Oxytocin amplifies sex differences in human mate choice

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Keywords: oxytocin, sex difference, mate choice, evolutionary theory, infidelity

Abstract

Infidelity is the major cause of partnership breakups across cultures and individuals with a history of infidelity are more likely to repeat it, although they may also present a greater opportunity for short-term sexual relationships. Here we have firstly investigated sex-differences in the attractiveness and perceived relationship potential of individuals who have exhibited fidelity or infidelity in a previous relationship. We also examined whether these sex differences are amplified by the neuropeptide oxytocin which promotes partner bonds but may also enhance sex-differences in social priorities. While both sexes valued faithful individuals most for long-term relationships, men were more interested in having short-term relationships with previously unfaithful individuals than women, irrespective of current relationship status. Oxytocin administration increased men's attraction to unfaithful women and wanting short-term relationships with them, whereas women became more averse to unfaithful men and instead exhibited an even greater preference for having long-term relationships with faithful ones. The oxytocin effect on relationship-choice was only found in single individuals in line with their higher priority for finding a prospective partner. Thus, oxytocin release during courtship may first act to amplify sex-dependent priorities in attraction and mate choice before subsequently promoting romantic bonds with preferred individuals.

Individuals who have previously been unfaithful in a relationship are over 3 times more likely to repeat this in subsequent ones[1], and infidelity is the most common cause of divorce[2].

Infidelity in a partner represents a long-term relationship risk to both sexes that can particularly impact negatively on females in terms of loss of support for raising offspring but for males may also increase the risk of being cuckolded and raising another male's offspring[3]. Indeed, it is argued that this difference in the perceived risk of infidelity by the sexes is reflected in women being more concerned by emotional infidelity but men by sexual infidelity[4,5]. However, while both sexes clearly prefer fidelity in a prospective long-term partner men across cultures are more likely to pursue short-term relationships and engage in casual sex in order to increase their reproductive potential[3,6], although women may also do so to maximize their chance of reproducing with more masculine men who have the highest levels of genetic fitness[7]. Rates of infidelity are highest in powerful individuals of both sexes who are also likely to have higher testosterone and therefore good genes[8]. There is also an element of social learning in mate choice: "wanting women other men want or vice versa", known as "mate choice copying"[9] which could be evidenced by knowledge that individuals have had multiple affairs. As Scott Fitzgerald wrote of Gatsby's perception of Daisy in "The Great Gatsby"[10]: "It excited him, too, that many men had already loved Daisy – it increased her value in his eyes". Overall therefore, individuals with a previous history of infidelity could be considered as more attractive for short-term relationships, due to a greater perceived potential availability for reproduction opportunities and possibly greater genetic fitness.

One potential candidate for a role in influencing sex differences in mate choice is the highly evolutionarily conserved neuropeptide oxytocin which plays a key role in the formation and maintenance of affiliative and partner bonds in a number of species[11,12], including humans[13–15], as well as in social learning[16] and conformity[17,18]. In humans, oxytocin

facilitates sex-dependent differences in social priorities, particularly in terms of positive or negative social attributes[19–21]. Oxytocin can also sex-dependently facilitate approach or avoidance behavior towards attractive strangers of the opposite sex although its effects can be modulated by relationship status[13]. However, it is currently unknown whether oxytocin may influence sex-differences in human mate-choice priorities. Here in a pre-registered, randomized, double-blind, placebo-controlled trial study involving 160 subjects (80 females, see Fig. 1), we have therefore investigated whether sex-dependent biases in patterns of mate choice revealed by knowledge of previous emotional or sexual fidelity/infidelity in men and women who are currently single, or in a committed relationship, are influenced by intranasal oxytocin administration. We used a paradigm where subjects rated attraction towards, and interest in having short- or long-term relationships with, unfamiliar men or women when presented with their face pictures paired with descriptions of examples of faithful or unfaithful behavior in a previous relationship.

We specifically hypothesized that in line with previous research the control placebo-treated group men would exhibit a greater attraction towards, and preference for having a short-term relationship with individuals who had previously been unfaithful compared to women. We also hypothesized based on previous findings that women would be more influenced by previous emotional fidelity and infidelity whereas men would be more influenced by sexual fidelity and infidelity. Finally, based on previous findings we hypothesized that oxytocin administration would amplify or even generate sex-differences in attraction to, and choice of short vs. long-term relationships with, individuals who had

exhibited examples of emotional or sexual fidelity or infidelity behavior in a previous relationship.

Results

Sex-differences on the impact of knowledge of previous fidelity or infidelity

To identify treatment-independent sex differences on evaluations of a potential partner who had previously displayed infidelity or fidelity in a relationship, we first analyzed data from the placebo control group using four-way repeated-measures ANOVAs with fidelity (fidelity vs. infidelity) and type (emotional vs. sexual) as within-subject factors and sex and relationship status as between-subject factors. For ratings of the face pictures paired with examples of fidelity or infidelity behaviors there was a significant type x sex interaction for attraction ratings ($F(1,76) = 5.308$, $p = 0.024$, $\eta^2_p = 0.065$; attraction was calculated using an average of facial attractiveness and personal liking ratings since they were highly correlated, $r = 0.829$, $p < 0.001$, but see SI for a separate analysis). Post hoc comparisons revealed that women rated men who showed emotional fidelity or infidelity more attractive than those who showed sexual fidelity or infidelity ($p = 0.004$, $d = 0.553$). An additional analysis using the attraction rating difference between emotional and sexual fidelity revealed that in comparison with men, women rated individuals exhibiting emotional fidelity significantly higher than those exhibiting sexual fidelity ($t(78)= 2.203$, $p = 0.031$, $d = 0.493$). There were no sex-differences for other ratings or the memorability of faithful or unfaithful individuals.

Analysis of mate choice for a short-term relationship in the placebo group revealed a significant fidelity x sex interaction ($F(1,76) = 4.051$, $p = 0.048$, $\eta^2_p = 0.051$). Post-hoc

111 comparisons showed that men were more interested than women in having a short-term
112 relationship with a previously unfaithful individual (p = 0.002, d = 0.739 – see Fig. 2a).
113 Indeed, 32.4 ± 3.6% (mean ± sem) of responses made by men expressed interest (i.e. "yes" or
114 "maybe" decisions) in having a short-term relationship with an unfaithful individual, whereas
115 only 17.0 ± 3.6% of responses made by women did (p = 0.004, d = 0.677 – see Fig. 2b).
116 There was also a significant fidelity x type x sex x relationship status interaction (F(1,76) =
117 4.448, p = 0.038, η^2_p = 0.055) with post-hoc tests revealing that single men preferred to have
118 short term relationships with individuals who had exhibited sexual fidelity than women (p =
119 0.022, d = 0.672). There was also a similar trend for this with long-term relationships
120 although the interaction did not achieve significance (F(1,76) = 3.861, p = 0.053, η^2_p = 0.048).
121 There were no sex differences in the percentage of responses by subjects expressing an
122 interest in having long-term relationships with faithful individuals (43.1 ± 4.8% of responses
123 by men and 47.9 ± 4.8% by women - p = 0.487). A separate analysis on female subjects
124 found no evidence for a significant influence of menstrual cycle stage (i.e. whether women
125 were at a stage representing either a high or low risk of conception) on any of the measures
126 taken (see SI).

127 Thus our findings in the placebo group demonstrate a clear sex-dependent bias in mate
128 choice with men expressing a greater interest than women in having short-term relationships
129 with previously unfaithful individuals. In addition, and in line with previous studies, we
130 found some evidence for sex-differences in responses to emotional and sexual fidelity, with
131 females finding emotionally faithful males more attractive and males being more interested in
132 having short-term relationships with faithful women who had exhibited sexual fidelity.

Effects of intranasal oxytocin on sex-differences in mate choice

To examine the effects of oxytocin on evaluations of potential partners showing previous fidelity or infidelity, five way repeated-measures ANOVAs with fidelity (fidelity vs. infidelity) and type (emotional vs. sexual) as within-subject factors and treatment, sex and relationship status as between-subject factors were performed on rating scores, recognition memory and mate choice. There was a significant fidelity x treatment x sex interaction ($F(1,152) = 8.172$, $p = 0.005$, $\eta^2_p = 0.051$) for attraction ratings. Post-hoc comparisons showed that compared to placebo oxytocin significantly increased men's attraction ratings for women who had previously been unfaithful ($p = 0.017$, $d = 0.506$), whereas it correspondingly decreased the attractiveness of unfaithful men to women ($p = 0.044$, $d = 0.446$; see Fig. 3a). Thus, unlike the placebo group, in the group treated with oxytocin there was a significant sex difference in attraction ratings for previously unfaithful individuals ($p < 0.001$, $d = 1.115$). There were no significant sex-dependent effects of oxytocin on attraction ratings given to previously faithful men ($p = 0.814$) and women ($p = 0.767$) and it did not alter the pattern of female subjects giving higher ratings than men for emotionally compared to sexually faithful individuals (type x treatment x sex interaction: $p = 0.394$; fidelity x type x treatment x sex interaction: $p = 0.998$). See Fig. S1 for facial attractiveness and personal liking ratings separately. No significant effects involving treatment and gender were found for trustworthiness or arousal ratings indicating that sex-dependent effects of oxytocin on attraction ratings were specific.

Analysis of recognition memory accuracy for faces revealed a significant fidelity x treatment x sex interaction ($F(1,148) = 4.971$, $p = 0.027$, $\eta^2_p = 0.032$; note: for this analysis 4

155 subjects were excluded due to incomplete data). Post-hoc comparisons demonstrated that
156 women in the oxytocin group were less likely than women in the placebo group to remember
157 the faces of individuals who had previously exhibited infidelity (p = 0.007, d = 0.608; see Fig.
158 3b). Oxytocin therefore effectively increased the chances that women would only remember
159 men with a history of being faithful.

160 For short-term relationship preference, analysis revealed a significant fidelity x type x
161 treatment x sex x relationship status interaction (F(1,152) = 4.384, p = 0.038, η^2_p = 0.028).
162 Post-hoc comparisons showed that oxytocin selectively increased single men's interest (using
163 a derived interest index) in having a short-term relationship with women exhibiting previous
164 sexual infidelity (p = 0.042, d = 0.518, see Fig. 4a), but not for men already in a relationship
165 (p = 0.634). In a separate confirmatory analysis which used the percentage of yes/maybe
166 responses given by single men for having a short-term relationship with sexually unfaithful
167 women we found that this increased from 29.5 ± 4.9% in the placebo group to 45.8 ± 5.0% in
168 the oxytocin group (p = 0.021, d = 0.604 – see Fig. S2). For interest in having a long-term
169 relationship there was a significant fidelity x treatment x sex x relationship status interaction
170 (F(1,152) = 5.567, p = 0.020, η^2_p = 0.035). Post-hoc comparisons showed that oxytocin only
171 increased single women's interest in having a long-term relationship with men exhibiting
172 previous fidelity of any type (p = 0.025, d = 0.700, see Fig. 4b). Once again this was
173 confirmed by a separate analysis of the percentage of yes/maybe responses made by single
174 women for having a long-term relationship with faithful men which increased from 41.7 ± 6.8%
175 in the placebo group to 64.1 ± 6.4% in the oxytocin group (p = 0.018, d = 0.699 – see Fig.
176 S2). In female subjects, menstrual cycle stage did not influence the oxytocin effects found

177 above (see SI). Thus, in terms of mate choice, oxytocin increased interest in single men for
178 having short-term relationships specifically with sexually unfaithful women, whereas for
179 single women it increased their interest in having long-term relationships with faithful men in
180 general.
181
182 **Discussion**
183 Overall, our findings demonstrate firstly that in support of our hypothesis knowledge of
184 previous fidelity and infidelity in a prospective heterosexual partner effectively reveals sex
185 differences in mate choice strategy. Thus, men in the control placebo treated group generally
186 exhibited greater interest in having a short-term relationship with previously unfaithful
187 individuals than women, and independent of relationship status. However, in the context of
188 long-term relationships we did not observe a predicted sex difference, with both sexes
189 showing an equivalent and greater preference for partners exhibiting previous fidelity. In
190 support of previous findings[4,5] women rated individuals exhibiting emotional as opposed to
191 sexual fidelity as more attractive than men, with men effectively showing the opposite
192 pattern.
193 Compared to placebo treatment, oxytocin administration firstly created sex-differences
194 in the influence that knowledge of previous fidelity or infidelity had on attractiveness ratings
195 and memory for prospective partners but importantly had no effect on potential confounders
196 such as arousal and trustworthiness ratings and effects were independent of relationship status.
197 More specifically, oxytocin increased men's attractiveness ratings of previously unfaithful
198 women but correspondingly decreased those for unfaithful men by women. Furthermore,

following oxytocin women found the face pictures of men associated with previous infidelity less memorable suggesting that they would be more likely to only remember faithful individuals. Interestingly however oxytocin did not alter the sex-specific preferences for the attractiveness ratings given to individuals who had previously exhibited emotional (female) as opposed to sexual (male) fidelity. This may reflect the fact that oxytocin effects on sex-differences were mainly in the context of interest in previous infidelity or that it may have less influence on such strongly established within-sex patterns of preference. Both the sex-differences observed in the placebo group and in response to oxytocin treatment were all medium or large effect sizes both confirming the appropriateness of the power analysis for the study (see SI) and supporting the robustness of the findings.

While oxytocin's sex-dependent effects on attraction ratings and memory for faces occurred irrespective of relationship status, those for increasing interest in having short or long-term relationships were restricted to single individuals. This finding supported our hypothesis that oxytocin would enhance current social and reproductive priorities in both sexes[20,22], with single individuals having a higher priority for seeking a potential partner. That oxytocin primarily increased single men's interest in having short-term relationships with women who had been sexually, as opposed to emotionally, unfaithful might also reflect a higher priority for gaining sexual access to females in single men. Similarly, single women's increased interest in faithful males, and decreased interest in and memory for unfaithful ones, may reflect a higher priority for avoiding potential philandering males.

Oxytocin release associated with partner bonding across species is primarily evoked by mating or sexual arousal as well as by social touch[22], and can even occur in response to visual

221 cues from the face[23]. While there is some evidence that oxytocin can increase the perceived
222 attractiveness of the faces of unfamiliar members of the opposite sex[22] our current findings
223 emphasize that its release during initial flirtation might serve to focus attention on pertinent
224 information concerning a prospective partner's behavior and history and not merely on their
225 physical appearance. Indeed, previous studies have also demonstrated that intranasal oxytocin
226 administration can potently, and sex-dependently, alter behavioral and neural responses to
227 faces when they are paired with information on positive or negative social qualities[20] and
228 reduce recognition speed for positive romantic and bonding-related words[24]. Thus, while
229 oxytocin release can ultimately promote the formation of partner bonds, it may first play a
230 key role in highlighting the attractiveness of personal characteristics in a prospective partner
231 which best match an individual's current specific priorities. It pays therefore for both sexes to
232 know first, for example, who are "stayers" and who are "strayers", as well as other salient
233 characteristics, so that oxytocin release during romantic encounters will ultimately promote
234 bonds with the most appropriate partners in terms of current mate-choice priorities.
235
236 **Methods**
237 **Participants.** 160 heterosexual subjects (80 males, age range 18-27 years) were recruited to
238 take part in a double-blind, placebo-controlled, between-subject design experiment. An initial
239 power analysis showed that with this number of subjects the study had 80.7% statistical
240 power for detecting treatment and gender effects with a medium effect size of 0.45
241 (fpower.sas). All subjects had normal or corrected-to-normal vision, were not color-blind and
242 reported no history of or current neurological or psychiatric disorders. Subjects were free of

243 regular and current use of medication and instructed to abstain from caffeine, nicotine and
244 alcohol intake the day before and on the day of the experiment. None of the female subjects
245 was pregnant or using oral contraceptives or tested at specific stages of their menstrual cycle.
246 Using date of onset of previous menses and cycle length (30.83 ± 0.37 days) provided by the
247 subjects we estimated (backward counting[25]) whether they were in follicular phase (between
248 the end of menses and ovulation, high conception risk) or luteal phase (after ovulation and
249 before the onset of menses, low conception risk) on the experimental day[7]. Eight females
250 reported having irregular menstrual cycles and were excluded for menstrual cycle related
251 analysis. The proportion in their follicular (n = 39; 22 in oxytocin group) or luteal (n = 33; 16
252 in oxytocin group; Fisher's test: p = 0.636, two-sided) phases did not differ between the
253 groups. There were no significant menstrual cycle effects found for results obtained in the
254 study itself (see SI). Both subjects who were currently single (n = 82; 39 males) and those
255 who were currently in a committed relationship of > 6 months duration (32.00 ± 2.45 months;
256 n = 78; 43 males) were included since relationship status can modulate oxytocin effects in
257 men[13,26]. All single subjects were interested in finding a romantic partner and those in a
258 relationship reported that it was a stable exclusive one (indeed subjects in a relationship
259 scored significantly higher on the passionate love scale than single subjects (102.09 ± 1.55 vs.
260 96.39 ± 1.69 - $t(158) = 2.478$, p = 0.014, d= 0.392) providing further support for their being
261 in love). All subjects signed written informed consent and received monetary compensation
262 for their participation. The study was approved by the local ethics committee at the
263 University of Electronic Science and Technology of China and was in accordance with the

latest revision of the Declaration of Helsinki. The study was also pre-registered on the NIH registration website (clinicaltrials.gov NCT02733237).

To control for potential confounds, before intranasal treatment all subjects completed a range of validated questionnaires (Chinese versions) measuring mood, personality traits and attitudes toward love, trust and forgiveness. These included: Positive and Negative Affective Schedule – PANAS[27]; NEO-Five Factor Inventory – NEO-FFI[28]; Self-Esteem Scale – SES[29]; Interpersonal Reactivity Index – IRI[30]; Autism Spectrum Quotient – ASQ[31]; Beck's Depression Inventory – BDI[32]; Leibowitz's Social Anxiety Scale – LSAS[33]; Passionate Love Scale – PLS[34]; Love Attitude Scale – LAS[35]; General Trust Scale – GTS[36]; Tendency to Forgive Scale – TTF[37]; Attitudes toward Forgiveness Scale – ATF[37]; Trait Forgivingness Scale – TFS[38]. Multivariate ANOVA on questionnaires and age showed no significant differences between the oxytocin- and placebo-treated males and females (sex x treatment interaction: all *ps* > 0.090; See Table S1).

Intranasal administration. Subjects were randomly assigned to receive intranasal administration of either oxytocin (*n* = 80, 40 males and 40 females; 40 IU; Oxytocin-Spray, Sichuan Meike Pharmaceutical Co. Ltd, China; 5 puffs of 4 IU per nostril with a 30s between each puff) or placebo (*n* = 80, 40 males and 40 females; identical sprays with the same ingredients other than the neuropeptide, i.e., glycerin and sodium chloride) following a standardized protocol[39]. In previous studies, we have found similar behavioral and neural effects of 24 and 40IU oxytocin doses, although in our studies the higher dose tends to produce more consistent results[40,41] and this was recently supported by a study from another group showing dose-dependent effects using these same doses[42]. We therefore decided to use

286 the higher 40 IU dose here to try and maximize effects. Although we could not measure
287 blood or cerebrospinal fluid oxytocin concentrations following intranasal application other
288 studies have reported that they produce only relative small increases within the general
289 physiological range[43,44]. Subjects and experimenter were blind to drug condition. In post
290 experiment interviews subjects were unable to guess better than chance whether they had
291 received oxytocin or placebo treatment (79 subjects guessed correctly; $\chi 2 = 0.025$, $p = 0.874$).
292 In line with standardized recommendations[39] and two studies reporting pharmacodynamics of
293 central effects of intranasal OXT in humans[45,46] the experimental paradigm started 45 minutes
294 after intranasal treatment. While it is currently unclear whether functional effects of
295 intranasal oxytocin are mediated via direct effects on the brain or indirectly via peripheral
296 effects, it has been established that oxytocin administered via this route does enter into the
297 brain cerebroventricular system in monkeys[47] and alters cerebral blood flow in an extensive
298 number of brain regions known to express oxytocin receptor mRNA in humans[45]. A recent
299 study comparing functional and brain effects of intranasal and intravenous oxytocin
300 administration have only found effects when it is given intranasally[48].
301 **Stimuli.** Before the formal experiment, we generated 54 sentences describing a behavior
302 indicative of fidelity or infidelity (either emotional or sexual; 12~14 sentences for each
303 behavior type) that a male or female individual had performed during a past relationship.
304 Sexual and emotional infidelity were defined as in Takahashi et al[49]. Sexual infidelity
305 (fidelity) included situations where a (or no) sexual relationship or deep physical contact with
306 other members of the opposite sex was indicated explicitly or implicitly. Emotional infidelity
307 (fidelity) included situations indicating some (or no) form of romantic emotional response or

commitment to other members of the opposite sex. Each sentence was written in Chinese, used the past tense and had male and female versions (i.e. "She……." for male subjects in the study and "He……" for female subjects). In a pre-study, an independent sample of forty volunteers (21 males) were asked to decide whether the behavior described was an example of emotional or sexual infidelity/fidelity and also to rate how strong it was using a 9-point scale. Based on the data from this pre-study, we selected 40 sentences (10 for each behavior type) with a high discrimination between sexual and emotional fidelity or infidelity (i.e. all the chosen sentences were correctly classified as representing fidelity or infidelity behaviors by the raters and with a mean accuracy of 87.6% for distinguishing emotional from sexual examples). There were no differences between male and female examples in terms of discrimination accuracy or strength (all *ps* > 0.258). Table S2 gives examples of the fidelity/infidelity behavior sentences.

Facial images of 80 males and 80 females with neutral expressions were selected from an in-house database of 260 face images following a pilot rating by 36 subjects (17 males) of valence, attractiveness, trustworthiness, likability of the faces from the opposite sex as well as how aroused they were by them. All face images were carefully edited (removing accessories or background details, but keeping hair, ears and neck) and presented in full color at a 600×800 Pixel resolution on a black background (faces life-size). All selected faces were rated as having a neutral valence (emotional valence: range 4.3-6.0; mean = 5.09). Half of the faces used for the rating task were divided randomly into four groups (i.e. 10 faces per group for each sex). Mean attractiveness, valence, trustworthiness and arousal ratings of the faces in each group did not differ significantly for both male and female faces (ANOVAs all *ps* >

330 0.964). Each group of faces was assigned for pairing with sentences describing one of the
331 four different fidelity/infidelity types. Additionally, to control for possible
332 face/sentence-group differences, the pairings of face group and sentence type were
333 randomized across individual subjects in the main study. The remaining faces were used as
334 novel stimuli in the recognition memory test and had equivalent valence, attractiveness,
335 trustworthiness, likability and arousal ratings compared to the faces paired with sentences for
336 both sexes (all *ps* > 0.727).

337 **Procedure.** The experimental task (see Fig. 1) was presented on a computer with a 27-inch
338 monitor (screen resolution: 1920*1080 pixels; refresh rate: 60 Hz). In the rating task, subjects
339 viewed neutral expression face pictures of 40 unfamiliar members of the opposite sex with
340 average attractiveness paired with verbal information describing examples of how they had
341 been either emotionally or sexually faithful or unfaithful during a previous relationship (see
342 Table S2). We included fidelity type as a factor since previous research has reported that men
343 are more influenced by sexual infidelity and women by emotional infidelity[4,5]. Subjects were
344 told that these individuals were currently single and instructed to view their faces, read the
345 sentences describing their previous behavior silently and then rate (on a 9-point scale) their
346 attractiveness, likeability and trustworthiness, and arousal elicited by them, based on their
347 overall impression of them. Next, subjects were asked whether they would like to have a
348 short- or long-term romantic relationship with the person (response options: “yes”, “maybe”
349 or “no” - see Fig.1). There was no time limitation for subjects’ responses. For the main
350 analysis, the decisions “yes”, “maybe” and “no”, were scored numerically as 2, 1 and 0
351 respectively and this was used to create an overall “Interest Index” indicating willingness to

have a relationship with the person. A separate confirmatory analysis was also performed using the percentage of "yes/maybe" responses made by subjects (see SI).

Finally, subjects completed a surprise recognition memory test for these 40 faces intermixed with another 40 novel faces (order of stimuli randomized). Each trial started with a 600-800 ms fixation cross followed by a face presented for 1500 ms and subjects responded whether the face was familiar or not without any time limitation. Four subjects had to be excluded from this part of the analysis due to technical failures during data acquisition.

Statistical Analysis. All data analyses were performed using SPSS 23.0 software (SPSS Inc., Chicago, Illinois, USA). In all cases, data from ratings, recognition memory and indicating interest in having either a short- or long-term relationship with a target individual were subjects to four (analysis of placebo group alone) or five (analysis of placebo vs. oxytocin treatment groups) factor repeated-measures ANOVAs and significant ($p < 0.05$) main effects and relevant interactions reported. Significant interactions were explored using Simple Effect Tests, which were all Bonferroni-corrected for multiple comparisons. For both ANOVAs and post-hoc tests measures of effect size are given (Partial eta squared (η^2_p) or Cohen's d). Small, medium, and large effects were represented respectively as 0.01, 0.06, and 0.14 for η^2_p, 0.20, 0.50, and 0.80 for Cohen's d[50].

References

1. Lansford, J. E. Parental divorce and children's adjustment. *Perspect. Psychol. Sci.* **4,** 140–152 (2009).
2. Knopp, K. *et al.* Once a Cheater, Always a Cheater? Serial Infidelity Across Subsequent Relationships. *Arch. Sex. Behav.* **46,** 2301–2311 (2017).
3. Buss, D. M. & Schmitt, D. P. Sexual Strategies Theory: An evolutionary perspective on human mating. *Psychol. Rev.* **100,** 204–232 (1993).
4. Buss, D. M., Larsen, R. J., Westen, D. & Semmelroth, J. Sex differences in jealousy: Evolution, physiology, and psychology. *Psychol. Sci.* **3,** 251–256 (1992).

5. Buss, D. M. Sexual and emotional infidelity: Evolved gender differences in jealousy prove robust and replicable. *Perspect. Psychol. Sci.* **13,** 155–160 (2018).
6. Oliver, B. M. & Hyde, S. J. Gender Differences in Sexuality: A Meta- Analysis. *Psychol. Bull.* **114,** 29–51 (1993).
7. Penton-Voak, I. S. *et al.* Menstrual cycle alters face preference. *Nature* **399,** 741 (1999).
8. Lammers, J. & Maner, J. Power and Attraction to the Counternormative Aspects of Infidelity. *J. Sex Res.* **53,** 54–63 (2016).
9. Place, S. S., Todd, P. M., Penke, L. & Asendorpf, J. B. Humans show mate copying after observing real mate choices. *Evol. Hum. Behav.* **31,** 320–325 (2010).
10. Fitzgerald, F. S. *The Great Gatsby*. (Charles Scribner's Sons, 1925).
11. Donaldson, Z. R. & Young, L. J. Oxytocin, Vasopressin, and the Neurogenetics of Sociality. *Science.* **322,** 900–904 (2008).
12. Cavanaugh, J., Mustoe, A. C., Taylor, J. H. & French, J. A. Oxytocin facilitates fidelity in well-established marmoset pairs by reducing sociosexual behavior toward opposite-sex strangers. *Psychoneuroendocrinology* **49,** 1–10 (2014).
13. Scheele, D. *et al.* Oxytocin Modulates Social Distance between Males and Females. *J. Neurosci.* **32,** 16074–16079 (2012).
14. Scheele, D. *et al.* Oxytocin enhances brain reward system responses in men viewing the face of their female partner. *Proc. Natl. Acad. Sci.* **110,** 20308 LP-20313 (2013).
15. Preckel, K., Scheele, D., Kendrick, K. M., Maier, W. & Hurlemann, R. Oxytocin facilitates social approach behavior in women. *Front. Behav. Neurosci.* **8,** 191 (2014).
16. Hu, J. *et al.* Oxytocin selectively facilitates learning with social feedback and increases activity and functional connectivity in emotional memory and reward processing regions. *Hum. Brain Mapp.* **36,** 2132–2146 (2015).
17. De Dreu, C. K. W. & Kret, M. E. Oxytocin conditions intergroup relations through upregulated in-group empathy, cooperation, conformity, and defense. *Biol. Psychiatry* **79,** 165–173 (2016).
18. Luo, R. *et al.* Oxytocin facilitation of acceptance of social advice is dependent upon the perceived trustworthiness of individual advisors. *Psychoneuroendocrinology* **83,** 1–8 (2017).
19. Scheele, D. *et al.* Opposing effects of oxytocin on moral judgment in males and females. *Hum. Brain Mapp.* **35,** 6067–6076 (2014).
20. Gao, S. *et al.* Oxytocin, the peptide that bonds the sexes also divides them. *Proc. Natl. Acad. Sci.* **113,** 7650–7654 (2016).
21. Luo, L. *et al.* Sex-dependent neural effect of oxytocin during subliminal processing of negative emotion faces. *Neuroimage* **162,** 127–137 (2017).
22. Hurlemann, R. & Scheele, D. Dissecting the role of oxytocin in the formation and loss of social relationships. *Biol. Psychiatry* **79,** 185–193 (2016).
23. Fabre-Nys, C., Ohkura, S. & Kendrick, K. M. Male faces and odours evoke differential patterns of neurochemical release in the mediobasal hypothalamus of the ewe during oestrus: an insight into sexual motivation? *Eur. J. Neurosci.* **9,** 1666–1677 (1997).
24. Unkelbach, C., Guastella, A. J. & Forgas, J. P. Oxytocin selectively facilitates recognition of positive sex and relationship words. *Psychol. Sci.* **19,** 1092–1094 (2008).
25. Gangestad, S. W. *et al.* How valid are assessments of conception probability in

ovulatory cycle research? Evaluations, recommendations, and theoretical implications. *Evol. Hum. Behav.* **37,** 85–96 (2016).

26. Zhao, W. *et al.* Oxytocin biases men to be more or less tolerant of others' dislike dependent upon their relationship status. *Psychoneuroendocrinology* **88,** 167–172 (2018).
27. Watson, D., Clark, L. A. & Tellegen, A. Development and validation of brief measures of positive and negative affect: the PANAS scales. *J. Pers. Soc. Psychol.* **54,** 1063 (1988).
28. Costa, P. & Mccrae, R. R. *The NEO-PI/NEO-FFI manual supplement*. (Psychological Assessment Resources, 1989).
29. Rosenberg, M. *Society and the adolescent self-image*. **11,** (Princeton university press Princeton, NJ, 1965).
30. Davis, M. H. A multidimensional approach to individual differences in empahty. *Cat. Sel. Doc. Psychol.* **40,** 3480 (1980).
31. Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J. & Clubley, E. The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, malesand females, scientists and mathematicians. *J. Autism Dev. Disord.* **31,** 5–17 (2001).
32. Beck, A. T., Steer, R. A. & Brown, G. K. *Beck depression inventory-II*. **78,** (The Psychological Corporation, 1996).
33. Liebowitz, M. R. Social phobia. in *Anxiety* **22,** 141–173 (Karger Publishers, 1987).
34. Hatfiled, E. & Sprecher, S. Measuring passionate love in intimate relations. *J. Adolesc.* **9,** 383–410 (1986).
35. Hendrick, C. & Hendrick, S. A theory and method of love. *J. Pers. Soc. Psychol.* **50,** 392–402 (1986).
36. Siegrist, M., Keller, C., Barle, T. C. & Gutscher, H. Effects of general trust on cooperation in the investment game and in a social dilemma. *Unpubl. manuscript, Inst. Environ. Decis. Zurich, Switz.* (2005).
37. Brown, R. P. Measuring individual differences in the tendency to forgive: Construct validity and links with depression. *Personal. Soc. Psychol. Bull.* **29,** 759–771 (2003).
38. Berry, J. W., Worthington, E. L., O'Connor, L. E., Parrott, L. & Wade, N. G. Forgivingness, vengeful rumination, and affective traits. *J. Pers.* **73,** 183–226 (2005).
39. Guastella, A. J. *et al.* Recommendations for the standardisation of oxytocin nasal administration and guidelines for its reporting in human research. *Psychoneuroendocrinology* **38,** 612–625 (2013).
40. Zhao, W. *et al.* Oxytocin increases the perceived value of both self-and other-owned items and alters medial prefrontal cortex activity in an endowment task. *Front. Hum. Neurosci.* **11,** 272 (2017).
41. Xu, L. *et al.* Oxytocin enhances attentional bias for neutral and positive expression faces in individuals with higher autistic traits. *Psychoneuroendocrinology* **62,** 352–358 (2015).
42. Shin, N. Y., Park, H. Y., Jung, W. H. & Kwon, J. S. Effects of Intranasal Oxytocin on Emotion Recognition in Korean Male: A Dose-Response Study. *Psychiatry Investig.* **15,** 710 (2018).

43. Striepens, N. *et al.* Elevated cerebrospinal fluid and blood concentrations of oxytocin following its intranasal administration in humans. *Sci. Rep.* **3,** (2013).
44. Quintana, D. S. *et al.* Saliva oxytocin measures do not reflect peripheral plasma concentrations after intranasal oxytocin administration in men. *Horm. Behav.* **102,** 85–92 (2018).
45. Paloyelis, Y. *et al.* A spatiotemporal profile of in vivo cerebral blood flow changes following intranasal oxytocin in humans. *Biol. Psychiatry* **79,** 693–705 (2016).
46. Spengler, F. B. *et al.* Kinetics and dose dependency of intranasal oxytocin effects on amygdala reactivity. *Biol. Psychiatry* **82,** 885–894 (2017).
47. Lee, M. R. *et al.* Oxytocin by intranasal and intravenous routes reaches the cerebrospinal fluid in rhesus macaques: determination using a novel oxytocin assay. *Mol. Psychiatry* **23,** 115 (2018).
48. Quintana, D. S. *et al.* Low dose intranasal oxytocin delivered with Breath Powered device dampens amygdala response to emotional stimuli: A peripheral effect-controlled within-subjects randomized dose-response fMRI trial. *Psychoneuroendocrinology* **69,** 180–188 (2016).
49. Takahashi, H. *et al.* Men and women show distinct brain activations during imagery of sexual and emotional infidelity. *Neuroimage* **32,** 1299–1307 (2006).
50. Cohen, J. The Effect Size index: d. in *Statistical Power Analysis for the Behavioral Sciences* 20–26 (1988).

ACKNOWLEDGEMENTS

We thank Professor Trevor Robbins for valuable discussions and suggestions on the paper and its findings. **Funding:** This project was supported by National Natural Science Foundation of Science (NSFC) grant number 31530032. **Author contributions:** LX and KMK designed the experiment. LX, RL, XZ and WZ carried out the experiment. LX, KMK, BB and QZ analyzed the experiment and LX, KMK and BB wrote the paper. All authors contributed to the conception of the study and approved the paper. **Competing interests:** The authors declare that they have no competing interests.

Figures

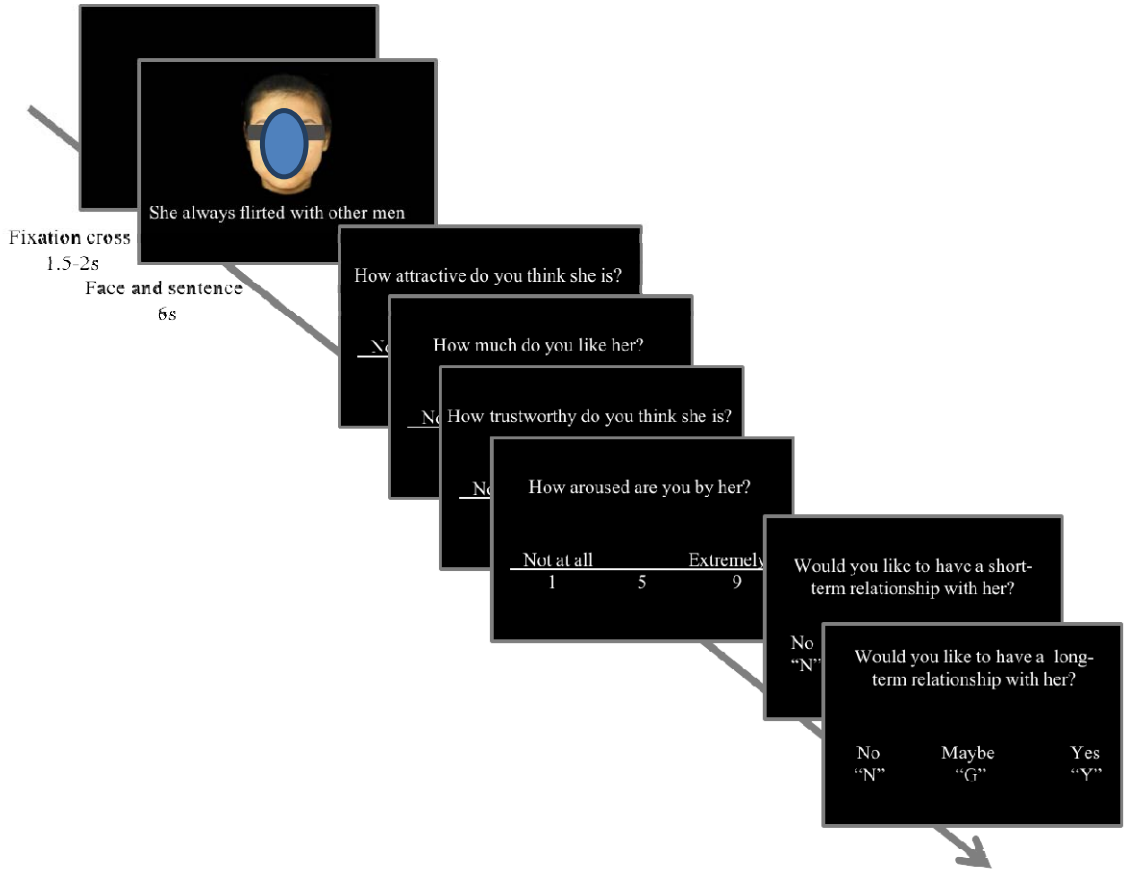


Fig. 1. Example of a single trial in the rating task. Following a 1.5~2 second fixation cross, each facial picture (unknown, opposite sex) was shown for 6 seconds and paired with a sentence describing a behavior indicative of fidelity or infidelity (either emotional or sexual) he/she exhibited during a previous relationship. Each subject viewed 10 trials for each fidelity/infidelity type - emotional fidelity, sexual fidelity, emotional infidelity and sexual infidelity. For mate choices, the decisions “yes”, “maybe” and “no”, were scored numerically as 2, 1 and 0 respectively and this was used to create an overall “Interest Index” indicating willingness to have a relationship with the person.

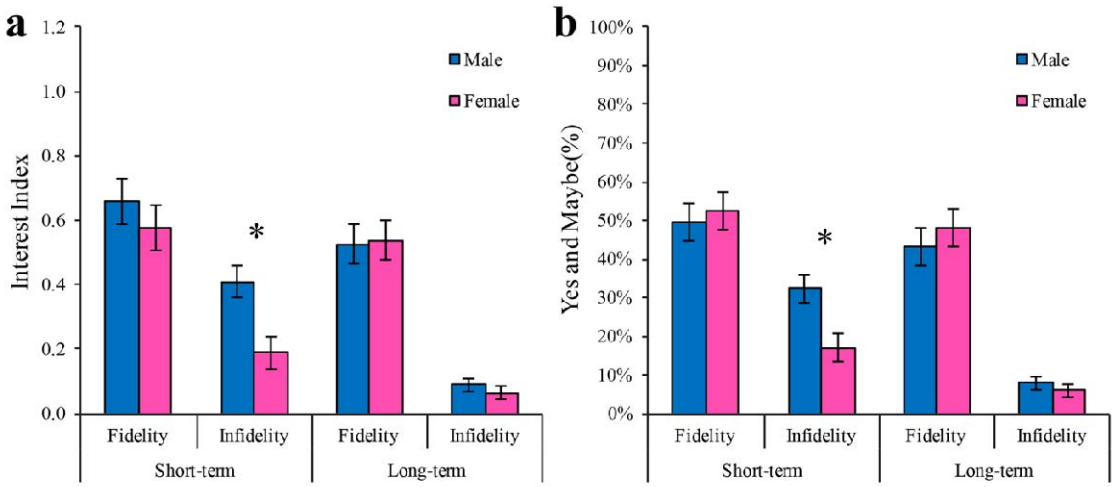
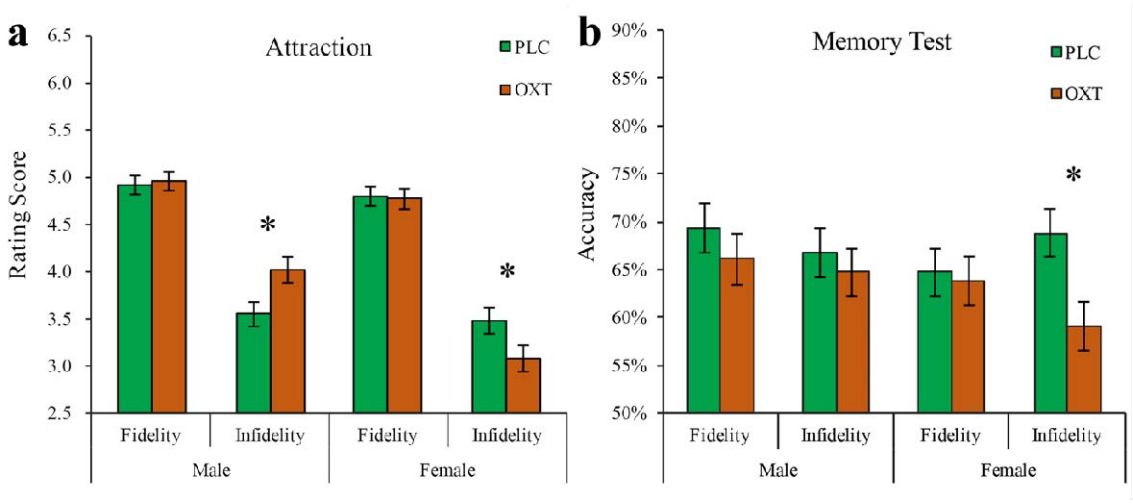


Fig. 2. Sex difference in preference for a short-term, but not long-term, relationship with individuals showing previous infidelity in the placebo (PLC) treated group. **a**, Analysis using an interest index (derived from scores from decisions made on each face, with: "yes" = 2, "maybe" = 1, "no" = 0). **b**, the percentage of yes/maybe responses made by subjects for having a relationship with individuals in the four categories. Data from single individuals and those in a relationship are combined. Bars represent means and standard errors. *$p < 0.05$ for males vs. females.



514

515 **Fig. 3.** Effects of oxytocin (OXT) on attraction (**a**) and recognition memory (**b**) for faces of the opposite

516 sex associated with previous fidelity or infidelity in all male and female subjects. Bars represent means and

517 standard errors. *$p < 0.05$ OXT vs. placebo (PLC).

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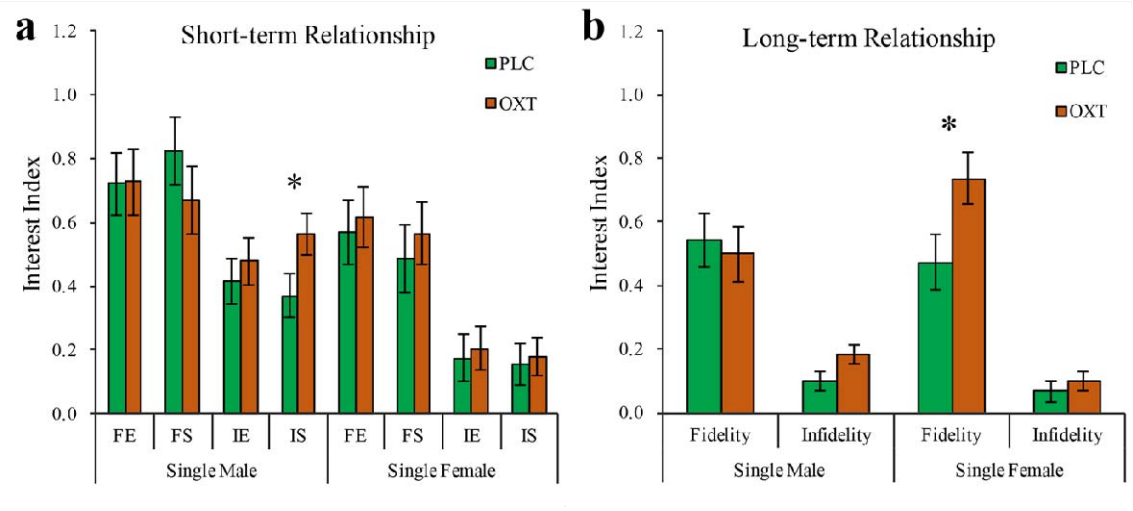

519

520 **Fig. 4.** Effect of oxytocin **(**OXT) on interest in single male and female subjects for having a short-term (**a**)

521 or long-term relationship (**b**) with an individual of the opposite sex associated with previous (emotional or

522 sexual) fidelity or infidelity (FE = emotional fidelity; FS = sexual fidelity; IE = emotional infidelity; IS =

523 sexual infidelity). The interest index is derived from scores from decisions made on each face, with: "yes"

524 = 2, "maybe" = 1, "no" = 0. Bars represent means and standard errors. *$p < 0.05$ OXT vs. placebo (PLC).

Supporting Information

Oxytocin amplifies evolutionary sex differences in human mate choice

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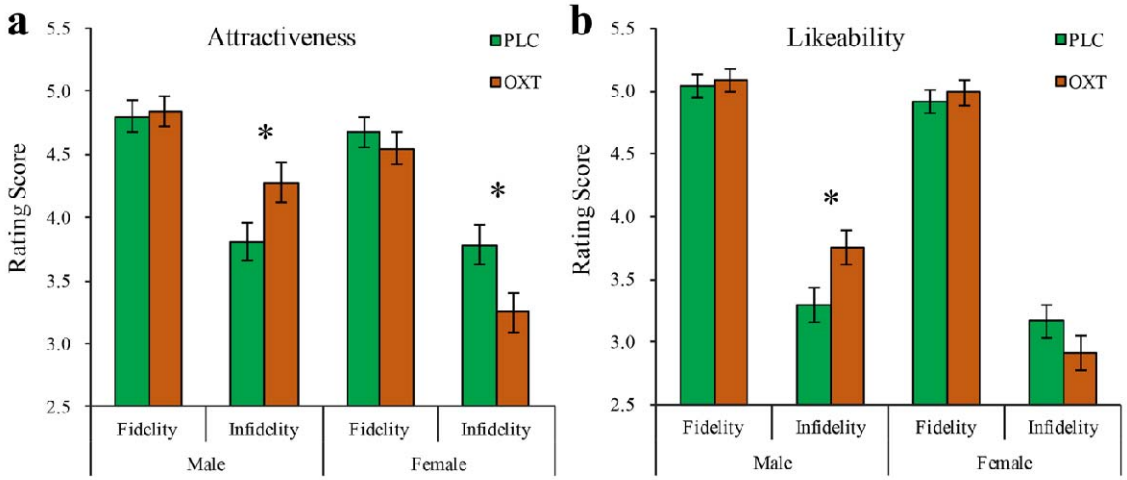
A separate analysis of face attractiveness and likeability ratings revealed similar findings to those reported in the main paper using the two combined. In placebo control group, (marginal) type x sex interactions were found for face attractiveness ($F(1,76) = 3.873$, $p = 0.053$, $\eta^2_p = 0.048$) and likeability ratings ($F(1,76) = 4.786$, $p = 0.032$, $\eta^2_p = 0.059$). Post-hoc comparisons showed that women give higher face attraction ($p = 0.071$, $d = 0.136$) and likeability ($p = 0.001$, $d = 0.366$) rating scores to men who showed emotional fidelity or infidelity than those who showed sexual fidelity or infidelity. For oxytocin effects, significant fidelity x treatment x sex interactions were found for both face attractiveness ($F(1,152) = 8.244$, $p = 0.005$, $\eta^2_p = 0.051$) and likeability ratings ($F(1,152) = 6.021$, $p = 0.015$, $\eta^2_p = 0.038$). Post-hoc comparisons showed that in men oxytocin increased both face attraction ($p = 0.032$, $d = 0.455$) and likeability of previously unfaithful women ($p = 0.016$, $d = 0.511$), while in women oxytocin decreased attractiveness ($p = 0.016$, $d = 0.529$) but not likeability ($p = 0.183$) of previously unfaithful men (see Fig. S1). There were no significant oxytocin effects on face attractiveness or likeability of previously faithful men and women (all $ps > 0.458$).

Repeated-measures ANOVAs on the percentage of “yes/maybe” responses for mate choice reveals similar finding to those reported in the main paper using interest index. In placebo control group, there was a significant fidelity x sex interaction on mate choice for a

549 short-term relationship ($F(1,76) = 10.621$, $p = 0.002$, $\eta^2_p = 0.123$, see Fig. 2). For the effect of
550 oxytocin there was a significant fidelity x type x treatment x sex x relationship status
551 interaction ($F(1,152) = 4.398$, $p = 0.038$, $\eta^2_p = 0.028$) in short-term relationship preference
552 and a significant fidelity x treatment x sex x relationship status interaction ($F(1,152) = 4.811$,
553 $p = 0.030$, $\eta^2_p = 0.031$) in long-term relationship preference were found (see Fig. S2).

554 Repeated-measures ANOVAs added menstrual cycle as a between-subjects factor in
555 female subjects suggested that the stage of their menstrual cycle did not influence our
556 findings. There were no significant interactions related to menstrual cycle for mate choice,
557 memory and rating scores in the placebo group (all *ps* > 0.089). For the effects of oxytocin
558 there were also no significant interactions involving menstrual cycle, treatment and fidelity
559 for either mate choice or rating scores or recognition memory accuracy (all *ps* > 0.128).
560



561
562 **Fig. S1.** Effects of oxytocin (OXT) on attractiveness (**a**) and likeability (**b**) for faces of the opposite sex
563 associated with previous fidelity or infidelity in all male and female subjects. Bars represent means and
564 standard errors. *$p < 0.05$ OXT vs. placebo (PLC).
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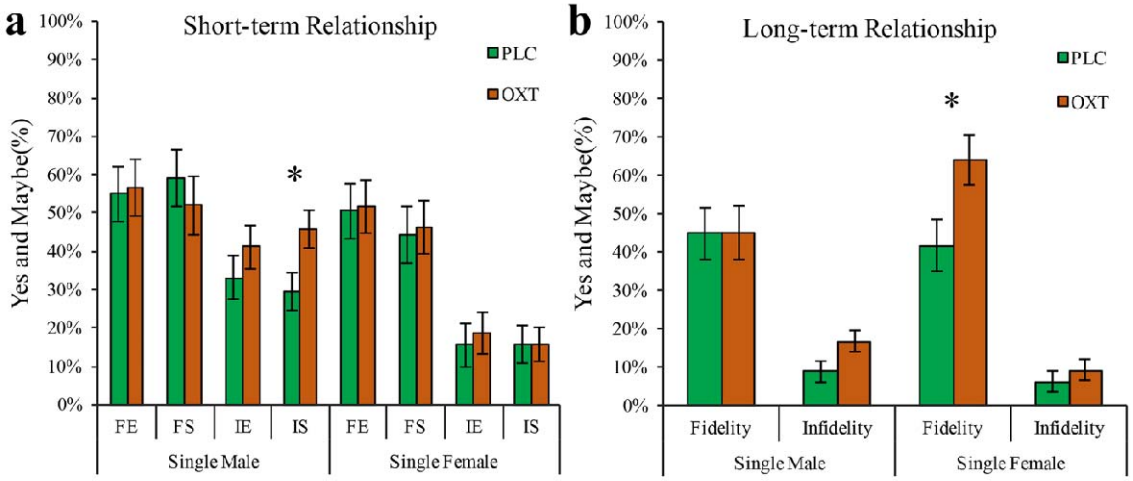

Fig. S2. Effect of oxytocin **(**OXT) on percentage of yes/maybe responses in single male and female subjects for having a short-term (**a**) or long-term relationship (**b**) with an individual of the opposite sex associated with previous (emotional or sexual) fidelity or infidelity (FE = emotional fidelity; FS = sexual fidelity; IE = emotional infidelity; IS = sexual infidelity). Bars represent means and standard errors. *$p <$ 0.05 OXT vs. placebo (PLC).

Table S1. Ages and questionnaire scores in the four experimental groups (mean±S.E.M.)

Measurements	Placebo		Oxytocin		Sex x Treatment
	Male	Female	Male	Female	*p*-value
Age(years)	23.0±0.3	22.8±0.3	22.9±0.3	22.7±0.3	0.905
Beck Depression Inventory (BDI-II)	8.2±0.8	7.9±1.2	8.9±1.2	7.2±0.9	0.516
Autism Spectrum Quotient (ASQ)	20.1±0.7	20.7±0.9	20.9±0.6	19.7±0.8	0.221
General Trust Scale (GTS)	32.0±0.5	31.6±0.6	31.1±0.6	31.8±0.7	0.380
Tendency to Forgive Scale (TFS)	32.8±0.9	32.5±0.9	32.2±0.8	30.9±1.0	0.585
Trait Forgivingness Scale (TTF)	14.4±0.5	14.3±0.5	14.1±0.6	13.9±0.7	0.896
Attitudes toward Forgiveness Scale (ATF)	28.6±0.6	27.9±0.7	27.4±0.6	26.5±0.7	0.895
Passionate Love Scale (PLS)	103.1±2.4	99.0±2.3	97.9±2.0	96.7±2.5	0.531
Self-Esteem Scale (SES)	30.5±0.7	31.3±0.6	30.5±0.6	30.8±0.8	0.755
Interpersonal Reactivity Index (IRI)	50.3±1.6	51.9±1.5	45.8±1.4	50.8±1.6	0.256
Positive and Negative Affective Scale (PANAS) -Positive	31.5±0.8	29.2±0.9	28.9±0.9	28.5±1.0	0.285
Positive and Negative Affective Scale (PANAS) -Negative	21.6±1.3	18.1±1.1	19.3±1.1	18.0±1.0	0.337
Liebowitz's Social Anxiety Scale (LSAS)-Avoid	20.9±1.9	19.1±1.8	20.7±1.4	21.5±1.9	0.476
Liebowitz's Social Anxiety Scale (LSAS)-Fear	24.3±2.0	21.6±1.6	22.6±1.5	25.3±2.1	0.143
NEO-Five Factor Inventory-Agreeableness	42.3±0.7	41.4±0.6	40.6±0.6	40.9±0.8	0.355
NEO-Five Factor Inventory-Conscientiousness	42.5±0.8	41.7±0.7	41.4±0.8	42.3±0.8	0.252

NEO-Five Factor Inventory-Extraversion	41.1±0.8	38.8±1.0	40.0±1.0	40.8±0.8	0.090
NEO-Five Factor Inventory-Neuroticism	34.2±1.3	34.5±1.1	34.4±1.1	34.1±1.2	0.770
NEO-Five Factor Inventory-Openness	40.4±0.7	38.2±0.9	39.9±0.8	39.3±0.8	0.326
Love Attitude Scale (LAS)-Agape	26.9±0.6	22.0±0.5	25.3±0.6	20.8±0.5	0.781
Love Attitude Scale (LAS)-Eros	24.0±0.5	23.5±0.5	23.5±0.6	23.6±0.6	0.633
Love Attitude Scale (LAS)-Ludus	19.4±0.7	19.0±0.6	19.8±0.5	18.9±0.5	0.683
Love Attitude Scale (LAS)-Mania	21.3±0.7	19.7±0.7	21.1±0.6	19.9±0.7	0.734
Love Attitude Scale (LAS)-Pragma	22.6±0.7	23.1±0.6	20.9±0.7	23.0±0.6	0.207
Love Attitude Scale (LAS)-Storge	22.9±0.8	21.5±0.7	21.3±0.8	21.7±0.8	0.243

Table S2. Examples of sentences describing sexual and emotional fidelity or infidelity

Type	Sentence Examples
Emotional Fidelity	He/She always ignored other women/men who tried to flirt with him/her.
	He/She always refused to go out on a date with other women/men.
Sexual Fidelity	He/She threw wine on his/her female/male client's face when she/he tried to seduce him/her.
	He/She refused to have sex with his/her boss even though that would have resulted in gaining a promotion.
Emotional Infidelity	He/She expressed his/her love to another woman/man without his/her girlfriend/boyfriend knowing.
	He/She sent many romantic text messages to another woman/man.
Sexual Infidelity	He/She had sex with girlfriend's/boyfriend's best friend.
	He/She gave another woman/man oral sex.