Biological Psychology 88 (2011) 223–226

Contents lists available at SciVerse ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

CD 38 expression, attachment style and habituation of arousal in relation to trust-related oxytocin release☆

Imre Kiss[a], Einat Levy-Gigi[b], Szabolcs Kéri[a,c,*]

[a] National Psychiatry Center, Budapest, Hungary
[b] Rutgers University, Center for Molecular and Behavioral Neuroscience, Newark, USA
[c] University of Szeged, Faculty of Medicine, Department of Physiology, Szeged, Hungary

ARTICLE INFO

Article history:
Received 7 May 2011
Accepted 12 August 2011
Available online 3 September 2011

Keywords:
Oxytocin
CD38
Trust
Attachment
Skin conductance response
Autonomic arousal

ABSTRACT

Oxytocin plays an important role in human attachment, trust, social perception, memory, and fear regulation. Evidence suggests that CD38, a regulator of oxytocin release, may also be critical in these processes. The purpose of this study was to investigate the predictors of plasma oxytocin level measured after a task requiring intimate trust (secret sharing), modeling psychotherapeutic processes, and a neutral social interaction. Results revealed that peripheral CD38 expression positively predicted both trust-related and trust-unrelated oxytocin levels. In addition, habituation of arousal, as measured by skin conductance response, and attachment anxiety also emerged as predictors of oxytocin level in the trust-related condition. These results suggest that CD38 plays a general role in oxytocin secretion, whereas habituation of arousal and attachment anxiety are specifically related to situations involving intimate trust.

1. Introduction

After decades of extensive research using animal models, it is proposed that oxytocin may play a definitive role in human social behavior (Ebstein et al., 2010; Insel, 2010). The leading assumption is that oxytocin is crucial for pro-social and cooperative behavior based on trust and perceived trustworthiness (Campbell, 2008, 2010; Heinrichs et al., 2009; Meyer-Lindenberg, 2008). Jin et al. (2007) reported that CD38, a transmembrane glycoprotein extensively expressed on lymphocytes and macrophages, participates in the regulation of central oxytocin release and in social behavior in mice. Specifically, CD38 knockout mice showed deficits in maternal nurturing, social behavior and memory, and decreased plasma level of oxytocin (Jin et al., 2007). Human studies have revealed a positive correlation between the expression of CD38 in peripheral lymphoblasts and social skills in people with autism–spectrum disorders, which was associated with polymorphisms of the CD38 gene (Ebstein et al., 2009; Lerer et al., 2010). The most likely explanation is that the CD38/cADP-ribose system acts as a modulator of intracellular messengers in the hypothalamic-neurohypophysial system, affecting neurotransmitter- and depolarization-induced oxytocin release (Salmina et al., 2010).

Although oxytocin is often considered as a mediator of positive social behavior, such as trust and bonding, there are novel data delineating a more sophisticated and multi-faceted scenario (Campbell, 2010). For example, increased oxytocin release after experimental exposure to social stress was more pronounced in people who experienced trauma during their childhood (Pierrehumbert et al., 2010). In addition, higher oxytocin levels may indicate disturbed pair–bond relationships in women (Tabak et al., 2011; Taylor et al., 2010). It is important to consider, however, that baseline oxytocin levels show a wide variety, whereas induced oxytocin levels (e.g., during a social interaction) are more predictable; the most appropriate way is to compare changes relative to the baseline and to take into consideration both baseline and induced oxytocin levels (Kéri et al., 2009; Kéri and Kiss, 2011; Zak et al., 2005).

The effect of intranasally administered oxytocin on social behavior is context-dependent (Alvares et al., 2010). Furthermore, oxytocin elicits negative social emotions (e.g., envy) (Shamay-Tsoory et al., 2009) and increases fear recognition (Fischer-Shofty et al., 2010). Bartz et al. (2010) found that intranasal oxytocin *decreased* trust and cooperation in patients with borderline personality disorder. These findings may suggest that the effect of oxytocin depends on attachment style; in rejection-sensitive and anxiously attached people, oxytocin may have an opposite effect to that observed in people with stable attachment.

☆ The study was supported by the Hungarian Research Fund (OTKA NF72488).
* Corresponding author at: University of Szeged, Department of Physiology, Dóm sq. 10, H6720, Szeged, Hungary. Tel.: +36 20 448 3530; fax: +36 62 545 842.
E-mail address: keri.szabolcs.gyula@med.u-szeged.hu (S. Kéri).

0301-0511/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.biopsycho.2011.08.005

Table 1
Descriptive statistics of the variables.

	Mean	Standard deviation
Age (years)	30.7	8.0
Education (years)	12.2	3.6
Beck anxiety	7.6	4.9
Attachment anxiety	2.8	1.4
Attachment avoidance	2.9	1.5
Oxytocin – trust (pg/ml)	294.2	121.3
Oxytocin – non-trust (pg/ml)	221.8	93.5

In our previous study (Kéri and Kiss, 2011), we explored the relationship between plasma oxytocin level after a task requiring intimate trust (secret sharing) and habituation of autonomic arousal (skin conductance response). We found that plasma oxytocin was elevated after the trust-related task, but it was strongly related to the baseline degree of habituation, that is, stronger habituators with less arousal exhibited a more pronounced elevation of oxytocin (Kéri and Kiss, 2011). A possible explanation of these results may be that more aroused people are less able to respond to social stimulation with an increased oxytocin release.

The present study was designed to address two hypotheses. The first assumption was that attachment style is related to the habituation of arousal and to oxytocin release during a trust-related task. Specifically, we expected that anxiously attached people show less baseline habituation (more intensive arousal) and lower oxytocin levels in a trust game. Second, we investigated how peripheral expression of CD38 is related to trust-related and trust-unrelated oxytocin levels. The specific hypothesis was that a less marked expression of CD38 in peripheral lymphocytes will be associated lower oxytocin level in the trust game.

2. Methods

2.1. Participants

Eighty two healthy volunteers with negative history of mental disorders were recruited by using community and acquaintance networks (Table 1). The assessment of attachment style, state anxiety, and orienting response was carried out before plasma oxytocin measurements. In the two consecutive days of the experiment, a trained clinical psychologist monitored the mood and stress level of the participants in order to exclude major changes. The study was approved by the local ethics board. All participants received and signed a written consent form before the beginning of the experiment.

2.2. Oxytocin measurements during the trust game

We followed the method used in our previous studies (Kéri et al., 2009; Kéri and Kiss, 2011). Volunteers were told that they participate in a psychological assessment, which consists of an interview, scales, skin conductance measurements, and a "secret sharing" game that models intimate correspondence and processes experienced during psychotherapy.

Both oxytocin measurements were performed in the same period of the day (9–10 a.m.). On the first occasion, participants were asked to write a neutral statement on a piece of paper and to give that to the experimenter. The experimenter then gave his own neutral written message to the participant. Both of them read the message. Immediately after this, venous blood sample was taken. Blood samples were drawn from the antecubital vein using a sterile vacuum blood collection system (ZheJiang Gongdong Medical Plastic Factory, China). The blood was placed in refrigerated centrifuges. Tubes containing plasma and serum were placed on dry ice and transferred to a −70 °C freezer. Plasma oxytocin was measured using an ELISA assay (Oxytocin EIA Kit, Assay Designs, Ann Arbor, MI). The inter- and intra-assay coefficients of variation were 3.4% and 4.6%, respectively.

On the second occasion, participants were requested to write down an important secret of their life. Then the experimenter responded by writing down a secret, and then both of them read the messages. According to our previous studies using psychometric measures (Kéri et al., 2009), this action required trust and trustworthiness. Immediately after the response, venous blood sample was drawn again, as described above. The whole social interaction, including the introduction of participant and experimenter, a brief interview, collection of demographic data during a conversation, description of task structure and instructions, and written information exchange between participant and experimenter required 50–60 min, which is, in accordance with our previous studies (Kéri et al., 2009; Kéri and Kiss, 2011), sufficient to elicit an oxytocin response. The messages were anonymously evaluated by two independent raters in order verify whether they contained neutral statements or secrets. Only those trials were included in the data analysis in which both raters made consistent judgments on the messages (Kéri et al., 2009).

2.3. Orienting response and habituation of arousal

We placed silver/silver chloride electrodes on the index and middle fingers of the dominant hand of the participants. After a 5 min baseline recording, we presented 10 consecutive tones binaurally through headphones (80 dB, 800 Hz). The inter-stimulus interval varied between 40 and 80 s. Skin conductance response was recorded during the baseline period and during the orienting response to the tones. The orienting response was measured in a latency window of 0.5 s after stimulus offset. The amplitude threshold was 0.05 μS.

The habituation index was calculated in the following way: the orienting response amplitude of the third trial was subtracted from the amplitude of the first trial (habituation is the most pronounced during the first three trials). Positive values of the index indicate normal strong habituation, whereas zero or negative values indicate weak habituation. For methodological details, see Kéri and Kiss (2011).

2.4. Measurement of relative CD38 gene expression

We used a real-time reverse transcription-PCR assay for the measurement of the expression of CD38 and GADPH (glyceraldehyde 3-phosphate dehydrogenase) genes (ABI Prism 7000 Sequence Detection System, Applied Biosystems) (Jamroziak et al., 2009). Total RNA was extracted from peripheral blood lymphoblasts (Trizol, Invitrogen, Life Technologies, Inc.) (Lerer et al., 2010). The RNA – cDNA transformation was performed using the SuperScript II RNase Transcriptase System (Invitrogen, Life Technologies). After a triplicate amplification of the cDNA, the following samples were prepared: 0.3–0.3 μmol/L of forward and reverse primer, fluorescent probe, and 50 μL qPCR Mastermix for SYBR Green I (Eurogentec). The primers for CD38 and GADPH were as follows: 5′-CAGCAACCCTGTTTCAGT-3′; 5′-TTGAGCATCACATGGACCAC-3′ (CD38) and 5′-AGCCACATCGCTGAGACA-3′; 5′-GCCCAATACGACCAAATCC-3′ (GADPH). Incubation was performed at 50 °C for 2 min and at 95 °C for 10 min. The samples were cycled at 95 °C for 30 s, 56 °C for 1 min, and 72 °C for 1 min (40 cycles). We used the critical threshold (C_t) to quantify mRNA (SYBR Green I fluorescence emission, ABI Prism 7000, SDS Software). CD38 was normalized to GADPH using the DDC_t method (Jamroziak et al., 2009).

2.5. Assessment of attachment style and anxiety

We used the Experience in Close Relationship (ECR) scale (Brennan et al., 1998). This scale is a self-report instrument that was designed and validated to measure attachment anxiety and avoidance in adults. The ECR consists of 36 items, 18 for attachment anxiety (sensitivity to and anxiety about rejection and abandonment) and 18 for attachment avoidance (discomfort with and desire to avoid closeness and intimacy). Participants are asked to use a 7-point scale to indicate whether they agree or disagree with the statements of items, which are related to the subjective personal experience of close relationships. In addition, each participant answered the Beck Anxiety Inventory (BAI) (Beck et al., 1988).

2.6. Data analysis

The STATISTICA (version 9) software (StatSoft Inc., Tulsa, USA) was used for data analysis. All data were checked for normality of distribution using Kolmogorov–Smirnov tests. Pearson product-moment correlation coefficients were calculated among age, education, BAI, attachment style, habituation index, and oxytocin plasma levels in the trust-related and trust-unrelated conditions. Predictors of trust-related and trust-unrelated oxytocin levels were calculated using forward stepwise linear regression analyses. In two separate regression analyses, the dependent variables were trust-related and trust-unrelated oxytocin levels, whereas the independent variables (predictors) were age, BAI, mean-centered attachment style scores, habituation index, and CD38 expression. We also calculated the predictors of oxytocin response, which was the difference of trust-related and trust-unrelated oxytocin levels. Oxytocin levels from trust-related and trust-unrelated conditions were compared with two-tailed t tests. The level of statistical significance was set at alpha < 0.05.

3. Results

3.1. Descriptive statistics and correlations

The summary of descriptive statistics is shown in Table 1. As expected, there was a significantly increased oxytocin level in the trust-related condition (mean: 294.2 pg/ml, SD = 121.3) relative to the trust-unrelated condition (mean: 221.8 pg/ml, SD = 93.5) ($t(162) = 4.28$, $p < 0.001$).

Table 2
Correlations among the variables.

	Age	Education	BAI	AtAnx	AtAvoid	HI	OT (non-trust)	OT (trust)
Education	−0.10							
BAI	−0.05	−0.15						
AtAnx	0.14	−0.03	0.01					
AtAvoid	−0.06	−0.06	0.15	0.29*				
HI	−0.01	−0.03	−0.51*	0.10	0.06			
OT (non-trust)	−0.21	−0.20	−0.09	0.21	0.48*	0.16		
OT (trust)	−0.15	−0.19	−0.14	0.45*	0.25*	0.47*	0.62*	
CD38	−0.04	−0.20	−0.13	0.11	0.06	0.24	0.42*	0.53*

AtAnx – attachment anxiety, AtAvoid – attachment avoidance, BAI – Beck Anxiety Inventory, HI – habituation index, OT – oxytocin.
* $p < 0.05$, Pearson product-moment correlation coefficients.

Table 2 depicts the correlations among the variables. Both trust-related and trust-unrelated oxytocin levels were positively correlated with CD38 expression. In addition, there was a positive relationship between trust-related oxytocin level and habituation, attachment anxiety, and attachment avoidance. Regarding the psychological measures, trust-unrelated oxytocin level was correlated only with attachment avoidance (Table 2).

3.2. Predictors of oxytocin level in the trust game

In the second part of the data analysis, we investigated the predictors of trust-related oxytocin level. The forward stepwise linear regression analysis revealed significant predictive effects for CD38 expression (step 1) (b* [CD38] = 0.53, $R^2 = 0.27$, $F(1,80) = 31.12$, $p < 0.001$), habituation index (step 2) (b* [CD38] = 0.44, b* [habituation index] = 0.36, $R^2 = 0.39$, $F(2,79) = 26.48$, $p < 0.001$), and attachment anxiety (step 3) (b* [CD38] = 0.43, b* [habituation index] = 0.34, b* [anxious attachment] = 0.21, $R^2 = 0.42$, $F(3,78) = 20.70$, $p < 0.001$).

In a separate analysis, we investigated the interaction between attachment anxiety and attachment avoidance, entering their interaction into the regression model. This analysis indicated that attachment anxiety remained a significant predictor (partial correlation: 0.2, $t(75) = 2.57$, $p < 0.05$), whereas attachment avoidance did not reach the level of statistical significance (partial correlation: 0.04, $p > 0.5$).

3.3. Predictors of oxytocin level in the trust-unrelated condition

In the next part of the data analysis, we investigated the predictors of trust-unrelated oxytocin level. The forward stepwise linear regression analysis revealed significant predictive effects for CD38 expression (step 1) (b* [CD38] = 0.42, $R^2 = 0.16$, $F(1,80) = 16.98$, $p < 0.001$) and attachment avoidance (b* [CD38] = 0.40, b* [attachment avoidance] = 0.26, $R^2 = 0.22$, $F(2,79) = 12.53$, $p < 0.001$). When the interaction between attachment anxiety and attachment avoidance was investigated, attachment avoidance remained significant (partial correlation: 0.2, $t(75) = 2.64$, $p < 0.05$), whereas attachment anxiety was not significant (partial correlation: 0.03, $p > 0.5$).

3.4. Predictors of oxytocin response

Oxytocin response was defined as the difference between oxytocin levels in the trust-related and trust-unrelated conditions (trust-related minus trust-unrelated oxytocin mean: 72 pg/ml, SD = 96.2). We conducted a regression analysis to study the predictors of oxytocin response. The single significant positive predictor was the habituation index (b* = 0.48, $R^2 = 0.28$, $t(78) = 4.16$, $p < 0.001$).

4. Discussion

The data from the present study do not support the hypothesis that anxiously attached persons show weaker habituation of arousal and lower oxytocin levels in the trust game. In contrast, anxious attachment was associated with *increased* oxytocin release during trust-related social interaction, similarly to that found during social stress in people experiencing childhood trauma and in women with disturbed interpersonal relationship (Pierrehumbert et al., 2010; Tabak et al., 2011; Taylor et al., 2010). The exaggerated oxytocin level may be related to neuroendocrine reaction to stress and trauma-related dysregulation of the hypothalamic–pituitary–adrenal axis, which may be implicated in various forms of mental disorders (Heinrichs and Gaab, 2007). It is also possible that there is a set-point of oxytocin level, and values below or above this set-point are associated with behavioral dysregulation. Finally, oxytocin receptor functions may also play a role in the altered regulation of secretion.

Although previous studies indicated a relationship between attachment style and autonomic arousal (e.g., Dozier and Kobak, 1992; Lemche et al., 2006), in the current paradigm such relationship was not revealed; instead, autonomic arousal correlated with the actual level of anxiety. It is important to emphasize that the strength of autonomic habituation and attachment anxiety was positively correlated with the oxytocin level measured after the trust game. Contrary, trust-unrelated oxytocin level was positively associated with attachment avoidance but not with autonomic habituation, which is consistent with our previous study (Kéri and Kiss, 2011). Given the role of oxytocin in human fear, autonomic reactivity, and social cognition (Grewen and Light, 2011; Heinrichs et al., 2009; Meyer-Lindenberg, 2008), these findings may be important to predict individual differences in response to oxytocin administration (Bartz et al., 2010; Norman et al., 2011). When oxytocin response was defined as the difference between trust-related and trust-unrelated oxytocin levels, only the habituation index emerged as a significant positive predictor, highlighting the importance of the association between oxytocin response and autonomic arousal.

CD38 expression was the strongest positive predictor of both trust-related and trust-unrelated oxytocin levels, which is consistent with its role in the regulation of nanopeptide release (Jin et al., 2007). Importantly, the predictive effect of CD38 expression was not confined to the trust-related condition and it did not correlate with attachment style, which suggests a general role of CD38 in the regulation of oxytocin release. CD38 level is a stable parameter, which is not likely to change during such a short-term social interaction.

Data from animal experiments suggest that CD38 may be implicated in the development of social behavior (Higashida et al., 2010). In CD38 knockout mice, low oxytocin level was observed only after the weaning period, which changed in parallel with the age-dependent maturation of the CD38 signaling system (Higashida

et al., 2010). In humans, Munesue et al. (2010) showed that a mutation of the CD38 gene is associated with autism–spectrum disorders and lower oxytocin levels. However, none of the psychological (anxiety and attachment) and psychophysiological parameters (habituation index) correlated significantly with CD38 expression in our study, which is against its specific role in trust- and attachment-associated release of oxytocin.

Although a few studies demonstrated specific activation patterns in the human brain after oxytocin administration (e.g., Baumgartner et al., 2008; Gamer et al., 2010; Kirsch et al., 2005), it is not likely that its effect is precise in time and exhibits a high degree of anatomic specificity (Leng and Ludwig, 2008; Veening et al., 2010). Furthermore, although there is evidence from rodents that peripheral and brain oxytocin releases are coupled (Wotjak et al., 1998), this relationship is less clear in humans.

One of the most important aims for future studies is to assess the relationship between endogenously released and externally administered oxytocin as a function of attachment style, personality, and social context. Zak et al. (2005) showed that increased endogenous oxytocin level is related to trustworthiness (reciprocation of trust) during an economic trust game, whereas Kosfeld et al. (2005) found that externally administered oxytocin increases trust in a similar paradigm (see also Mikolajczak et al., 2010). However, more recent results, together with the findings of the present study, suggest that these phenomena may be modulated by social factors (Alvares et al., 2010; Declerck et al., 2010) and by individual psychological traits (Bartz et al., 2010; Luminet et al., 2011). Therefore, it is an oversimplification to label hormones as "good" or "bad" without taking into consideration the wider context. For example, De Dreu et al. (2011) demonstrated that oxytocin not only increases human in-group favoritism but also enhances out-group derogation.

The results of the present study raise several questions that should be addressed by future research. First, it is important to note that the regression–correlation design does not provide information on causal relationships. In this respect, only indirect evidence can be used from previous animal studies and human pharmacological investigations. Second, given the moderate sample size, an independent replication is necessary.

References

Alvares, G.A., Hickie, I.B., Guastella, A.J., 2010. Acute effects of intranasal oxytocin on subjective and behavioral responses to social rejection. Experimental Clinical Psychopharmacology 18, 316–321.

Bartz, J., Simeon, D., Hamilton, H., Kim, S., Crystal, S., Braun, A., et al., 2010. Oxytocin can hinder trust and cooperation in borderline personality disorder. Social Cognitive and Affective Neuroscience [Epub ahead of print], doi:10.1093/scan/nsq085.

Baumgartner, T., Heinrichs, M., Vonlanthen, A., Fischbacher, U., Fehr, E., 2008. Oxytocin shapes the neural circuitry of trust and trust adaptation in humans. Neuron 58, 639–650.

Beck, A.T., Epstein, N., Brown, G., Steer, R.A., 1988. An inventory for measuring clinical anxiety: psychometric properties. Journal of Consultant and Clinical Psychology 56, 893–897.

Brennan, K.A., Clark, C.L., Shaver, P.R., 1998. Self-report measurement of adult attachment: an integrative overview. In: Simpson, J.A., Rholes, W.S. (Eds.), Attachment Theory and Close Relationships. Guilford Press, New York, pp. 46–76.

Campbell, A., 2008. Attachment, aggression and affiliation: the role of oxytocin in female social behavior. Biological Psychology 77, 1–10.

Campbell, A., 2010. Oxytocin and human social behavior. Personality and Social Psychology Review 14, 281–295.

Declerck, C.H., Boone, C., Kiyonari, T., 2010. Oxytocin and cooperation under conditions of uncertainty: the modulating role of incentives and social information. Hormones and Behavior 57, 368–374.

De Dreu, C.K., Greer, L.L., Van Kleef, G.A., Shalvi, S., Handgraaf, M.J., 2011. Oxytocin promotes human ethnocentrism. Proceedings of the National Academy of Sciences of the USA 108, 1262–1266.

Dozier, M., Kobak, R.R., 1992. Psychophysiology in attachment interviews: converging evidence for deactivating strategies. Children Development 63, 1473–1480.

Ebstein, R.P., Israel, S., Lerer, E., Uzefovsky, F., Shalev, I., Gritsenko, I., et al., 2009. Arginine vasopressin and oxytocin modulate human social behavior. Annals of the New York Academy of Science 1167, 87–102.

Ebstein, R.P., Israel, S., Chew, S.H., Zhong, S., Knafo, A., 2010. Genetics of human social behavior. Neuron 65, 831–844.

Fischer-Shofty, M., Shamay-Tsoory, S.G., Harari, H., Levkovitz, Y., 2010. The effect of intranasal administration of oxytocin on fear recognition. Neuropsychologia 48, 179–184.

Gamer, M., Zurowski, B., Büchel, C., 2010. Different amygdala subregions mediate valence-related and attentional effects of oxytocin in humans. Proceedings of the National Academy of Sciences of the USA 107, 9400–9405.

Grewen, K.M., Light, K.C., 2011. Plasma oxytocin is related to lower cardiovascular and sympathetic reactivity to stress. Biological Psychology 87, 340–349.

Heinrichs, M., Gaab, J., 2007. Neuroendocrine mechanisms of stress and social interaction: implications for mental disorders. Current Opinion in Psychiatry 20, 158–162.

Heinrichs, M., von Dawans, B., Domes, G., 2009. Oxytocin, vasopressin, and human social behavior. Frontiers in Neuroendocrinology 30, 548–557.

Higashida, H., Lopatina, O., Yoshihara, T., Pichugina, Y.A., Soumarokov, A.A., Munesue, T., et al., 2010. Oxytocin signal and social behaviour: comparison among adult and infant oxytocin, oxytocin receptor and CD38 gene knockout mice. Journal of Neuroendocrinology 22, 373–379.

Insel, T.R., 2010. The challenge of translation in social neuroscience: a review of oxytocin, vasopressin, and affiliative behavior. Neuron 65, 768–779.

Jamroziak, K., Szemraj, Z., Grzybowska-Izydorczyk, O., Szemraj, J., Bieniasz, M., Cebula, B., et al., 2009. CD38 gene polymorphisms contribute to genetic susceptibility to B-cell chronic lymphocytic leukemia: evidence from two case–control studies in Polish Caucasians. Cancer Epidemiology, Biomarkers and Prevention 18, 945–953.

Jin, D., Liu, H.X., Hirai, H., Torashima, T., Nagai, T., Lopatina, O., et al., 2007. CD38 is critical for social behaviour by regulating oxytocin secretion. Nature 446, 41–45.

Kéri, S., Kiss, I., Kelemen, O., 2009. Sharing secrets: oxytocin and trust in schizophrenia. Social Neuroscience 4, 287–293.

Kéri, S., Kiss, I., 2011. Oxytocin response in a trust game and habituation of arousal. Physiology and Behavior 102, 221–2244.

Kirsch, P., Esslinger, C., Chen, Q., Mier, D., Lis, S., Siddhanti, S., et al., 2005. Oxytocin modulates neural circuitry for social cognition and fear in humans. Journal of Neuroscience 25, 11489–11493.

Kosfeld, M., Heinrichs, M., Zak, P.J., Fischbacher, U., Fehr, E., 2005. Oxytocin increases trust in humans. Nature 435, 673–676.

Lemche, E., Giampietro, V.P., Surguladze, S.A., Amaro, E.J., Andrew, C.M., Williams, S.C., et al., 2006. Human attachment security is mediated by the amygdala: evidence from combined fMRI and psychophysiological measures. Human Brain Mapping 27, 623–635.

Leng, G., Ludwig, M., 2008. Neurotransmitters and peptides: whispered secrets and public announcements. Journal of Physiology 586, 5625–5632.

Lerer, E., Levi, S., Israel, S., Yaari, M., Nemanov, L., Mankuta, D., et al., 2010. Low CD38 expression in lymphoblastoid cells and haplotypes are both associated with autism in a family based study. Autism Research 3, 293–302.

Luminet, O., Grynberg, D., Ruzette, N., Mikolajczak, M., 2011. Personality-dependent effects of oxytocin: greater social benefits for high alexithymia scorers. Biological Psychology 87, 401–406.

Meyer-Lindenberg, A., 2008. Impact of prosocial neuropeptides on human brain function. Progress in Brain Research 170, 463–470.

Mikolajczak, M., Pinon, N., Lane, A., de Timary, P., Luminet, O., 2010. Oxytocin not only increases trust when money is at stake, but also when confidential information is in the balance. Biological Psychology 85, 182–184.

Munesue, T., Yokoyama, S., Nakamura, K., Anitha, A., Yamada, K., Hayashi, K., et al., 2010. Two genetic variants of CD38 in subjects with autism–spectrum disorder and controls. Neuroscience Research 67, 181–191.

Norman, G.J., Cacioppo, J.T., Morris, J.S., Malarkey, W.B., Berntson, G.G., Devries, A.C., 2011. Oxytocin increases autonomic cardiac control: moderation by loneliness. Biological Psychology 86, 174–180.

Pierrehumbert, B., Torrisi, R., Laufer, D., Halfon, O., Ansermet, F., Beck Popovic, M., 2010. Oxytocin response to an experimental psychosocial challenge in adults exposed to traumatic experiences during childhood or adolescence. Neuroscience 166, 168–177.

Salmina, A.B., Lopatina, O., Ekimova, M.V., Mikhutkina, S.V., Higashida, H., 2010. CD38/cyclic ADP-ribose system: a new player for oxytocin secretion and regulation of social behaviour. Journal of Neuroendocrinology 22, 380–392.

Shamay-Tsoory, S.G., Fischer, M., Dvash, J., Harari, H., Perach-Bloom, N., Levkovitz, Y., 2009. Intranasal administration of oxytocin increases envy and schadenfreude (gloating). Biological Psychiatry 66, 864–870.

Tabak, B.A., McCullough, M.E., Szeto, A., Mendez, A.J., McCabe, P.M., 2011. Oxytocin indexes relational distress following interpersonal harms in women. Psychoneuroendocrinology 36, 115–122.

Taylor, S.E., Saphire-Bernstein, S., Seeman, T.E., 2010. Are plasma oxytocin in women and plasma vasopressin in men biomarkers of distressed pair-bond relationships? Psychological Science 21, 3–7.

Veening, J.G., de Jong, T., Barendregt, H.P., 2010. Oxytocin-messages via the cerebrospinal fluid: behavioral effects: a review. Physiology and Behavior 101, 193–210.

Wotjak, C.T., Ganster, J., Kohl, G., Holsboer, F., Landgraf, R., Engelmann, M., 1998. Dissociated central and peripheral release of vasopressin, but not oxytocin, in response to repeated swim stress: new insights into the secretory capacities of peptidergic neurons. Neuroscience 85, 1209–1222.

Zak, P.J., Kurzban, R., Matzner, W.T., 2005. Oxytocin is associated with human trustworthiness. Hormones and Behavior 48, 522–527.