ORIGINAL ARTICLE

The Effect of Intranasal Oxytocin on the Association Between Couple Interaction and Sleep: A Placebo-Controlled Study

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ABSTRACT

Objective: Although most people in romantic relationships cosleep, biosocial modulators of sleep quality have only recently come into focus. Oxytocin (OT) might be one such modulator, as it had been shown to increase social attachment and safety. We investigated the association between everyday life couple interaction and sleep quality, as well as the effects of OT on this association.

Methods: Eighty heterosexual couples ($N = 160$ individuals, mean [standard deviation] age = 28 [5] years) were randomized to self-administer a) 32 international units of intranasal OT or b) placebo during 5 consecutive days. Each morning, they reported on sleep quality, and on subjective feelings of closeness and valence of couple interaction at a maximum of four times a day. Data were analyzed using hierarchical linear models.

Results: Subjective closeness ($B = 0.43$, $t(73) = 3.80$, $p < .001$) and valence (negative − positive) of couple interaction ($B = 0.50$, $t(73) = 3.91$, $p < .001$) were positively associated with sleep quality. Persons with OT reported higher levels of sleep quality than those without ($B = 0.47$, $t(74) = 2.32$, $p = .023$). The association between closeness and sleep quality was stronger with OT than without (OT by closeness: $B = 0.31$, $t(72) = 2.29$, $p = .025$; OT by valence of interaction: $B = 0.27$, $t(72) = 1.77$, $p = .081$). Whereas the effect of couple interaction on sleep quality was strong in men, the OT effects were especially pronounced in women.

Conclusions: Our results suggest that enhancing closeness and positive couple interaction in cosleeping partners might be a way to improve sleep quality. The moderating effects of OT and sex on the association between couple interaction and sleep quality can have important implications for sleep therapy.

Trial Registration: The study was preregistered at ClinicalTrials.gov ("Oxytocin, Couple Interaction, and Wound Healing" study, identifier NCT01594775). The present analyses were not preregistered.

Key words: sleep quality, oxytocin, couple interaction, ecological momentary assessment.

INTRODUCTION

Sleep is essential for maintaining health and functioning (1). Chronic poor sleep quality is implicated in reduced quality of life, physical diseases like hypertension, diabetes, cancer, and premature mortality (2–4). To prevent these adverse consequences and improve early interventions, there is a need for research on biosocial factors influencing sleep.

Up to 75% of the population (and 89% of those married or partnered) sleep with a significant other (5), and recently, sleep research has begun to focus on how close social relationships influence sleep quality. In the past decade, growing evidence suggests the effects of couples' bed sharing on sleep outcomes (6,7). Because humans spend about one-third of life sleeping, couple-level influences on sleep quality might represent one of the pivotal pathways linking relationship functioning with health benefits (7–9). For example, Hasler and Troxel (10) found that less negative partner interactions during the day predicted higher sleep efficiency in cosleeping couples. Other studies showed that husband's anxiety and depressive symptoms negatively predicted wife's sleep duration (11), and the stable presence of a male partner predicted better sleep quality in women (6). Sex differences are reported throughout studies with regard to the effects of relationship functioning on

B = unstandardized coefficient (increase/decrease in outcome with 1 increase in predictor), **EMA** = ecological momentary assessment, **HPA** = hypothalamic-pituitary-adrenal axis, **ICC** = intraclass correlation, **IU** = international units, **NPAT** = no partnership appreciation task, **OT** = oxytocin, **PAT** = partnership appreciation task

SDC Supplemental Digital Content

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sleep (for an overview, see Ref. (7)). A recent study showed that husbands' sleep problems decrease with increasing marital satisfaction due to a couple intervention (12). The same study, however, did not find beneficial effects in women. Another study could show that sleep quality covaries across days within couples (13). With regard to sleep, this means that improving sleep quality in one partner can positively affect both partners' health outcomes. Furthermore, distress in close relationships may lead to ruminative thoughts at bedtime and upregulated arousal, which may interfere with the sleep state (14–16).

With a focus on psychobiological mechanisms underlying social influences on sleep quality, the neuropeptide oxytocin (OT) may serve as a potential neurobiological substrate underpinning associations between relationship quality and sleep (17). In a seminal study, OT increased trust behavior in healthy men (18), although replication suggests that this seems only true for those with low levels in dispositional trust (19). In line with this, central nervous system OT has been related to reduced anxiety and stress levels and to an increased focus on prosocial stimuli, making the OT system a potential mechanism important for effects of behavioral treatments (17,20,21). Furthermore, OT administration increased positive communication (22) and reduced cortisol and autonomic arousal (although the latter in women only) during couple conflict (23). More specifically, OT increased the appraisal of positive aspects within one's own relationship (24) and improved the stress-reducing effects of social touch (25,26), suggesting it to mediate the processing of social safety signals (27). As an underlying mechanism, an attentional shift toward social cues triggered by the interactions of OT with the dopaminergic (reward) system has been suggested (28).

Trust, relaxation, and the perception of social safety are essential for sleep health (29). It is, thus, likely that OT mechanisms might be involved in sleep and exert such effects by modulating social interactions. There is evidence that OT increases the stress-buffering effect of social interactions (see also Ref. (30)), leading to a decrease in arousal, which should promote sleep. Furthermore, OT might promote sleep directly via a functional link between the paraventricular nucleus (the release sight of OT) and the suprachiasmatic nucleus (important for sleep-wake patterns) of the hypothalamus (31,32). Indeed, sleep-promoting effects of OT have been observed in male rats under basal conditions (33). Human studies investigating the effect of OT on sleep are scarce. One study found an increase in subjective sleep satisfaction and a reduction of apnea events in patients with sleep apnea after intranasal OT administration (34), albeit relying on a very small sample of eight participants. Lipschitz and colleagues (35), on the other hand, did not find a significant association between sleep problems and evening basal salivary OT levels in cancer survivors with sleep problems, although descriptively the effect was in the expected direction (negative). Interestingly, Fekete and colleagues (36) found evidence that basal blood OT levels moderated the association between social support and sleep in women with human immunodeficiency virus: women with high OT levels seemed to benefit from social support, but social support and sleep were negatively associated in women with low levels of blood OT. However, the latter two studies did not administer OT. Also, caution is mandatory when interpreting peripheral OT levels with regard to central nervous system mechanisms. However, these initial studies suggest some associations of endogenous OT with sleep. We are not aware of another study investigating the effect of OT administration on sleep.

Driven by these preliminary findings, we hypothesized that intranasal administration of OT might enhance relationship quality, such as positive couple interaction, as well as sleep quality in couples. We also hypothesized that there would be a positive association between couple interaction and sleep and that OT might modulate that association. Furthermore, we investigated possible differences between women and men in these associations. We chose a randomized (OT/placebo) ecological momentary assessment (EMA) design gathering data in the everyday life of couples. EMA designs result in higher ecological validity (37), reduce retrospective bias (38), and add a crucial perspective in behavioral medicine (39).

METHODS

Participants

Eighty heterosexual couples were recruited via flyers; information brochures; Internet ads; mailing lists of the University of Zurich, Switzerland; and social media. Inclusion criteria were age between 21 and 45 years, exclusive dating, relationship duration between 1 and 15 years, cohabitation, and cosleeping. Exclusion criteria comprised having children and shiftwork due to their effects on sleep. We also excluded persons with a current or chronic physical or psychiatric illness (based on self-report during an initial phone contact), or currently using medication (except for hormonal contraceptives) or drugs (no alcohol intake on a daily basis or smoking more than five cigarettes a day). Couples were asked to participate during a normal week in their lives and not to spend any night during the assessment period apart from each other. Naturally cycling women ($n = 40$) were studied during the early follicular phase of the menstrual cycle, and the remainder ($n = 40$) were using oral contraception. All participants gave written informed consent. Each couple received 500 Swiss franks (about 510 US dollars) for study completion.

Study Design

Data collection took place between November 2011 and July 2013. The study protocol was approved by the ethics committee of the Canton of Zurich, and the study was monitored by the Clinical Trials Center Zurich. The research was conducted in accordance with the Declaration of Helsinki. The study was preregistered at ClinicalTrials.gov ("Oxytocin, Couple Interaction, and Wound Healing" study, identifier NCT01594775). The study addressed, among other questions, the effects of OT and couple interaction on wound healing (of a standard suction blister skin wound, see Ref. (40)). The present analyses were not preregistered. We used a 2×2 design. Couples were randomized into OT group versus placebo group, and a condition in which one group was instructed to engage in a short verbal partnership appreciation task (PAT) (41) which they should implement in their everyday lives during the assessment period and a group without such instructions (NPAT). This intervention, conceptualized as appreciation of the relationship and positive personal characteristics of each partner (40), was supposed to lead the focus on highly individual and positive relationship aspects, thereby increasing relationship satisfaction and decreasing stress reactivity. For a more in-depth description of the task, see Ref. (24). In addition to the initial laboratory session, couples in the PAT condition were instructed to engage in the task at least once more during the 5 days of assessment. To check for compliance, participants in the PAT condition were asked if they engaged in the task or not each day at the last measurement point. Overall, results show that every couple in the PAT condition engaged in the task at least once, but in 60% (233 of possible 390 occasions) of the days, the couples did not engage in the task. Based on the prestudy phone interview, couples were stratified with half of the women in each group using hormonal contraception, and the other half were naturally cycling.

After checking for inclusion and exclusion criteria during the initial phone contact, couples were invited to an instruction session at the laboratory. They provided information on their general awakening times (for the 5 days of EMA to follow), to match the iPod touch programming to participants' daily routine. At this first laboratory appointment, participants provided urine samples to rule out drug consumption and pregnancy in the women. Furthermore, they completed electronic questionnaires to assess baseline relationship criteria and were instructed to use a preprogrammed (iDialogPad; G. Mutz, Cologne, Germany) iPod touch and a nasal spray that contained either OT or placebo. The device used for this study was iPod touch, third generation, with a screen size of 3.5 inches and 32GB storage space.

An EMA design was used with 5 consecutive days of data collection. Measurement time points were prompted by iDialogPad directly after awakening; +30 minutes, +2.5 hours, +8 hours, and +12 hours after awakening; and at bedtime. Sleep variables were assessed at awakening referencing the prior night's sleep. Information on couple interaction was reported at four of the six time points (excluding awakening and +30-minute measurements). Study participants self-administered the nasal spray containing either intranasal OT (Syntocinon Spray; Novartis, Basel, Switzerland) or placebo (containing identical ingredients except for the peptide; Cantonal Pharmacy of Zurich) in two puffs per nostril each evening at +8 and +12 hours after awakening. One puff of OT spray exposed participants to 4 international units (IU) of OT, which resulted in 32 IU of OT (2 puffs × 2 nostrils × 2 times × 4 IU) per day (42). To check for compliance, participants indicated if they sprayed in both nostrils at each of these measurement points. Participants indicated "yes" in 90% of the occasions (1% "no," 9% missing data). Furthermore, nasal spray bottles were weighed before and after data collection period.

MEASURES

Relationship Quality

Relationship Quality: Baseline Measure

As a measure of general relationship satisfaction, the Relationship Questionnaire by Hahlweg (43) was used. This questionnaire comprises three scales with 10 items each, which are assessed on a scale from 0 (never) to 3 (very often). The scales are as follows: 1, quarreling (aggressive behavior of the partner during argument); 2, tenderness (physical contact, and verbal as well as physical intimacy); and 3, togetherness (shared activities, communication, and feelings of belonging together). A general score can then be calculated as a sum of the "tenderness and togetherness" scales and the inverted "quarreling" scale. Good validity and reliability of the instrument have been shown in previous studies (44).

Couple Interaction and Closeness: Daily Measures

Four times daily, participants indicated whether they had interacted with their partners since the previous data entry ("Since the last beep, did you interact with your partner?" yes/no), and if so, they rated the valence of this couple interaction ("Which valence did the interaction with your partner have?") on a scale from 0 (negative) to 9 (positive), as well as how close to the partner they felt ("Did you feel close to your partner?") on a scale from 0 (not at all close) to 9 (very close). Using single-item scales to ensure briefness and compliance is a common approach in EMA studies (45), and scales with opposite valences have been found to be highly valid in prior EMA studies (46).

Measure of Sleep Quality

Sleep was assessed via self-report every morning after awakening. For the assessment of sleep quality, participants indicated how well they had slept during the previous night ("How well did you sleep?") on a scale from 0 (very bad) to 9 (very good). This item constitutes the main outcome in our analyses.

Furthermore, sleep duration was assessed by the item "How long did you sleep?" which the participants could adjust by scrolling on screen in hours and minutes, but the output of the iDialog program was given in minutes. Participants also indicated if they had woken up during the night (yes/no) and if they had problems falling asleep (yes/no). For measurements of awakening time and bedtime, we used electronic time stamps of the first and last measurement time points per day.

Statistical Analyses

We used three-level hierarchical linear regression models using the statistics software package HLM 7 (47), with days (level 1) nested within persons (level 2) within couples (level 3) to gain estimations of the effects for the whole data set (men and women). In addition, we used multilevel models for distinguishable dyads (48). This approach controls for interdependencies of reports within couples while distinguishing between members of the dyad (in our case, men and women) in the output of the program. Sleep quality was measured on a daily basis (outcome at level 1). In a first step of analyses, we were interested in the effects of daily couple interactions on the following night's sleep quality. Therefore, daily measures (valence of couple interaction and felt closeness, daily means, 1-day lag) were included at level 1. As for covariates, we controlled for day of assessment (1–5) at level 1, as well as sex, and age at level 2. Substance (OT/placebo) and intervention group (PAT/NPAT) were included at level 3. Baseline relationship quality (as assessed via the Relationship Questionnaire) did not have an effect on sleep quality (data not shown) and did not change the results, which is why we did not include this variable into the final models. In a second step, we were interested in between-person effects and added mean momentary measures (valence of couple interaction and felt closeness, person means) at level 2 while controlling for daily means at level 1. In addition, multilevel models for distinguishable dyads as explained previously were modeled with daily means of couple interaction variables at level 1, and person means of couple interaction variables as well as substance (OT/placebo) at level 2. A list of the specific regression equations for each model is available in the Supplemental Digital Content, http://links.lww.com/PSYMED/A844.

The intraclass correlations (ICCs) of sleep quality showed 73% of variance at the within-person level (day), 15% at the between-person/within-couple level, and 12% at the between-couple level. ICCs of valence of couple interaction showed 58% of the variance at the within-person level (day), 15% at the between-person/within-couple level, and 27% at the between-couple level. ICCs of felt closeness showed 50% of variance at the within-person level (day), 28% at the between-person/within-couple level, and 22% at the between-couple level. The χ^2 tests of the empty models indicated that there was significant variance at each level for every outcome variable. As a measure of effect size, pseudo-R^2 was used where pseudo-R^2 = (aggregated variance across levels reference model − aggregated variance across levels final model)/aggregated variance across levels reference model (49); the reference model was the final model excluding the predictor in question.

RESULTS

Sample Characteristics

Two couples were excluded from the analyses because they indicated they slept alone during all nights of the study period. Another was excluded because time of measurements indicated incompliance (i.e., the iPod touch time stamps indicated that data were entered once daily for every measurement point). The final sample consisted of 77 opposite-sex couples, which results in 770 possible data entries (77 couples × 2 individuals per couple-5 days). Compliance was generally high with 2% missing data at level 1 for sleep quality and 3% missing data for valence of interaction as well as felt closeness. Time points with missing data in at least one relevant variable at level 1 were automatically deleted by the HLM program during analyses. There were no missing person-level data. Participants had a mean (standard deviation) age of 28 (5) years. The education level was rather high, with 22.4% holding a high school diploma (Matura), 28.6% holding a bachelor's degree, and 24.7% holding a master's degree. More than three-quarters of the sample (79.9%) were employed. Descriptive values of relationship as well as sleep data are shown in Table 1. Other than sleep quality (Figure 1), there were no differences in these variables between groups when assessed with hierarchical linear models.

Day-to-Day Associations Between Couple Interaction, OT, and Sleep Quality

We found no significant associations between couple interaction (daily means) and following night's sleep quality (valence of couple interaction: $B = -0.10$, $t(74) = -1.16$, $p = .25$; felt closeness: $B = 0.06$, $t(74) = 0.71$, $p = .48$) on a within-person level. Furthermore, couple interaction did not differ between OT/placebo groups (neither valence of couple interaction $B = 0.06$, $t(74) = 0.27$, $p = .78$; nor felt closeness: $B = 0.19$, $t(74) = 0.88$, $p = .39$) or positive relationship appreciation (PAT/NPAT) groups (valence of interaction: $B = 0.13$, $t(74) = 0.63$, $p = .53$; felt closeness: $B = 0.12$, $t(74) = 0.53$, $p = .60$). However, in the OT group, sleep quality was better than in the placebo group ($B = 0.51$, $t(74) = 2.24$, $p = .028$, pseudo-$R^2 = 0.18$). There was no difference in sleep quality between the PAT groups ($B = 0.00$, $t(74) = 0.01$, $p = .99$).

Between-Person Associations Between Couple Interaction, OT, and Sleep Quality

As explained previously, we included daily means of couple interaction variables at level 1, additional to person means at level 2. In this model, we found a significant association between couple interaction (person mean) and sleep quality (such that more positive interaction was associated with better sleep quality; see Table 2, model 1, for valence of interaction and Table 3, model 2, for felt closeness). Because substance (OT/placebo) did not have a cross-level interaction effect with the couple interaction variables when entered at the couple level (level 3; data not shown), we decided to investigate the interaction effect at level 2 (person level). In these models, we found a significant interaction effect of substance (OT/placebo) by felt closeness on sleep quality (Table 3, model 2.a). The interaction effect of substance by valence of interaction on sleep quality (Table 2, model 1.a) failed to reach significance at the 5% level, but was significant at the trend level ($p < .10$). The respective associations were stronger in the OT than in the placebo group. Therefore, OT seems to be a moderator of the effect of couple interaction on sleep quality on a between persons basis. There was no interaction effect of substance(OT/placebo) by PAT group ($B = 0.34$, $t(72) = 0.83$, $p = .41$).

Although sleep quality and couple interaction reports did not differ between women and men, we further found significant

TABLE 1. Descriptive Data of Relationship Related and Sleep-Related Variables

	OT (38 Couples), M (SD)	Placebo (39 Couples), M (SD)
Relationship		
Baseline questionnaire data		
Relationship length, y	3.86 (2.62)	3.76 (2.53)
Cohabitation length, y	2.07 (1.98)	1.98 (1.68)
Overall relationship satisfaction[a]	71.64 (9.37)	72.69 (7.46)
EMA data		
No. partner interactions[b]	14.11 (2.97)	13.36 (3.55)
Valence of interaction[c]	7.25 (1.00)	7.17 (1.02)
Felt closeness[d]	7.47 (1.00)	7.26 (1.20)
Sleep (EMA)		
Sleep quality[e,f]	6.71 (1.02)	6.26 (1.23)
Sleep duration[g]	7 h 21 min (38 min)	7 h 24 min (43 min)
No. awakening during the night[h]	1.83 (1.52)	1.97 (1.57)
No. sleep problems[i]	0.43 (0.68)	0.51 (0.79)
Waking time[j]	7:46 AM (1 h 32 min)	7:47 AM (1 h 39 min)
Bedtime[k]	11:34 PM (1 h 35 min)	11:43 PM (1 h 50 min)

OT = oxytocin; M (SD) = mean (standard deviation); EMA = ecological momentary assessment.

Boldface represents outcome (sleep quality) and main predictors (felt closeness, valence of interaction) in the upcoming analyses. Relationship length (range, 1.0–11.5 years), cohabitation length (range, 0.1–9.0 years), and overall relationship satisfaction (range, 49–89) were measured with questionnaires at baseline, the other variables shown here were measured via self-report or via electronic time stamps (waking and bedtime) during the 5 days of ecological momentary assessment.

[a] Overall relationship satisfaction was measured with the relationship questionnaire, the given values match stanine values between 6 and 9 (average to high) when compared with a norm sample provided by Hahlweg (43).

[b] Did you interact with your partner since the last beep? (sum of "yes "answers; range, 4–20).

[c] Which valence did your interaction have? ("0 [negative]–9 [positive]; range, 0–9.

[d] How close to your partner did you feel (during your interaction)? (0 [not at all close]–9 [very close]; range, 0–9.

[e] How well did you sleep last night? ("0 [very bad]–9 [very good]; range, 0–9.

[f] Results of *t* tests show no differences between OT and placebo in any of these parameters except for sleep quality ($p = .017$).

[g] How long did you sleep? (range, 2 hours 50 minutes–11 hours 30 minutes).

[h] Did you wake up during the night? (sum of "yes" answers; range, 0–5).

[i] Did you have problems falling asleep? (sum of "yes" answers; range, 0–3).

[j] Range, 3:11 AM to 2:01 PM.

[k] Range, 8:48 PM to 7:40 AM.

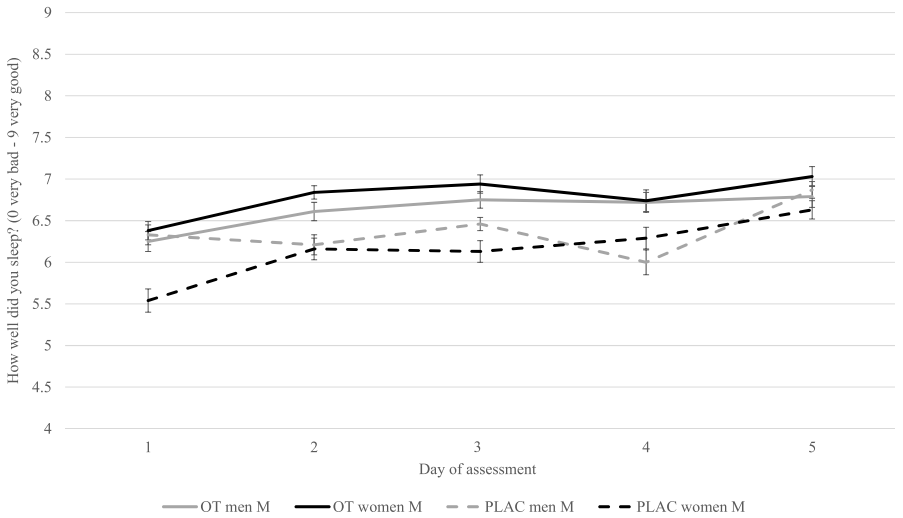

FIGURE 1. M (SE) values of sleep quality (on a scale from 0 [very bad] to 9 [very good]) throughout the 5 days of assessment, separate lines for men and women as well as substance groups. OT = oxytocin; PLAC = placebo; M = mean; SE = standard error.

TABLE 2. Effects of Valence of Interaction and OT on Sleep Quality, 3-Level (Days Within Persons Within Couples) Hierarchical Linear Model Using Full Maximum Likelihood (Level 1, $n = 770$; Level 2, $n = 154$; Level 3, $n = 77$)

	Model 1			Model 1.a		
	B (SE)	*t*	*p*	*B* (SE)	*t*	*p*
Fixed effects						
Level 3 (couples)						
Intercept	6.24 (0.18)	35.40	<.001	6.27 (0.20)	32.11	<.001
Substance[a]	0.50 (0.21)	2.32	.023	−1.46 (1.12)	−1.31	.20
PAT/NPAT[b]	−0.01 (0.22)	−0.06	.95	−0.03 (0.21)	−0.13	.90
Level 2 (persons)						
Valence of interaction (person mean)	0.50 (0.13)	3.91	<.001	0.35 (0.17)	2.01	.049
Sex[c]	−0.00 (0.15)	−0.03	.97	−0.03 (0.17)	0.21	.84
Age	0.02 (0.04)	0.42	.68	0.01 (0.04)	0.40	.69
Substance by valence of interaction				0.27 (0.15)	1.77	.081
Level 1						
Valence of interaction (daily mean)	0.09 (0.07)	1.25	.22	0.09 (0.07)	1.29	.20
Day of assessment	0.14 (0.05)	2.61	.010	0.14 (0.04)	3.47	<.001
	Variance Component (SD)	χ^2	*p*	Variance component (SD)	χ^2	*p*
Random effects						
Levels 1 and 2						
Intercept	0.36 (0.60)	137.45	<.001	0.39 (0.63)	139.60	<.001
Valence of interaction (daily mean)	0.05 (0.22)	161.00	.16	0.05 (0.23)	161.27	.154
Level 3						
Intercept	0.46 (0.68)	162.92	<.001	0.38 (0.62)	145.89	<.001

OT = oxytocin; *B* = unstandardized coefficient; SE = standard error; PAT = partnership appreciation task; NPAT = no partnership appreciation task; SD = standard deviation.

Valence of interaction (daily mean) has been centered around the person mean; valence of interaction (person mean) and age have been centered around the group mean. Predictors relevant to our hypotheses are captured in bold.

[a] Substance: Oxytocin = 1, placebo = 0.

[b] Positive relationship appreciation = 1, neutral = 0.

[c] Men = 0 women = 1; *df* = 74 at level 3, 73 at level 2 (model 1.a: 72 at level 2), 352 at level 1; substance: pseudo-$R^2 = 0.02$; valence of interaction: pseudo-$R^2 = 0.01$, substance by valence of interaction: pseudo-$R^2 = 0.02$.

TABLE 3. Effects of Felt Closeness and OT on Sleep Quality, 3-Level (Days Within Persons Within Couples) Hierarchical Linear Model Using Full Maximum Likelihood (Level 1, $n = 770$; Level 2, $n = 154$; Level 3, $n = 77$)

	Model 2			Model 2.a		
	B (SE)	*t*	*p*	*B* (SE)	*t*	*p*
Fixed effects						
Level 3						
Intercept	6.24 (0.20)	31.43	<.001	6.29 (0.19)	32.56	<.001
Substance[a]	0.45 (0.21)	2.11	.038	−1.87 (0.97)	−1.92	.059
PAT/NPAT[b]	−0.00 (0.21)	−0.02	.99	−0.04 (0.21)	−0.18	.86
Level 2						
Felt closeness (person mean)	0.43 (0.11)	3.80	<.001	0.30 (0.14)	2.18	.033
Sex[c]	0.03 (0.15)	0.22	.83	−0.02 (0.15)	−0.14	.89
Age	0.03 (0.04)	0.71	.48	0.02 (0.04)	0.61	.55
Substance by felt closeness				0.31 (0.14)	2.29	.025
Level 1						
Felt closeness (daily mean)	0.04 (0.06)	0.68	.50	0.04 (0.06)	0.66	0.51
Day of assessment	0.14 (0.05)	2.56	.011	0.14 (0.05)	2.54	.011
	Variance Component (SD)	χ^2	*p*	Variance Component (SD)	χ^2	*p*
Random effects						
Levels 1 and 2						
Intercept	0.33 (0.58)	118.90	<.001	0.36 (0.60)	121.91	<.001
Felt closeness (daily mean)	0.03 (0.00)	123.39	>.50	0.00 (0.05)	123.49	>.50
Level 3						
Intercept	0.45 (0.67)	162.05	<.001	0.37 (0.60)	143.17	<.001

OT = oxytocin; *B* = unstandardized coefficient; SE = standard error; PAT = partnership appreciation task; NPAT = no partnership appreciation task; SD = standard deviation.

Felt closeness (daily mean) has been centered around the person mean; felt closeness (person mean) and age have been centered around the group mean. Predictors relevant to our hypotheses are captured in bold.

[a] Substance: Oxytocin = 1, placebo = 0.

[b] Positive relationship appreciation = 1, neutral = 0.

[c] Men = 0 women = 1; *df* = 74 at level 3, 73 at level 2 (model 2.a: 72 at level 2), 352 at level 1; substance: pseudo-$R^2 = 0.02$; felt closeness: pseudo-$R^2 = 0.02$, substance by valence of interaction: pseudo-$R^2 = 0.02$.

interaction effects of male sex by valence of interaction ($B = 0.46$, $t(72) = 3.64$, $p < .001$, pseudo-$R^2 = 0.04$) and male sex by felt closeness ($B = 0.37$, $t(72) = 2.98$, $p = .004$, pseudo-$R^2 = 0.02$). These results indicate a stronger relationship between valence of interaction and sleep quality as well as felt closeness and sleep quality in men as compared with women. This is in line with results we found from multilevel models for distinguishable dyads (Tables 4 and 5, Figure 2). Here, the main effects of couple interaction (valence and felt closeness) remain significant only in men, whereas the main substance effect and the interaction effects of substance by couple interaction are statistically significant in women. When comparing the models, we find that the coefficients for valence and felt closeness in men, as well as the coefficient for the interaction effect of valence of interaction by substance fall outside of the 95% confidence intervals for the three-level model coefficients (Table S1, Supplemental Digital Content, http://links.lww.com/PSYMED/A844). Therefore, the pattern of results depends on taking into account sex differences.

DISCUSSION

In this study, participants who, on average, reported more positive interactions with their partner and more closeness in everyday life throughout a period of 5 days slept better at night. Couples who received OT reported better sleep quality, but not more positive interactions or closeness in their everyday lives, than those receiving placebo. Furthermore, participants who reported more closeness and received OT reported the highest sleep quality. Specifically, the interaction effect was moderated by OT insofar that the association between felt closeness and sleep quality was stronger in the OT than in the placebo group. This effect showed the same direction for valence of interaction but failed to reach statistical significance. Furthermore, we found a stronger association between average reports of couple interaction and sleep quality in men than in women, whereas the effects of OT were especially pronounced in women as compared to in men when investigating both sexes separately.

The association between relationship quality and sleep quality is in line with other EMA studies: a study by Hasler and Troxel (10) found a positive effect of relationship satisfaction on actigraphy assessed sleep efficiency. Gordon and Chen (50) reported a bidirectional relationship between daily couple conflict and sleep in a student sample. In a recent study, Tracy and colleagues (51) found negative dyadic effects of own and partner's stress on sleep in patients with diabetes. In addition, Kane and colleagues (52) showed a beneficial impact of self-disclosure on different self-rated sleep

TABLE 4. Hierarchical Linear Models for Distinguishable Dyads (Women/Men) Predicting Sleep Quality by Valence of Interaction (Model 3) and Oxytocin (Model 3.a) Using Restricted Maximum Likelihood (n = 77 Couples)

	Model 3						Model 3.a					
	Women			Men			Women			Men		
	B	SE	*t*	*B*	SE	*t*	*B*	SE	*t*	*B*	SE	*t*
Fixed effects												
Intercept	5.65	0.21	27.46***	6.21	0.21	29.83***	5.61	0.21	27.23***	6.21	0.20	30.58***
Level 2												
Valence of interaction (person mean)	0.06	0.10	0.59	0.53	0.12	4.30***	−0.13	0.14	−0.96	0.58	0.12	4.69***
Age	0.02	0.02	1.01	0.00	0.02	0.11	0.02	0.02	1.13	0.00	0.02	0.06
PAT/NPAT	0.30	0.19	1.62	−0.15	0.24	−0.66	0.31	0.19	1.69	−0.15	0.19	−0.81
Substance	0.62	0.18	3.37**	0.30	0.24	1.23	0.63	0.18	3.3***	0.30	0.18	1.64
Substance by valence of interaction							0.44	0.20	2.16*	−0.09	0.17	−0.56
Level 1												
Day of assessment	0.18	0.06	2.78**	0.11	0.06	1.64	0.18	0.06	2.78**	0.11	0.06	1.64*
Valence of interaction (daily mean)	0.05	0.10	0.48	0.09	0.09	1.05	0.05	0.10	0.48	0.09	0.10	0.91
	SD	VC	χ^2	SD	VC	χ^2	SD	VC	χ^2	SD	VC	χ^2
Random effects												
Valence of interaction (daily mean)	0.20	0.04	75.56	0.05	0.00	46.16	0.21	0.04	75.86	0.05	0.00	46.38

B = unstandardized coefficient; SE = standard error; PAT/NPAT = partnership appreciation task (yes = 1, no = 0); SD = standard deviation; VC = variance component.

Valence of interaction has been centered around the person mean. Substance: oxytocin = 1, placebo = 0; for comparability with the main analyses, valence of interaction was entered at level 2 (person mean) and centered around the grand mean; *df* = 572 at level 1 (for model 3.a; 570 at level 1), 76 at level 2. Substance: pseudo-R^2 = 0.02; valence of interaction: pseudo-R^2 = 0.05; substance by valence of interaction: pseudo-R^2 = 0.004. Predictors relevant to our hypotheses are captured in bold.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

measures in couples. Contrary to these studies, we did not find an effect on a day-to-day basis, but exclusively on a between-person basis. However, our study differs from the aforementioned ones in several ways, including our multiple measurements of couple interaction throughout the day and our focus on valence of interaction as well as felt closeness as specific indicators of the couple interaction. It can be assumed that certain couple behaviors exert their effects on sleep in a different time frame than others.

Another explanation is that day-to-day changes in relationship quality were not strong enough to influence sleep in our sample. There is no indication that the couples that took part in our study experienced a major argument during the assessment period, which might have led to, for example, bedtime worrying, which is known to affect sleep (53). We might therefore suspect that "normal" day-to-day variance in couple interaction does not lead to changes in sleep quality in couples with generally high relationship satisfaction. However, the between-person effect suggests that enhancing overall closeness in cosleeping partners might have beneficial effects on sleep hygiene.

On a neuroendocrine level, it has been hypothesized that these positive effects of relationship quality on sleep are mediated via neurotransmitters or neuromodulators, which promote felt safety and relaxation on the central nervous system level (6). OT might be one of these neuromodulators involved, and although OT is known for its calming effects (27), its effects on sleep had not been systematically investigated. Using repeated measurements for the duration of 5 days in healthy adult men and women's everyday lives, we find that application of OT might, indeed, improve sleep quality. This is in line with animal research (33) and an initial sample with eight sleep apnea patients (34) where OT improved sleep quality. The mechanism underlying this effect might stem from the functional link between the paraventricular nucleus of the hypothalamus, where OT is released (31), and the suprachiasmatic nucleus of the hypothalamus, which plays a central role in regulating sleep-wake patterns (32). Furthermore, studies in rats suggest that OT might be associated with sleep by its influence on hypothalamic-pituitary-adrenal (HPA) axis activity and its interaction with corticotropin-releasing hormone (54,55). Human studies support a suppressing effect of OT on HPA axis activity, depending, however, on the kind of stress exposure and the study population (for a review, see Ref. (56)). In addition to HPA axis dynamics, OT was found to increase parasympathetic activity (as assessed via heart rate variability; see Ref. (57)) and might lead to an overall more relaxed state that facilitates sleep. Moreover, we found that the effect of OT on sleep quality, as well as the interaction effect of OT and couple interaction variables on sleep quality, was of special relevance in women. This is in line with research showing a stronger negative effect of intranasal OT on autonomic arousal (measured with salivary α-amylase (23)), as well as a stronger positive effect on feelings of relaxation in women than in men (58).

TABLE 5. Hierarchical Linear Models for Distinguishable Dyads (Women/Men) Predicting Sleep Quality by Felt Closeness (Model 4) and Oxytocin (Model 4.a) Using Restricted Maximum Likelihood (n = 77 Couples)

	Model 4						Model 4.a					
	Women			Men			Women			Men		
	B	SE	*t*	*B*	SE	*t*	*B*	SE	*t*	*B*	SE	*t*
Fixed effects												
Intercept	5.63	0.21	27.17***	6.21	0.21	30.24***	5.61	0.21	27.11***	6.23	0.21	30.36***
Level 2												
Felt closeness (person mean)	0.00	0.09	0.02	0.42	0.08	5.23***	−0.14	0.11	−1.31	0.32	0.11	2.92*
Age	0.02	0.02	1.03	0.01	0.02	0.64	0.02	0.02	0.92	0.01	0.02	0.80
PAT/NPAT	0.33	0.19	1.76†	−0.15	0.19	−0.80	0.31	0.19	1.64	−0.18	0.19	−0.94
Substance	0.63	0.19	3.36***	0.27	0.19	1.45	0.60	0.19	3.20**	0.26	0.18	1.40
Substance by felt closeness							0.46	0.19	2.40*	0.21	0.16	1.30
Level 1												
Day of assessment	0.18	0.07	2.70**	0.11	0.07	1.70†	0.18	0.07	2.69**	0.11	0.06	1.71†
Felt closeness (daily mean)	0.03	0.11	0.24	0.05	0.10	0.53	0.05	0.10	0.24	0.03	0.11	0.24
	SD	VC	χ^2	SD	VC	χ^2	SD	VC	χ^2	SD	VC	χ^2
Random effects												
Felt closeness (daily mean)	0.08	0.01	55.01	0.04	0.00	33.35	0.09	0.01	55.44	0.03	0.00	35.64

B = unstandardized coefficient; SE = standard error; PAT/NPAT = partnership appreciation task (yes = 1, no = 0); SD = standard deviation; VC = variance component.

Substance: oxytocin = 1, placebo = 0; felt closeness (daily mean) has been centered around the person mean; felt closeness (person mean) and age have been centered around the grand mean; *df* = 572 at level 1 (for model 4.a; 570 at level 1) and 76 at level 2; substance: pseudo-R^2 = 0.02; felt closeness: pseudo-R^2 = 0.03; substance by felt closeness: pseudo-R^2 = 0.01. Predictors relevant to our hypotheses are captured in bold.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

† $p < .10$.

The lack of an association between OT and couple interaction, as well as the lack of effect of the positive relationship appreciation task, might be due to a lack of variance in actual couple behavior during the 5 days of assessment. OT being a moderator of the association between relationship quality and sleep is in line with earlier findings by Fekete and colleagues (36), who reported that social support is positively associated with better sleep in those participants (women suffering from human immunodeficiency virus) with high OT levels and is negatively associated with sleep in those with low OT levels (investigating blood OT and one-time questionnaire measurements). Our study expands on these findings and confirms the results with regard to everyday life assessments in both sexes. A moderating role of OT in the association between positive human interaction and health outcomes is also in line with earlier results by Heinrichs and colleagues (30), who found that intranasal OT and social support interacted to suppress psychobiological stress responses in healthy men. A potential mechanism of this moderation or "catalyst effect" is that higher OT availability in the central nervous system might lead to an attentional shift toward social cues (for an overview, see Ref. (59)). If positive, such cues can then trigger perceptions of trust and safety, which would consequently reduce amygdala activation and alertness (21). Our results therefore support the contention that OT may be a catalyst for the effects of positive social interaction on improved sleep. In turn, such effects could promote physical health in general by promoting healthy immune and metabolic functioning. However, more multimethod psychobiological research is needed to substantiate these assumptions.

Interestingly, we found a stronger association of average couple interaction and daily sleep quality in men than in women. This is not in line with previous studies suggesting that women's sleep is more strongly influenced by relationship quality than men's (for an overview, see Ref. (7)). However, Lee and colleagues (13) reported no difference in the intradyadic covariation of sleep quality between sexes. Also, they found that only men's sleep duration was influenced by their spouse's sleep duration, not women's. Another recent study suggested that increases in men's marital satisfaction had beneficial effects on their symptoms of insomnia, an effect that was not found in women (12). In addition, Hasler and colleagues (10) found an effect of positive partner interaction as indicated by the wife on diary-based sleep efficiency in their husbands, whereas actigraphy-measured sleep parameters were influenced by partner interaction exclusively in women. Thus, there might be a dissociation between self-rated and objectively measured sleep parameters concerning the association between couple interaction and sleep between men and women. In addition, the study by Kane and colleagues (52) suggests that different sleep parameters (awakening after sleep onset versus sleep onset latency)

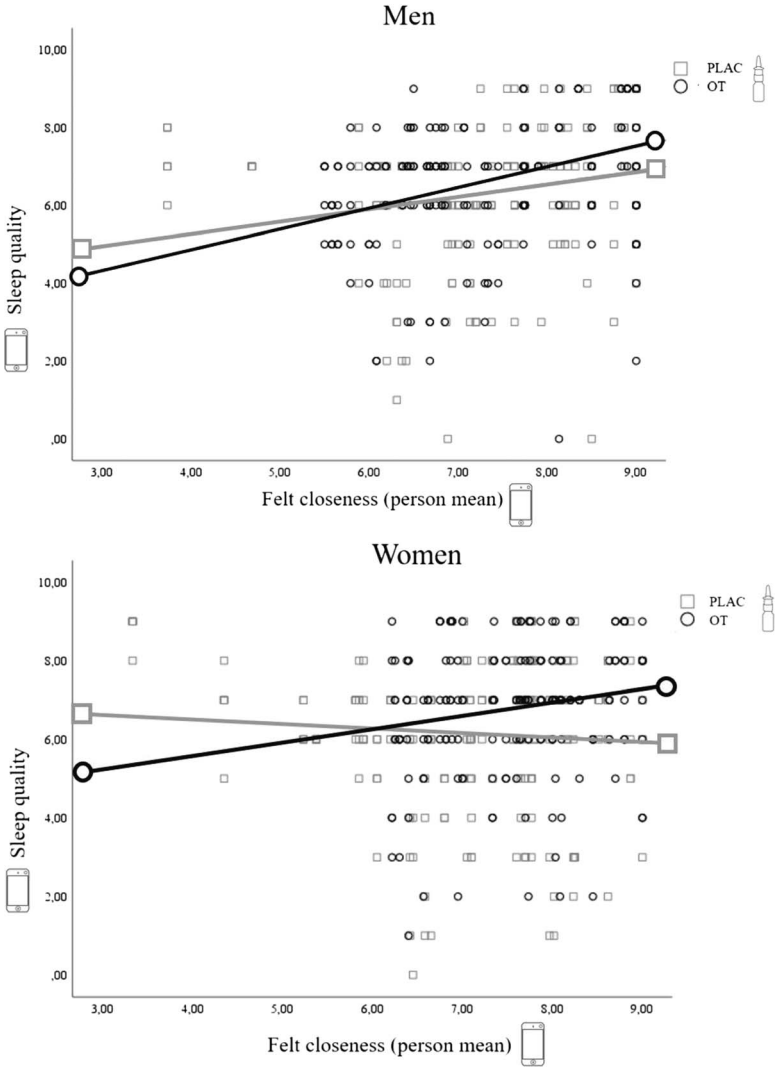

FIGURE 2. Sleep quality as a function of felt closeness (on a scale from 0 [little close] to 9 [very close]) by substance, separate diagrams for men and women. OT = oxytocin; PLAC = placebo.

might be affected by couple interaction depending on sex. Also considering our finding that the effect of OT on sleep might be stronger in women, it is clear that more research is needed on the matter. Preferably, future studies should use subjective and objective sleep measures in couples comparing sex effects.

An important strength of our study is the assessment in everyday life, which ensures a high ecological validity. Furthermore, we investigated both parts of a couple as opposed to assessing relationship-specific variables in individuals. Another strength is the randomized design and rigid investigation and control of confounding variables, such as hormonal contraceptives, menstrual cycle phase, and medication, sports, caffeine, etc. Furthermore, with an assessment period of several days, we had the possibility of comparing within- and between-person effects.

On the other hand, we investigated a relatively homogenous sample of (premenopausal) adults in a stable heterosexual relationship with relatively high relationship satisfaction, high socioeconomic status, and no children. Therefore, results might not necessarily be applicable to all individuals living in a relationship, and ceiling and floor effects might have occurred, as discussed previously. For example, future studies should consider comparing couples in diverse stages of their relationship. We did not find an effect of relationship length in our analyses (data not shown), but former research indicates that sleep-relevant parameters like couples' emotional strain (60) and the importance of similarity in daily patterns (61) decrease with increasing relationship length. Related to that, excluding couples with children is another important limitation in the generalizability of our results, considering that about 50% of persons between the ages of 25 and 44 years living in Switzerland have children (62). However, we defined this exclusion criterion to ensure comparability between couples and reduce external influences on sleep. In addition, because of the everyday life design, we cannot rule out that un-assessed third variables, including the presence of sleep disorders, might have influenced sleep quality. We also had limited possibilities to surveil participants' behavior and ensure compliance. However, very few missing measurement points and mostly correct timing of the data entries, as well as entering of the SaliCap-number into the iPod

touch, make us confident that participants complied with the given instructions. Furthermore, most of the variables, including all of the sleep outcomes, were measured via self-report. Future research should therefore gather more information about the biological mechanisms transferring OT/relationship quality into better sleep, before we can draw conclusions about the exact causal pathways. Lastly, we did not adjust for multiple testing, which heightens the possibility of type 1 error, and replication of our findings is needed. Still, we hope that the results inspire future studies' hypotheses as explained previously.

In sum, the results of this study speak for a beneficial effect of OT and of high everyday life relationship quality on sleep quality. Furthermore, we found evidence that OT could be a catalyst of the association between couple interaction and sleep quality. We also found that the association between couple interaction and sleep quality was stronger in men than in women, whereas the effects of OT seemed to be more pronounced in women. Future studies should now investigate biological mechanisms responsible for this effect before further exploring the probable use of OT in sleep and couples' therapy.

Author Contributions: J.M.D. and K.K. analyzed the data and drafted the manuscript. W.T. and U.M.N. helped interpreting the data. B.D., M.H., G.B., and U.E. designed the study. B.D. led the study, including data acquisition, analysis, and interpretation of the data, and drafting of the manuscript. All authors provided critical feedback to the manuscript and approved the final version of the manuscript.

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REFERENCES

1. Banks S, Dinges DF. Behavioral and physiological consequences of sleep restriction. J Clin Sleep Med 2007;3:519–28.
2. Jennings JR, Muldoon MF, Hall M, Buysse DJ, Manuck SB. Self-reported sleep quality is associated with the metabolic syndrome. Sleep 2007;30:219–23.
3. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. Sleep 2010;33:585–92.
4. Philip P, Leger D, Taillard J, Quera-Salva MA, Niedhammer I, Mosqueda JG, Bioulac B, Gérard D. Insomniac complaints interfere with quality of life but not with absenteeism: respective role of depressive and organic comorbidity. Sleep Med 2006;7:585–91.
5. US National Sleep Foundation. 2013 International Sleep Poll. Washington, DC: National Sleep Foundation; 2013.
6. Troxel WM, Robles TF, Hall M, Buysse DJ. Marital quality and the marital bed: examining the covariation between relationship quality and sleep. Sleep Med Rev 2007;11:389–404.
7. Troxel WM. It's more than sex: exploring the dyadic nature of sleep and implications for health. Psychosom Med 2010;72:578–86.
8. Hale L. Sleep as a mechanism through which social relationships affect health. Sleep 2010;33:862–3.
9. Kiecolt-Glaser JK, Newton TL. Marriage and health: his and hers. Psychol Bull 2001;127:472–503.
10. Hasler BP, Troxel WM. Couples' nighttime sleep efficiency and concordance: evidence for bidirectional associations with daytime relationship functioning. Psychosom Med 2010;72:794–801.
11. Revenson TA, Marín-Chollom AM, Rundle AG, Wisnivesky J, Neugut AI. Hey Mr. Sandman: dyadic effects of anxiety, depressive symptoms and sleep among married couples. J Behav Med 2016;39:225–32.
12. Troxel WM, Braithwaite SR, Sandberg JG, Holt-Lunstad J. Does improving marital quality improve sleep? Results from a marital therapy trial. Behav Sleep Med 2017;15:330–43.
13. Lee S, Martire LM, Damaske SA, Mogle JA, Zhaoyang R, Almeida DM, Buxton OM. Covariation in couples' nightly sleep and gender differences. Sleep Health 2018;4:201–8.
14. Hall M, Buysse DJ, Nowell PD, Nofzinger EA, Houck P, Reynolds CF 3rd, Kupfer DJ. Symptoms of stress and depression as correlates of sleep in primary insomnia. Psychosom Med 2000;62:227–30.
15. Rogojanski J, Carney CE, Monson CM. Interpersonal factors in insomnia: a model for integrating bed partners into cognitive behavioral therapy for insomnia. Sleep Med Rev 2013;17:55–64.
16. Dahl RE, El-Sheikh M. Considering sleep in a family context: introduction to the special issue. J Fam Psychol 2007;21:1–3.
17. Meyer-Lindenberg A, Domes G, Kirsch P, Heinrichs M. Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. Nat Rev Neurosci 2011;12:524–38.
18. Kosfeld M, Heinrichs M, Zak PJ, Fischbacher U, Fehr E. Oxytocin increases trust in humans. Nature 2005;435:673–6.
19. Declerck CH, Boone C, Pauwels L, Vogt B, Fehr E. A registered replication study on oxytocin and trust. Nat Hum Behav 2020;4:646–55.
20. Domes G, Heinrichs M, Michel A, Berger C, Herpertz SC. Oxytocin improves "mind-reading" in humans. Biol Psychiatry 2007;61:731–3.
21. Kirsch P, Esslinger C, Chen Q, Mier D, Lis S, Siddhanti S, Gruppe H, Mattay VS, Gallhofer B, Meyer-Lindenberg A. Oxytocin modulates neural circuitry for social cognition and fear in humans. J Neurosci 2005;25:11489–93.
22. Ditzen B, Schaer M, Gabriel B, Bodenmann G, Ehlert U, Heinrichs M. Intranasal oxytocin increases positive communication and reduces cortisol levels during couple conflict. Biol Psychiatry 2009;65:728–31.
23. Ditzen B, Nater UM, Schaer M, La Marca R, Bodenmann G, Ehlert U, Heinrichs M. Sex-specific effects of intranasal oxytocin on autonomic nervous system and emotional responses to couple conflict. Soc Cogn Affect Neurosci 2013;8:897–902.
24. Aguilar-Raab C, Eckstein M, Geracitano S, Prevost M, Gold I, Heinrichs M, Bilderbeck A, Ehlert U, Ditzen B. Oxytocin modulates the cognitive appraisal of the own and others close intimate relationships. Front Neurosci 2019;13:714.
25. Scheele D, Kendrick KM, Khouri C, Kretzer E, Schläpfer TE, Stoffel-Wagner B, Güntürkün O, Maier W, Hurlemann R. An oxytocin-induced facilitation of neural and emotional responses to social touch correlates inversely with autism traits. Neuropsychopharmacology 2014;39:2078–85.
26. Kreuder AK, Scheele D, Wassermann L, Wollseifer M, Stoffel-Wagner B, Lee MR, Hennig J, Maier W, Hurlemann R. How the brain codes intimacy: the neurobiological substrates of romantic touch. Hum Brain Mapp 2017;38:4525–34.
27. Eckstein M, Almeida de Minas AC, Scheele D, Kreuder AK, Hurlemann R, Grinevich V, Ditzen B. Oxytocin for learning calm and safety. Int J Psychophysiol 2019;136:5–14.
28. Love TM. Oxytocin, motivation and the role of dopamine. Pharmacol Biochem Behav 2014;119:49–60.
29. Hale L, Emanuele E, James S. Recent updates in the social and environmental determinants of sleep health. Curr Sleep Med Rep 2015;1:212–7.
30. Heinrichs M, Baumgartner T, Kirschbaum C, Ehlert U. Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. Biol Psychiatry 2003;54:1389–98.
31. Gimpl G, Fahrenholz F. The oxytocin receptor system: structure, function, and regulation. Physiol Rev 2001;81:629–83.
32. Buijs RM, Hermes MH, Kalsbeek A. The suprachiasmatic nucleus-paraventricular nucleus interactions: a bridge to the neuroendocrine and autonomic nervous system. Prog Brain Res 1998;119:365–82.
33. Lancel M, Krömer S, Neumann ID. Intracerebral oxytocin modulates sleep-wake behaviour in male rats. Regul Pept 2003;114:145–52.
34. Jain V, Marbach J, Kimbro S, Andrade DC, Jain A, Capozzi E, Mele K, Del Rio R, Kay MW, Mendelowitz D. Benefits of oxytocin administration in obstructive sleep apnea. Am J Physiol Lung Cell Mol Physiol 2017;313:L825–33.
35. Lipschitz DL, Kuhn R, Kinney AY, Grewen K, Donaldson GW, Nakamura Y. An exploratory study of the effects of mind-body interventions targeting sleep on salivary oxytocin levels in cancer survivors. Integr Cancer Ther 2015;14:366–80.
36. Fekete EM, Seay J, Antoni MH, Mendez AJ, Fletcher MA, Szeto A, Schneiderman N. Oxytocin, social support, and sleep quality in low-income minority women living with HIV. Behav Sleep Med 2014;12:207–21.
37. Reis HT. Why Researchers Should Think "Real World": A Conceptual Rationale. In: Mehl MR, Conner TS, editors. Handbook of Research Methods for Studying Daily Life. New York, NY: Guilford Press; 2012:3–21.
38. Schwarz N. Why Researchers Should Think "Real Time": A Cognitive Rationale. In: Mehl MR, Conner TS, editors. Handbook of Research Methods for Studying Daily Life. New York, NY: Guilford Press; 2012:22–42.

39. Smyth J, Stone AA. Ecological momentary assessment research in behavioral medicine. J Happiness Stud 2003;4:35–52.
40. Pfeifer AC, Schroeder-Pfeifer P, Schneider E, Schick M, Heinrichs M, Bodenmann G, Ehlert U, Herpertz SC, Läuchli S, Eckstein M, Ditzen B. Oxytocin and positive couple interaction affect the perception of wound pain in everyday life. Mol Pain 2020;16:1744806920918692.
41. Warth M, Stoffel M, Winter F, Jarczok MN, Aguilar-Raab C, Ditzen B. Instructed partnership appreciation in depression: effects on mood, momentary relationship satisfaction, and psychobiological arousal. Front Psych 2020;11:701.
42. MacDonald E, Dadds MR, Brennan JL, Williams K, Levy F, Cauchi AJ. A review of safety, side-effects and subjective reactions to intranasal oxytocin in human research. Psychoneuroendocrinology 2011;36:1114–26.
43. Hahlweg K. Partnerschaftsfragebogen (PFB). In: Hahlweg K, editor. Fragebogen zur Partnerschaftsdiagnostik (FPD). Göttingen, Germany: Hogrefe; 1996:7–24.
44. Hinz A, Ströbel-Richter Y, Brähler E. Der Partnerschaftsfragebogen (PFB): Normierung und soziodemographische Einflussgrößen auf die Partnerschaftsqualität. Diagnostica 2001;47:132–41.
45. Stone AA, Broderick JE, Porter LS, Kaell AT. The experience of rheumatoid arthritis pain and fatigue: examining momentary reports and correlates over one week. Arthritis Care Res 1997;10:185–93.
46. Wilhelm P, Schoebi D. Assessing mood in daily life. Eur J Psychol Assess 2007; 23:258–67.
47. Raudenbush SW, Bryk AS, Cheong YF, Congdon R. HLM 5. Hierarchal Linear and Nonlinear Modeling. Chicago, IL: Scientific Software International; 2005.
48. Bolger N, Laurenceau J-P. Fundamentals of Intensive Longitudinal Data. Intensive Longitudinal Methods. New York, NY: Guilford; 2013:27–39. PSY. 0b013e318185c4fc [pii].
49. Singer JD, Willett JB. Applied Longitudinal Data Analysis. New York, NY: Oxford University Press; 2003.
50. Gordon AM, Chen S. The role of sleep in interpersonal conflict: do sleepless nights mean more fights? Soc Psychol Pers Sci 2014;5:168–75.
51. Tracy EL, Berg CA, Baucom KJW, Turner SL, Kelly CS, Van Vleet M, Butner J, Helgeson VS. Daily sleep quality and daily stressors in couples coping with type 1 diabetes. Health Psychol 2019;38:75–83.
52. Kane HS, Slatcher RB, Reynolds BM, Repetti RL, Robles TF. Daily self-disclosure and sleep in couples. Health Psychol 2014;33:813–22.
53. Akerstedt T, Kecklund G, Axelsson J. Impaired sleep after bedtime stress and worries. Biol Psychol 2007;76:170–3.
54. Neumann ID, Krömer SA, Toschi N, Ebner K. Brain oxytocin inhibits the (re)activity of the hypothalamo-pituitary-adrenal axis in male rats: involvement of hypothalamic and limbic brain regions. Regul Pept 2000;96:31–8.
55. Neumann ID, Wigger A, Torner L, Holsboer F, Landgraf R. Brain oxytocin inhibits basal and stress-induced activity of the hypothalamo-pituitary-adrenal axis in male and female rats: partial action within the paraventricular nucleus. J Neuroendocrinol 2000;12:235–43.
56. Cardoso C, Kingdon D, Ellenbogen MA. A meta-analytic review of the impact of intranasal oxytocin administration on cortisol concentrations during laboratory tasks: moderation by method and mental health. Psychoneuroendocrinology 2014;49:161–70.
57. Kemp AH, Quintana DS, Kuhnert RL, Griffiths K, Hickie IB, Guastella AJ. Oxytocin increases heart rate variability in humans at rest: implications for social approach–related motivation and capacity for social engagement. PLoS One 2012;7:e44014.
58. Behnia B, Heinrichs M, Bergmann W, Jung S, Germann J, Schedlowski M, Hartmann U, Kruger TH. Differential effects of intranasal oxytocin on sexual experiences and partner interactions in couples. Horm Behav 2014;65: 308–18.
59. Shamay-Tsoory SG, Abu-Akel A. The social salience hypothesis of oxytocin. Biol Psychiatry 2016;79:194–202.
60. Lantagne A, Furman W. Romantic relationship development: the interplay between age and relationship length. Dev Psychol 2017;53:1738–49.
61. Díaz-Morales JF, Parra-Robledo Z, Escribano C. Circadian preference and relationship satisfaction among three types of couples. Chronobiol Int 2019;36: 1351–61.
62. Bundesamt für Statistik SDuM. Anzahl leibliche und adoptierte Kinder, Personen im Alter von 25–80 Jahren 2018. Available at: www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/familien/kinderwunsch-elternschaft.assetdetail.10247119.html. Accessed May 21, 2021.