10. My partner really tries really to understand my concerns.
_____ 11. My partner really listens to me when I talk.
_____ 12. My partner behaves warmly toward me.

Report of Behavior and Feelings. For the following items, please indicate the extent to which you have engaged in the behavior or feeling in the past **2 days** (48 hours). When questions ask about another man or woman, only answer regarding others of the same sex (i.e. if you are a man, answer whether you put a *man* in his place after he dissed you). Use the following scale:

0 1 2 3 4
not at all a great deal

___ 1. I had strong feelings of sexual desire.
___ 2. I felt strong sexual attraction toward my primary current partner.
___ 3. I felt strong sexual attraction toward someone other than a current partner.
___ 4. I felt sexually aroused by the sight of a very physically attractive person (not my current partner).
___ 5. I felt sexually aroused by the scent of someone (other than a primary current partner).
___ 6. I fantasized about sex with a stranger or acquaintance.
___ 7. I fantasized about sex with a current partner.
___ 8. I fantasized about sex with a past partner.
___ 9. I spent time with a current romantic partner.
___ 10. I competed with another man/woman for a woman's/man's attention.
___ 11. I acted impulsively and without caution.
___ 12. I flirted with someone other than a current partner.
___ 13. I verbally put a woman/man in her place after she/he dissed me.
___ 14. I hit a man/woman after he/she dissed me.
___ 15. I lost confidence after a man/woman insulted me.
___ 16. I initiated an argument with another man/woman.
___ 17. I came away feeling I got the upper hand after a conflict with another man/woman.
___ 18. I came away feeling the other man/woman got the upper hand during a conflict I had with him/her.
___ 19. I felt competitive with other men/women.
___ 20. I just took it when another man/woman berated me.
___ 21. I dissed a man/woman who I thought was out of line.
___ 22. I got the best of a little "one-up-manship" with another man/woman.
___ 23. Some other man/woman got the best of a little "one-up-manship" with me.
___ 24. I humiliated another man/woman.
___ 25. Some other man/woman humiliated me.

Please answer the following questions with regard to what you WANT in your relationship?

For the following questions, use this scale:

1 2 3 4 5 6 7
Not at all Extremely

____ 1. I want to be emotionally close, in ways I've never felt before.
____ 2. I want my partner to be emotionally close to me, in ways she's/he's never felt before.
____ 3. I want to be intimate with my partner and share my deepest secrets, without fear.
____ 4. I want my partner to be intimate with me, and share his deepest secrets, without fear.
____ 5. I want my partner to be affectionate with me.
____ 6. I want my partner to want me to be affectionate with him/her.

____ 7. I want to be able to know my partner like I've known no one before.
____ 8. I want my partner to know me in a deep way that no one has ever known me.
____ 9. I want to be able to fully accept and embrace my partner, with all of his/her flaws.
____ 10. I want my partner to be able to accept and fully embrace me, with all of my flaws.
____ 11. I want to be able to trust my partner, like I've never been able to trust anyone.
____ 12. I want my partner to be able to trust me, like she's/he's never been able to trust anyone.

Answer the following questions with regard to HOW MUCH OF WHAT YOU WANT YOU HAVE. (Answering '1' does not mean that you have much of this quality. It only means that you have as much as you want. Thus, if you don't feel exceptionally close to your partner, but feel as close as you really want, you could answer '1' to the first item.)

For the following questions, use this scale:

1 2 3 4 5 6 7
I am fully satisfied I want much, much more

____ 1. to be emotionally close, in ways I've never felt before.
____ 2. my partner being emotionally close to me, in ways she's/he's never felt before.
____ 3. to be intimate with my partner and share my deepest secrets, without fear.
____ 4. my partner being intimate with me, and share his/her deepest secrets, without fear.
____ 5. my partner being affectionate with me.
____ 6. my partner wanting me to be affectionate with him/her.
____ 7. be able to know my partner like I've known no one before.
____ 8. my partner knowing me in a deep way that no one has ever known me.
____ 9. to be able to fully accept and embrace my partner, with all of his/her flaws.
____ 10, my partner being able to accept and fully embrace me, with all of my flaws.
____ 11. to be able to trust my partner, like I've never been able to trust anyway.
____ 12. my partner being able to trust me, like she's/he's never been able to trust anyone.

A few more questions about your relationship. Use the following scale to indicate your level of agreement with each statement.

1 2 3 4 5 6 7
I strongly disagree I strongly agree

____ 1. My partner is the person that I would *want* to go to, to help me feel better when something bad happens to me or I feel upset.
____ 2. I make an effort to stay in contact with my partner.
____ 3. If I achieved something good, my partner is the person that I would tell first.
____ 4. My partner is the person that I would like to be able to count on to always be there for me and care about me no matter what.
____ 5. My life would be severely disrupted if my partner was no longer a part of it.
____ 6. My partner is a person whom I count on for advice.
____ 7. My partner is the first person that I think of when I have a problem.
____ 8. My partner is the person that I would *actually* go to, to help me feel better when something bad happens to me or I feel upset.
____ 9. It is important to me to see or talk with partner regularly.
____ 10. My partner is a person whom I do not like to be away from.
____ 11. My partner is the first person that I would turn to if I had a problem.
____ 12. My partner's death would have a great impact on me.
____ 13. If my partner was no longer accessible to me, I would feel greatly distressed.
____ 14. My partner is my primary source of emotional support.
____ 15. When I am away from my partner, I feel down.

____ 16. My partner is the person that I would *actually* count on to always be there for me and care about me no matter what.

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