Supplementary Information

Oxytocin facilitates reciprocity in social communication

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SUPPLEMENTARY RESULTS

Experiment 1

The oxytocin (OXT) baseline concentrations were comparable between women (1.32 ± 0.92 pg/ml) and men (1.12 ± 0.81 pg/ml; $t_{(157)} = 1.39$, $P = 0.17$). There were no additional significant main or interaction effects when we included gender as an additional between-subject variable in the analysis of variance (all Ps > 0.05). Furthermore, OXT baseline concentrations were similar between women using hormonal contraception (1.38 ± 0.97 pg/ml) and women not using hormonal contraception (1.22 ± 0.82 pg/ml) ($t_{(96)} = -0.80$, $P = 0.43$). In freely cycling women (n = 34), the self-reported days since the last menstrual period did not correlate with OXT concentrations (before the task: $r = 0.23$, $P = 0.20$; after the task: $r = 0.14$, $P = 0.43$, "after minus before": $r = -0.10$, $P = 0.58$). The majority of participants described their interaction partner as a fellow student and only 18 participants indicated a more familiar relationship (i.e. relationship ≥ 4; 1 = fellow student; 7 = romantic partner).

Experiment 2

A repeated measures analysis of variance (ANOVA) with the 'senders' emotion' (happy, fearful, angry, and neutral) and the 'emotion rating categories' (happy, fearful, and angry) as within-subject factors and the intensity ratings of emotions expressed under placebo (PLC) as dependent variable yielded an interaction of 'senders' emotion' and 'emotion rating categories' (facial expression: $F_{(1.23,\ 67.57)} = 537.03$, $P < 0.01$, $\eta^2 = 0.81$, vocal expression: $F_{(1.87,\ 82.07)} = 218.84$, $P < 0.01$, $\eta^2 = 0.83$; cf. **Figure S1**). This interaction effect was decomposed by comparing the receivers' intensity ratings for the depicted emotion (e.g. the intensity rating of anger if the sender produced an angry expression) with the mean of the raters' intensity ratings for the emotion categories not depicted by the sender (e.g. intensity ratings of fear and happiness if the sender produced an angry expression). The intensity ratings of the depicted emotion were significantly higher than the other intensity ratings for

happy (facial expression: $t_{(55)} = 27.00$, $P < 0.01$, $d = 4.95$; vocal expression: $t_{(44)} = 15.74$, $P < 0.01$, $d = 2.83$), fearful (facial expression: $t_{(55)} = 17.74$, $P < 0.01$, $d = 3.25$; vocal expression: $t_{(44)} = 10.23$, $P < 0.01$, $d = 1.75$), and angry expressions (facial expression: $t_{(55)} = 20.25$, $P < 0.01$, $d = 3.60$; vocal expression: $t_{(44)} = 17.54$, $P < 0.01$, $d = 3.13$), thus showing successful emotion transmission in all emotion categories and both sensory domains.

Consistent with previous studies (Edwards *et al.*, 2002), successful emotion transmission (i.e. intensity ratings of the depicted emotion under PLC) differed between emotion categories (facial expression: $F_{(2, 110)} = 49.00$, $P < 0.01$, $\eta^2 = 0.47$; vocal expression: $F_{(1.75, 77.09)} = 31.31$, $P < 0.01$, $\eta^2 = 0.42$). Specifically, intensity ratings for happy facial expressions were significantly higher than ratings for fearful ($t_{(55)} = 8.11$, $P < 0.01$, $d = 0.68$) or angry ($t_{(55)} = 8.82$, $P < 0.01$, $d = 0.76$) facial expressions. The intensity ratings for fearful and angry facial expressions were comparable ($P = 0.76$). In the vocal domain, intensity ratings of angry expressions were significantly higher than ratings of fearful ($t_{(44)} = 9.96$, $P < 0.01$, $d = 0.89$) or happy expressions ($t_{(44)} = 2.98$, $P < 0.01$, $d = 0.37$). The intensity ratings of happy vocal expressions were also significantly higher than the ratings of fearful vocal expressions ($t_{(44)} = 4.27$, $P < 0.01$, $d = 0.51$) .

Importantly, stress ratings on a scale ranging from 0 (‘not at all stressful’) to 10 (‘very stressful’) after the experiment revealed that the recording of the facial and vocal emotion expressions was not experienced as stressful (facial expressions: PLC = 2.23 +/- 1.59, OXT = 2.29 +/- 1.51; vocal expressions: PLC = 2.32 +/- 1.35, OXT = 2.10 +/- 1.19). Furthermore, the treatment had no effect on stressfulness ratings (facial expressions: $t_{(30)} = -.24$, $P = 0.81$; vocal expressions: $t_{(30)} = 1.05$, $P = 0.30$). Furthermore, a repeated measures ANOVA with ‘senders’ treatment’ (OXT, PLC) and ‘time point’ (before, after) as within-subject factors and ‘cortisol concentration’ as dependent variables showed no significant main or interaction effects (all Ps > .05; pre task: OXT = 0.21 +/- 0.29 pg/ml, PLC = 0.15 +/- 0.14 pg/ml; post task: OXT = .19 +/-0.23 pg/ml, PLC = 0.12 +/-0.10 pg/ml), thereby confirming that the treatment had no effect on cortisol levels as a surrogate marker of stress axis activity.

Further repeated measures ANOVAs with ‘state anxiety’ (STAI), and ‘positive affect’ or ‘negative affect’ (PANAS) as dependent variables showed no significant main or interaction effects of treatment or time (all *P*s > 0.05). Thus, neither OXT nor the experimental procedure itself had any effect on senders’ state anxiety and mood, as measured by the PANAS and STAI before and after each testing session. Likewise, separate one-way ANOVAs with ‘group’ (senders, raters facial expression, and raters vocal expressions) as between-subject factor and demographic/neuropsychological measurements (age, years of education, BDI, AQ, TAS, and STAI trait) as dependent variables were not significant (all *P*s > 0.05). Neither in the OXT (correct estimates 34 %, $\chi^2_{(1)} = 3.1$, $P > 0.05$) nor in the PLC session (correct estimates 54 %, $\chi^2_{(1)} = 0.29$, $P > 0.05$) did the correct estimation of the received treatment significantly differ from chance, indicating that the subjects were unaware of whether they had received OXT or PLC.

A repeated measures ANOVA with the within-subject factors ‘time’ (baseline, pre task, post task) and ‘treatment’ (OXT, PLC) and the saliva OXT concentration as dependent variable yielded main effects of ‘time’ ($F_{(2, 58)} = 39.31$, $P < 0.01$, $\eta^2 = 0.58$) and ‘treatment’ ($F_{(1, 29)} = 87.05$, $P < 0.01$, $\eta^2 = 0.75$) as well as an interaction of ‘time’ and ‘treatment’ ($F_{(2, 58)} = 35.05$, $P < 0.01$, $\eta^2 = 0.55$). Post hoc t-tests revealed a significant difference between the PLC and OXT before and after the task, but did not reveal any differences in OXT concentration at baseline (baseline: PLC 1.52 ± 1.35 pg/ml; OXT: 1.20 ± 1.01 pg/ml; $t_{(29)} = -0.995$, $P = 0.33$, $d = -0.27$; pre task: PLC 2.59 ± 3.23 pg/ml; OXT 30.65 ± 23.48 pg/ml; $t_{(29)} = 6.42$, $P < 0.01$, $d = 1.67$; post task: PLC 1.63 ± 1.44 pg/ml; OXT 34.77 ± 20.39 pg/ml; $t_{(29)} = 9.00$, $P < 0.01$, $d = 2.29$).

Baseline OXT concentrations in the PLC condition were not associated with expressiveness under PLC in any sensory domain (all *P*s > 0.05). The OXT increase in saliva OXT levels (compared to increase in the PLC session) did not predict OXT effects on any of the vocal or facial emotion expressiveness ratings at any sampling time point (all *P*s > 0.05).

SUPPLEMENTARY TABLES

Table S1. Experiment 1: Demographics and psychological screening.

	Synchronous dyad Mean (± SD)		**Asynchronous dyad Mean (± SD)**		***F***	***P***
	Sender (n = 43)	Receiver (n = 47)	Actor A (n = 34)	Actor B (n = 35)		
Age (y)	21.36 (2.73)	21.57 (2.60)	22.44 (3.05)	22.17 (3.43)	1.13	0.34
Education (y)	14.95 (2.07)	14.70 (2.30)	15.65 (2.56)	15.51 (2.06)	1.58	0.20
BMI [1]	22.24 (3.29)	21.64 (2.49)	22.21 (2.80)	21.93 (2.82)	0.39	0.76
Empathy [2]	44.07 (6.38)	45.04 (6.01)	46.23 (5.43)	45.21 (6.10)	0.81	0.49
					χ^2	*P*
Gender (f)	28	29	20	21	0.37	0.95

Notes. [1] Body mass index. [2] Empathy was measured with the Saarbrücker Persönlichkeitsfragebogen, a German version of the Interpersonal Reactivity Index.

Table S2. Experiment 2: Demographics and psychological screening.

	Sender Mean (± SD) (n = 32)	**Receiver facial Mean (± SD)** (n = 56)	**Receiver vocal Mean (± SD)** (n = 45)	***F***	***P***
Age (y)	24.50 (4.11)	25.42 (4.22)	25.67 (4.36)	0.72	0.49
Education (y)	17.03 (2.74)	17.43 (3.12)	17.65 (2.91)	0.39	0.68
AQ [1]	15.23 (5.92)	12.84 (5.02)	13.62 (5.46)	1.92	0.15
TAS [2]	48.37 (6.33)	49.55 (7.45)	46.46 (6.95)	2.11	0.13
BDI [3]	1.96 (2.49)	2.83 (3.67)	2.89 (3.63)	0.74	0.48
STAI [4]	31.07 (6.11)	31.93(6.62)	32.40(5.60)	0.42	0.66
				X^2	*P*
Gender (f) [5]	0	35	23	1.32	0.17

Notes. [1] Autistic-like traits were measured with the Autism-Spectrum Quotient, AQ. [2] Alexithymia was measured with the Toronto Alexithymia Scale, TAS. [3] Depressive symptoms were measured with the Beck Depression Inventory, Version II, BDI. [4] Trait anxiety was measured with the State Trait Anxiety Inventory, STAI. [5] Senders were exclusively male. Pearson's chi squared test was calculated to compare receiver samples on the categorical variable gender.

SUPPLEMENTARY FIGURES

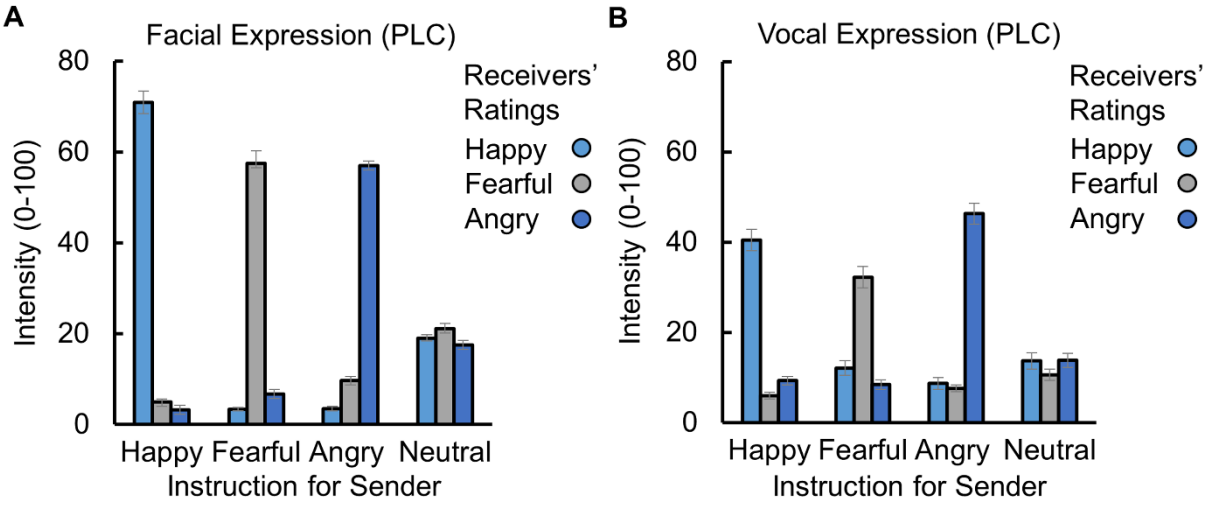

Figure S1. Emotion expression task validation.

Following the intranasal administration of oxytocin (OXT; 24 IU) or placebo (PLC), 32 male participants (senders) were instructed to produce facial and vocal expressions of anger, fear, and happiness. Two independent samples of women and men (receivers, n = 56 and n = 45) rated the intensity of the facial and vocal expressions. Under PLC, the transmission of emotions was more specific (i.e. the receiver attributed higher intensities to the emotional expressions) in the visual domain (**A**) than in the auditory domain (**B**). The intensity ratings for the depicted emotion were significantly higher than intensity ratings for the remaining two emotion categories for happy (facial expression: $t_{(55)} = 27.00$, $P < 0.01$, $d = 4.95$; vocal expression: $t_{(44)} = 15.74$, $P < 0.01$, $d = 2.83$), fearful (facial expression: $t_{(55)} = 17.74$, $P < 0.01$, $d = 3.25$; vocal expression: $t_{(44)} = 10.23$, $P < 0.01$, $d = 1.75$), and angry expressions (facial expression: $t_{(55)} = 20.25$, $P < 0.01$, $d = 3.60$; vocal expression: $t_{(44)} = 17.54$, $P < 0.01$, $d = 3.13$), thus showing successful emotion transmission in all emotion categories and both sensory domains.

SUPPLEMENTARY REFERENCES

Edwards, J., Jackson, H. J. & Pattison, P. E. (2002) Emotion recognition via facial expression and affective prosody in schizophrenia: a methodological review. Clinical Psychology Review, 22, 789-832.