Emotional maltreatment is associated with atypical responding to stimulation of endogenous oxytocin release through mechanically-delivered massage in males[☆]

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ABSTRACT

The neuropeptide oxytocin plays an important role in social behavior, parenting, and affectionate touch and there is some evidence that oxytocin release can be stimulated by massage or affectionate touch. We examined the effects of massage applied by a massage seat cover on salivary oxytocin levels in two exploratory studies using within-subject designs. In Study 1 massage effects on oxytocin levels were examined in a sample of N = 20 healthy female participants. Effects of a 15-min massage session were compared to a control condition during which participants sat on a comfortable chair without a massage seat cover. Salivary oxytocin levels were measured at baseline and up to three hours after the session. We found that massage attenuated oxytocin decreases over time, indicating that massage stimulates oxytocin release. In Study 2, we examined whether effects of massage in N = 46 healthy male participants depend on experiences of emotional maltreatment. In addition, we examined whether enhanced oxytocin levels after massage affect the use of excessive handgrip force in response to infant crying and laughter as measured with a handgrip dynamometer. Our findings show that massage results in elevated oxytocin levels compared to a control condition, but that the effects of massage are dependent on experiences of emotional maltreatment. Men with experiences of emotional maltreatment showed lower oxytocin levels, which did not increase after massage. Furthermore, we found that high oxytocin levels after massage were related to reduced handgrip force during exposure to infant crying and laughter, indicating that massage stimulates a sensitive response to infant signals by stimulating oxytocin release. Although massage did not affect oxytocin levels in individuals with experiences of maltreatment, it reduced the use of handgrip force in response to infant crying and laughter in these individuals. Our findings indicate that emotional maltreatment is associated with atypical responding to stimulation of endogenous oxytocin release.

1. Introduction

The neuropeptide oxytocin is well known for its role in social affiliation, parenting, and other forms of social behavior (Carter, 1998; Feldman, 2012; Feldman and Bakermans-Kranenburg, 2017). Research has shown that it is involved in initiating the "touch circuitry" between parents and infants (Gordon et al., 2010). For example, maternal oxytocin levels increased after infant contact in mothers who provided high levels of affectionate touch (Feldman et al., 2010). Maternal oxytocin has also been shown to be enhanced when newborns perform massage-like hand movements to the mothers' breast in preparation for the first breastfeeding (Matthiesen et al., 2001).

Other studies point to oxytocin enhancing effects of massage in adults. Holt-Lunstad et al. (2008) found that married couples who received a 4-week intervention to increase support through warm touch (touching their partner's neck, shoulders, and hands) showed increased

salivary oxytocin levels compared to a control group. In line with these findings, Morhenn et al. (2012) found that massage increases plasma oxytocin and reduces adreonocorticotropin hormone compared to a control group, possibly indicating that massage has stress-reducing and anxiolytic effects. These studies seem to indicate that massage stimulates endogenous oxytocin release. However, previous studies examining endocrine effects of massage report inconsistent findings and massage effects on cortisol are generally small (Moyer et al., 2011). It is, therefore, still uncertain whether massage stimulates oxytocin production and release. One explanation for previously reported inconsistent findings on endocrine effects of massage is that there may be individual differences in the response to massage or affectionate touch. Effects of massage may be different for men and women because of sex differences in the oxytocin system (Taylor, 2006); men have been shown to have higher plasma oxytocin levels than women (Weisman et al., 2013) and respond differently to exogenous intranasal oxytocin administration (Rilling et al., 2014).

Another individual difference factor that may influence the endogenous oxytocin release is childhood caregiving experiences. Childhood caregiving experiences play an important role in shaping the oxytocin system (Feldman, 2015) and influence oxytocin release in response to stress (Pierrehumbert et al., 2010). In addition, childhood caregiving experiences have been shown to affect sensitivity to intranasal oxytocin in multiple studies. For example, we found that intranasal oxytocin administration decreased the use of excessive handgrip force in response to infant crying, but only in individuals who reported positive childhood experiences and not in individuals who reported harsh caregiving experiences (Bakermans-Kranenburg et al., 2012). Negative childhood experiences also moderate oxytocin effects at the neural level: oxytocin effects on resting-state functional connectivity were only found in individuals who reported a supportive family background (Riem et al., 2013). In a similar vein, Meinlschmidt and Heim (2007) showed that individuals with experiences of early parental separation exhibited attenuated cortisol decreases after intranasal oxytocin administration (versus placebo) compared with control subjects without experiences of early separation. Furthermore, individuals with negative childhood experiences show lower oxytocin levels in cerebrospinal fluid (Heim et al., 2009) and plasma (Opacka-Juffry and Mohiyeddini, 2012), indicating that adverse childhood experiences may lead to a dysregulation of the oxytocin system. Individuals with negative childhood experiences may therefore also show abnormal responding to stimulation of endogenous oxytocin release through massage.

In the current studies, we examine whether massage stimulates endogenous oxytocin release in men and women and whether enhanced oxytocin levels after massage affect responses to infant crying and laughter. In a previous study, we found that intranasal oxytocin modulates neural responses to infant crying: oxytocin increased reactivity in empathy-related brain regions and decreased amygdala reactivity to crying (Riem et al., 2011). Similarly, reduced amygdala activity after intranasal oxytocin administration was also found during exposure to infant laughter (Riem et al., 2012). Reduced amygdala activity may be the mechanism underlying the anxiolytic and stress-reducing effects of oxytocin, which promote a sensitive caregiving response to an infant signal. This is particularly important during exposure to infant crying, as crying can elicit negative feelings of aversion and anger (Soltis, 2004) and excessive infant crying can even elicit harsh caregiving responses in some parents (Barr et al., 2006; Reijneveld et al., 2004). It is however unknown whether stimulation of endogenous oxytocin release influences responding to infant crying and laughter.

The current study is the first to examine whether massage stimulates endogenous oxytocin release through mechanically-delivered massage in a standardized setting. First, we examine whether massage applied by a massage seat cover influences salivary oxytocin levels in a pilot study with N = 20 healthy female participants (Study 1). We expected that massage stimulates endogenous oxytocin release and results in increased oxytocin levels. In Study 2, we examine whether effects of massage in N = 46 healthy male participants depend on experiences of emotional maltreatment. In addition, we examine whether enhanced oxytocin levels after massage affect the use of excessive handgrip force in response to infant crying and laughter as measured with a handgrip dynamometer. We expected that enhanced oxytocin levels after massage are related to decreased handgrip force in response to infant signals, but that oxytocin-releasing effects of massage are influenced by emotional maltreatment.

2. Study 1

2.1. Methods

2.1.1. Participants

Participants were 20 female students and employees from Leiden University, The Netherlands, who volunteered to participate in a pilot study. The mean age of the participants was 27.50 years (SD = 6.53, range 22–46). The majority (60%) used oral contraceptives and did not have children of their own (90%). Participants were invited for the study in the luteal phase of their menstrual cycle in order to control for hormonal influences due to the menstrual cycle. For one participant it was not possible to determine menstrual phase because of use of intrauterine device. Exclusion criteria were arm, neck, and back injuries, pregnancy, breastfeeding, and use of medications other than oral contraceptives. All participants were non-smokers.

2.1.2. Procedure

A within-subject design was used to examine the effects of mechanically-delivered massage. Participants were invited for lab sessions on two successive days. The order of massage and control conditions was counterbalanced. They were instructed to abstain from alcohol and excessive physical activity during the 24 h before the start of study, and from caffeine on the data collection days. The sessions started at 9:00 a.m. with saliva collection to assess baseline oxytocin levels. Afterwards, participants completed questionnaires on food and drink intake, physical exercise, mood, and stress. Participants were then instructed to sit either on a chair with the electric massage seat cover (massage condition) or on the same chair without the seat cover (control condition) for 15 min while looking at photographs of landscapes. Neck, shoulders, and back were massaged by the seat cover (type: Medisana 88930). A vibration massage was applied in the seat of the cover. The seat cover did not provide heat and has not been used in previous research. Mechanically delivered massage was examined because of practical reasons and because the use of the massage seat cover enabled the study of the effects of massage in a standardized setting. After the massage or control session, saliva was collected at 9:15, 10:00, 11:00 a.m., and 12:00 p.m. and the mood questionnaire was completed again at 9.15 a.m. and 12.00 p.m. Participants left the laboratory after the second saliva collection but were asked to stay around in order to provide saliva samples at 10:00, 11:00, a.m. and 12:00 p.m. Participants remained seated during the period of saliva collection and were requested not to engage in abnormal physical activity.

2.1.3. Questionnaires

Current mood was measured with the Positive Affect Negative Affect questionnaire (PANAS; Watson et al., 1988). These items include 10 items for positive affect (e.g., alert, enthusiastic, determined) and 10 items for negative affect (e.g., upset, irritable, nervous). Each item was rated on a 5-point scale ranging from 1 = not at all to 5 = a lot. We used the Positive Affect scale ($\alpha > 0.85$), indicating positive mood before and after sitting on the (massage) chair. In addition, participants rated on two 10-point rating scales how much stress they experienced at home and at work on the day of the lab session. We used work-related stress as covariate, because oxytocin levels were measured during working hours.

2.1.4. Salivary oxytocin

At least 1 ml of unstimulated saliva was collected into cryotubes for each sample using the passive drool method. Samples were immediately frozen and were stored at −20 °C until batch assay. Level of oxytocin in saliva was assayed using a commercially available kit as per the method previously described and used before (Grewen et al., 2010). Prior to the enzyme immunoassay procedure, in keeping with the manufacturer's strong recommendation, an extraction step was performed based on instructions accompanying the EIA kit available in February 2011 (ADI-900-153, Enzo Life Science, Plymouth Meeting, PA, USA). Oxytocin extraction efficiency was 94%. The lower limit of sensitivity was 1 pg/ml. 6.5% of the samples fell below the lower level of sensitivity. These values were replaced with 0.90 pg/ml. The intra- and inter-assay coefficients of variation were 7.56 and 8.20% respectively. The manufacturer reports that cross-reactivity with similar mammalian neuropeptides is less than 1%. Data was screened for outliers but there were none.

2.1.5. Data analysis

We analyzed the repeated measures of oxytocin with multilevel models, using the MIXED procedure in SPSS 21.0. Models were built step-wise, starting from a random intercept model with only linear time as a predictor. A random slope for time and effects of massage condition, work-related stress, and mood were added successively. Time was coded as −0.25, 0, 0.75, 1.75, 2.75, mimicking the actual time frame of measurement, and defining the moment just after massage in the experimental condition as the reference point. We coded condition as a time-varying covariate, with values 0, 1, 1, 1, 1 in the experimental, and 0, 0, 0, 0, 0 in the control condition. This coding allowed for a "skip" in the linear regression line at 9.15 (right after the massage) in the experimental condition. Continuous predictors (mood and stress) were centered at the grand mean.

We report unstandardized regression weights β and variance components. To assess overall model fit, we compared nested models using the −2 log likelihood test. To ensure the validity of this test, we used Full Maximum Likelihood estimation. Significance of model parameters was assessed by t-tests for the fixed part, and Wald Z-tests for the random part.

2.2. Results

The observed oxytocin levels at the five measurement points in the massage and control condition are displayed in Fig. 1. Note that there seems to be a "skip" in the regression line at 9:15 a.m. in the massage condition, but only after 10:00 a.m. the values in this condition were structurally higher compared to the control condition.

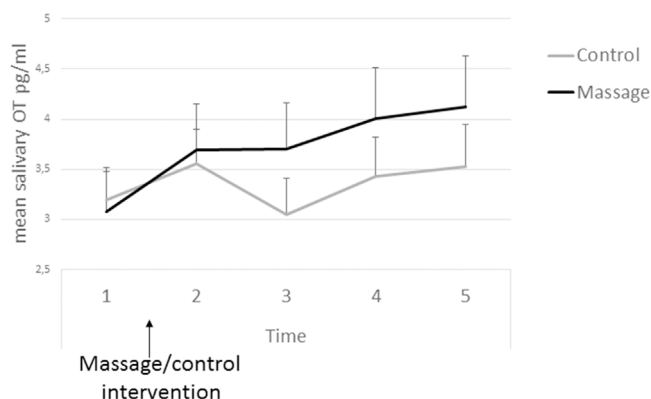In Table 1, the results for the estimated multilevel models are

Fig. 1. Observed mean values of oxytocin at the five measurement occasions (9.00, 9.15, 10.00, 11.00, a.m. 12.00 p.m.) for the massage and control condition (Study 1: female sample).

displayed. Model 1 only incorporates linear development in oxytocin across time, which can be specified as follows:

$$
\begin{aligned}
\text{Level:1} \quad & Y_{ti} = \pi_{0i} + \pi_{1i}(\text{time}) + e_{ti} \\
\text{Level: 2} \quad & \pi_{0i} = \beta_{00} + u_{0i} \\
& \pi_{1i} = \beta_{10}
\end{aligned}
$$

The conditional intra-class correlation equals $1.56/(1.56 + 1.91)$ = 0.45, indicating that 45% of the variation in the data was on the inter-personal level, after controlling for linear development across time. Note that the intercept refers to the predicted average oxytocin level at 9:15, and varied significantly across persons. Overall, there was a slight linear increase in predicted oxytocin levels across time.

Model 2 shows that neither the random slope for time nor the slope-intercept covariance was significant, indicating no significant inter-personal differences in development of oxytocin levels across time. Thus, following models do not incorporate a random slope. Model 3 includes the effect of massage/control condition. After massage, the regression line increased 0.51 pg/ml, $p = 0.01$. In both conditions, there was no significant development in oxytocin across time points, $\beta = 0.12$, $p = 0.16$. Including the interaction between time and massage (Model 4) did not lead to a better fit, $\chi2 (1) = 0.19$, $p = 0.66$. Note that when interactions are involved, the coefficient for massage refers to the predicted difference in oxytocin between conditions at 9:15.

Finally, Model 5 did not outperform Model 3, $\chi2 (3) = 3.23$, $p = 0.36$, indicating that work stress was not related to inter-personal differences in oxytocin level, and did not interact with time or condition. Finally, when we included mood in Model 3, no significant effect of this covariate emerged ($p = 0.33$). As mood was only measured at three time points, the fit of this model was not directly comparable to the other models.

To summarize, in this pilot study we examined whether mechanically-delivered massage influences oxytocin release. We found some evidence that, in females, massage applied by the seat cover increased salivary oxytocin levels compared to the control condition. Our finding extends previous studies investigating the effects of massage by showing that massage *without* human touch may also elevate oxytocin levels. Thus, human touch seems not an essential component in the oxytocin enhancing effects of massage. Based on the results of this pilot study, Study 2 was carried out in order to examine whether oxytocin-enhancing effects of massage were also present in males and whether enhanced oxytocin levels after massage would in turn affect responses to infant signals.

3. Study 2

3.1. Methods

3.1.1. Participants

Participants were 51 male students from Leiden University, The Netherlands (n = 16), or the University of Milan, Italy (n = 35). The mean age of the participants was 22.39 years (*SD* = 2.37, range 18–29) and age did not differ between Italian and Dutch participants ($t(42)$ = −0.24, $p = 0.81$). Exclusion criteria were use of medication, arm, neck, and back injuries, and psychiatric disorder. Participants did not have children. The study was approved by the Ethics Committees of the Institute of Education and Child Studies of Leiden University. Participants who did not abstain from coffee or alcohol or had wounds in their mouth were excluded from data analyses (n = 5), resulting in a final sample of 46 participants. Due to technical problems, handgrip data of two participants in the control condition and seven participants in the massage condition were missing.

3.1.2. Procedure

A within-subject design was used to examine the effects of

Table 1

Multilevel Models for Predicting Oxytocin Levels from Time (time), Massage Condition (mas), and Work Stress (stress); Within-subjects Design (N = 20).

Parameter		Model 1 Estimate (SE)	Model 2 Estimate (SE)	Model 3 Estimate (SE)	Model 4 Estimate (SE)	Model 5 Estimate (SE)
Fixed effects						
Level 1 predictors						
intercept	β_{00}	3.36** (0.31)	3.36** (0.31)	3.21** (0.31)	3.23** (0.32)	3.20** (0.34)
slope	β_{10} (time)	0.17** (0.09)	0.17 (0.11)	0.12 (0.09)	0.09 (0.11)	0.12 (0.09)
slope	β_{20} (mas)			0.51* (0.20)	0.42 (0.29)	0.53* (0.20)
slope	β_{30} (time × mas)				0.08 (0.18)	
Level 2 predictor						
intercept	β_{01}(stress)					−0.21 (0.14)
slope	β_{11} (stress)[a]					0.05 (0.05)
slope	β_{21} (stress)[b]					0.11 (0.11)
Random effects						
intercept	var(u_{0i})	1.56* (0.55)	1.61* (0.61)	1.57* (0.55)	1.57* (0.55)	1.88* (0.78)
slope	var(u_{1i})(time)		0.09 (0.08)			
	cov(u_{0i}, u_{1i})		−0.06 (0.16)			
residual	var(e_{ti})	1.91** (0.20)	1.78** (0.20)	1.84** (0.19)	1.83** (0.19)	1.78** (0.19)
Model fit						
−2 Log likelihood		740.99	738.44	734.65	734.46	731.42
AIC		748.99	750.44	744.65	746.46	747.42
Nr. parameters		4	6	5	6	8

* $p < 0.05$.
** $p < 0.01$.
[a] cross-level interaction with time.
[b] cross-level interaction with massage condition.

mechanically-delivered massage. Participants were invited for two lab sessions (one week time interval). After signing informed consent, they were instructed to abstain from alcohol and excessive physical activity during the 24 h before the start of study, and from caffeine on the data collection days. Similar to Study 1, the sessions started at 9:00 a.m. with saliva collection (T1) to assess baseline oxytocin levels. Participants completed questionnaires on food and drink intake, physical exercise, mood, and stress. Participants were then instructed to sit either on a chair with the same electric massage seat cover as in Study 1 (massage condition) or on the chair without the seat cover (control condition) for 15 min while looking at photographs of landscapes. Neck, shoulders, and back were massaged by the seat cover (type: Medisana 88930). The massage and control conditions were counterbalanced. Afterwards, saliva was collected at 9:15 (T2), 10:00 (T3), 11:00 (T4) a.m., and 12:00 p.m (T5). Between the saliva collection T2 and T3, an experimental infant cry paradigm was administered in order to examine whether enhanced oxytocin levels after massage influences responding to infant signals. Participants were exposed to sounds of infant crying and laughter and were asked to squeeze a handgrip dynamometer (as in Bakermans-Kranenburg et al., 2012). For the purpose of the current study, we focus on saliva collection T1 and T2 to prevent confounding by the handgrip dynamometer task. The procedure of saliva collection and salivary oxytocin analysis was the same as in Study 1.

3.1.3. Measurements

3.1.3.1. Mood. Similar to Study 1 current mood was measured with the PANAS (Watson et al., 1988) (positive affect α > 0.71, negative affect α > 0.73).

3.1.3.2. Stress. Participants rated on a 10-point rating scale how much stress they experienced at home.

3.1.3.3. Childhood trauma questionnaire. Participants completed the Dutch or Italian version of the Childhood Trauma Questionnaire Short Form (CTQ-SF, Bernstein et al., 1994, 2003). CTQ-SF is a measure of self-reported experiences of childhood abuse. Twenty-eight items were used to assess experiences of physical abuse, emotional abuse, sexual abuse, physical neglect, and emotional

neglect. Each item (e.g., "During my childhood I felt hated by family") was rated on a 5-point Likert scale ranging from never true to very often true. In the current study we focused on the emotional abuse and emotional neglect subscales because these subscales showed largest variability in the current sample. An emotional maltreatment scale was created (α = 0.85) by averaging the 10 items tapping into the emotional abuse and emotional neglect dimensions. The mean score was 1.91 (SD = 0.44) with scores ranging from 1.40 to 3.40. A log transformation was applied to the emotional maltreatment variable to approach a normal distribution.

3.1.3.4. Handgrip force. A handgrip dynamometer task (Bakermans-Kranenburg et al., 2012; Riem et al., 2016) was used to examine whether massage affects responding to infant signals. The handgrip dynamometer was used as an indicator of the use of excessive force during listening to infant crying and laughing. Squeeze intensities (in kg) were transferred directly from the dynamometer to the AcqKnowledge software program (version 3.8; Biopac Systems, 2004). Participants were asked to squeeze the handgrip dynamometer as hard as possible and then at 50% of their maximum handgrip strength. They performed as many trials as necessary for training, with their performance displayed on a monitor to check the 50% level of each second handgrip, until they were able to modulate the force of their second squeeze to half the strength of their first squeeze. Then the monitor was directed away from the participant in order to prevent receiving feedback regarding the performance during the remainder of the task. The handgrip-force task was administered on a laptop using E-Prime software (version 2.0; Psychology Software Tools, Inc., PA, USA). During the task participants were seated in front of a computer screen wearing headphones. As a prompt, the words "squeeze maximally" were displayed briefly in the middle of the screen, after 2 s followed by the prompt "squeeze at half strength", thus prompting the participants to perform a brief firm squeeze followed by a brief squeeze half the strength. After baseline squeezing (no sound), participants were requested to squeeze the handgrip dynamometer eight times at full and half strength, four times during listening to infant laughter and four times listening to infant crying (counterbalanced order). The infant laughter and cry sounds (duration = 2 min) from Groh and Roisman

(2009) were used. The intervening time between full- and half-strength prompts was 2 s; the intervening time period between half-strength and the next full-strength prompt was 25 s. Similar to studies on the same and other samples (Bakermans-Kranenburg et al., 2012; Compier-de Block et al., 2015; Riem et al., 2016), grip strength modulation was calculated by dividing the half-strength squeeze intensity by the full-strength squeeze intensity, so that scores of over 0.50 indicated excessive force on the half-strength squeeze attempt. We examined massage effects on the ratio handgrip strength half force and handgrip strength maximum force, which can be considered an implicit measurement of reactive force in response to infant signals.

3.1.4. Data analysis

Oxytocin levels > 2 SD from the mean were considered outliers and were replaced by the maximum observed non-outlying value per condition. The correlation between baseline oxytocin level (mean massage and control condition) and emotional maltreatment was assessed. To examine effects of massage on oxytocin levels, differences between oxytocin levels at T1 and T2 in the massage and control condition were calculated. Afterwards, a contrast score was calculated by subtracting the difference score of the control condition from the difference score of the massage condition (Massage (Post – Pre) – Control (Post – Pre)). This contrast score reflects the difference in oxytocin level changes between the massage and the control condition. A hierarchical regression analyses was conducted with the contrast oxytocin score as dependent variable, baseline oxytocin levels (T1) at the day of the massage condition and emotional maltreatment (both centered) as predictors in the first step and the interaction between baseline oxytocin levels (centered) and emotional maltreatment (centered) in the second step. Hierarchical regression analysis was used in order to predict oxytocin responses to massage with emotional maltreatment and baseline oxytocin levels as continuous variables. Because the interpretation of the contrast score may be difficult, an additional repeated measures Anova was performed with time (pre (T1) and post (T2) massage or control chair) and condition (massage, control) as within-subject factors, emotional maltreatment (dichotomized using a median split) and baseline oxytocin levels at the day of the massage condition (dichotomized using a median split) as between-subject factors. Mood and stress were excluded from analysis because these covariates did not contribute significantly to the model.

Furthermore, we conducted a repeated measures Anova with handgrip force ratio as dependent variable, condition (massage, control) and infant sound condition (baseline, infant crying, laughing) as within-subject factors and emotional maltreatment as covariate in order to examine effects of massage on handgrip force in response to infant crying and laughter. Hierarchical regression analysis with handgrip force ratio in the massage condition as the dependent variable was performed to examine whether higher oxytocin levels after massage predict handgrip force in response to infant crying and laughter. Emotional maltreatment and oxytocin levels at T2 (post massage) were entered as centered predictors in step 1 and the interaction between emotional maltreatment (centered) and oxytocin levels T2 after massage (centered) in step 2.

3.2. Results

3.2.1. Oxytocin levels

The results from the hierarchical regression analysis with the contrast oxytocin score as dependent variable are displayed in Table 2. The model was significant ($F(3,40) = 3.16$, $p = 0.04$) and the effects of baseline oxytocin level ($\beta = -0.33$, $p = 0.04$) and emotional maltreatment ($\beta = -0.43$, $p < 0.01$) were both significant, indicating that baseline oxytocin level and maltreatment influenced changes in oxytocin level in response to massage. The interaction between emotional maltreatment and baseline oxytocin level at the day of massage was not significant ($\beta = -1.66$, $p = 0.10$). This indicates that the

Table 2
Summary of hierarchical regression analysis with the contrast oxytocin (OT) score as dependent variable, baseline oxytocin levels (T1) at the day of the massage condition and emotional maltreatment in the first step and the interaction between baseline oxytocin levels and emotional maltreatment in the second step.

	OT contrast score (massage − control)			
	B	SE	ß	delta R^2
Step 1				0.14[*]
Baseline OT	− 0.49	0.23	− 0.33[*]	
Emotional maltreatment	− 27.56	10.05	− 0.43[**]	
Step 2				0.06
Baseline OT x Emotional maltreatment	− 5.25	3.16	− 0.25	

Betas derived from the final block of the regression model.
[*] $p < 0.05$.
[**] $p < 0.01$.

influence of emotional maltreatment on response to massage was the same for individuals with lower and higher baseline oxytocin levels. A repeated measures Anova with time and condition as within-subject factors and emotional maltreatment group and baseline oxytocin level group as between-subject factors was conducted to interpret the effects of baseline oxytocin level and emotional maltreatment on oxytocin level changes in response to massage. There was a significant main effect of time ($F(1,41) = 5.28$, $p = 0.03$, partial $\eta^2 = 0.11$), with higher pre-intervention oxytocin levels (M = 13.64, SD = 0.57) than post-intervention oxytocin levels (M = 12.60, SD = 0.59). The main effect of condition was not significant ($F(1,41) = 1.33$, $p = 0.26$, partial $\eta^2 = 0.03$). Neither was there a significant interaction between time and condition ($F(1,41) = 1.87$, $p = 0.18$, partial $\eta^2 = 0.04$). The effect of baseline oxytocin level group was significant ($F(1,41) = 10.65$, $p < 0.01$, partial $\eta^2 = 0.21$), but no significant main effect was found for emotional maltreatment group ($F(1,41) = 2.73$, $p = 0.11$, partial $\eta^2 = 0.06$). Further, there was a significant three-way interaction between condition, time, and emotional maltreatment group ($F(1,41) = 9.97$, $p < 0.01$, partial $\eta^2 = 0.20$) and a significant three-way interaction between condition, time, and baseline oxytocin level group ($F(1,41) = 7.26$, $p = 0.01$, partial $\eta^2 = 0.15$). These significant interactions indicate that only for individuals with low emotional maltreatment and for individuals with low baseline oxytocin levels, there was a significant decrease in oxytocin levels in the control condition, whereas this decrease was absent in the massage condition. These interactions are visualized in Fig. 2. Fig. 2 shows that oxytocin levels decrease during the control session and that this decrease over time is attenuated in the massage condition, but only for individuals with low emotional maltreatment and for individuals with low baseline oxytocin levels. Individuals with high levels of emotional maltreatment and with high baseline oxytocin levels do not show attenuated oxytocin decreases in the massage condition. The correlation between mean baseline oxytocin level and emotional maltreatment was significant ($r = -0.42$, $p < 01$).

3.2.2. Handgrip force

The repeated measures Anova with handgrip force ratio as dependent variable did not show main effects of massage versus control condition ($F(1,33) = 2.49$, $p = 0.12$, partial $\eta^2 = 0.07$) or infant sound (laugh versus cry) ($F(2,66) = 1.65$, $p = 0.20$, partial $\eta^2 = 0.05$) on handgrip force. The interaction between massage/control condition and infant sound was marginally significant ($F(2,66) = 2.84$, $p = 0.07$, partial $\eta^2 = 0.08$). Furthermore, there was a marginally significant effect of emotional maltreatment on handgrip force ($F(1,33) = 3.29$, $p = 0.08$, partial $\eta^2 = 0.09$) and a significant interaction between emotional maltreatment and massage condition ($F(1,33) = 4.35$, $p < 0.05$, partial $\eta^2 = 0.12$). Massage reduced handgrip force ratio at
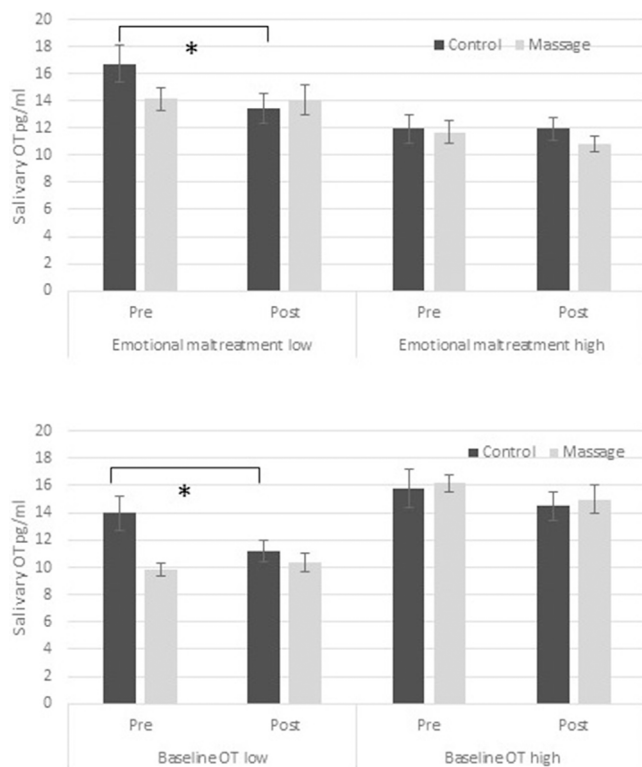
Fig. 2. Mean (SE) salivary oxytocin levels at T1 (pre massage/control chair) and T2 (post massage/control chair) in the control and massage condition for individuals with low and high emotional maltreatment (upper panel) and low and high baseline levels at the day of the massage condition (lower panel) (Study 2: male sample).
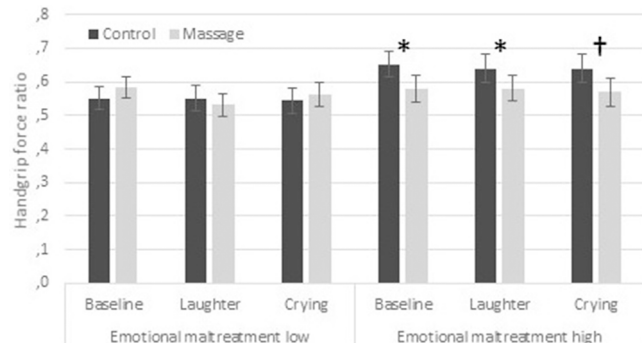

Fig. 3. Mean (SE) handgrip force ratio at baseline and during infant laughter and crying in the control and massage condition for individuals with low and high emotional maltreatment (Study 2: male sample).

baseline and during infant laughter and crying but only in individuals with experiences of maltreatment (see Fig. 3). The three-way interaction between massage, infant sound condition, and emotional maltreatment was not significant ($F(2,66) = 2.29$, $p = 0.11$, partial $\eta^2 = 0.07$).

The results from the hierarchical regression analysis with handgrip force ratio as dependent variable are displayed in Table 3. The model of the analysis with handgrip force in response to laughter was significant ($F(3,33) = 2.98$, $p < 0.05$). Oxytocin levels after massage were significantly related to handgrip force in response to laughter, with higher oxytocin levels related to less excessive force ($\beta = -0.47$, $p = 0.02$), but there was no significant effect of emotional maltreatment ($\beta = 0.12$, $p = 0.48$) and no significant interaction between oxytocin levels and emotional maltreatment ($\beta = -0.23$, $p = 0.21$). Results of the hierarchical regression analysis with handgrip force ratio in response to crying were similar. The model of the analysis with handgrip

force in response to crying was marginally significant ($F(3,33) = 2.54$, $p = 0.07$). Again, there was a significant effect of oxytocin levels after massage indicating an association between higher oxytocin levels and less excessive force during crying ($\beta = -0.48$, $p = 0.02$), but no effect of emotional maltreatment ($\beta = 0.03$, $p = 0.84$) and no significant interaction between oxytocin level and emotional maltreatment ($\beta = -0.26$, $p = 0.16$).

To summarize, Study 2 showed that massage attenuates oxytocin level decreases over time only in men with positive childhood experiences, but not in men with experiences of emotional maltreatment. In addition, high oxytocin levels after massage were related to reduced handgrip force during exposure to infant crying and laughter. This finding points to increased oxytocin release as one of the mechanism underlying the sensitivity enhancing effects of massage. Although massage did not affect oxytocin levels in individuals with experiences of maltreatment, it reduced the use of handgrip force in response to infant crying and laughter in these individuals, indicating that other mechanisms may underlie the positive effects of massage in maltreated individuals.

4. Discussion

In two studies we examined the effects of a 15-min massage applied by an electric massage seat cover on salivary oxytocin levels in women (Study 1) and men (Study 2). Compared to a control condition during which participants sat on a comfortable chair without massage, we found that the massage affected oxytocin levels in both men and women. Our finding extends previous studies investigating the effects of massage by showing that massage *without* human touch results in elevated oxytocin levels compared to a control condition and that human touch is not an essential component in the oxytocin enhancing effects of massage. This finding converges with Meaney's (2001) work on rats showing that stroking pups with a brush mimics the tactile stimulation by maternal licking and grooming and down-regulates corticosterone levels. It also reminds us of Harlow's (1958) search for the essence of love in infant macaque monkeys residing in contact comfort of surrogate mothers.

In Study 2 we examined whether enhanced oxytocin levels after massage influence responding to infant signals and whether the effects of massage are dependent on childhood caregiving experiences. Interestingly, we found that higher oxytocin levels after massage were related to reduced handgrip force during exposure to infant crying and laughter. Individuals with high oxytocin levels after massage exerted less force than individuals with lower oxytocin levels. Together, these findings may indicate that massage promotes a more sensitive response to infant signals by stimulating oxytocin release. Thus, our findings point to increased oxytocin release as one of the mechanism underlying sensitivity enhancing effects of massage. Previous studies showed that intranasal oxytocin stimulates parental sensitive responsiveness to infants (Naber et al., 2012; Naber et al., 2010), possibly by enhancing empathy-related brain activity and inhibiting anxiety-related amygdala activity during exposure to infant crying and laughter (Riem et al., 2011; Riem et al., 2012). The current study indicates that the stimulation of endogenous oxytocin release through massage may be another way of promoting positive parent-infant interactions.

Our findings may have implications for the development of parenting interventions. Previous research indicates that intranasal oxytocin administration is not effective as a stand-alone intervention targeting psychiatric disorders and insensitive parenting (Bakermans-Kranenburg and Van IJzendoorn, 2013). However, stimulation of endogenous oxytocin release might improve troubled parent-child relationships. Holt-Lunstad et al. (2011) showed that a 4-week intervention enhancing partner support through warm touch had stress-reducing effects and normalized oxytocin levels in individuals with depressive symptoms. Future studies should examine whether the stimulation of endogenous oxytocin release through massage promotes

Table 3
Summary of hierarchical regression analysis with handgrip ratio as dependent variable, oxytocin levels after massage (T2) and emotional maltreatment in the first step and the interaction between oxytocin levels after massage and emotional maltreatment in the second step.

	Handgrip Ratio Laughter				Handgrip Ratio Crying			
	B	SE	ß	delta R²	B	SE	ß	delta R²
Step 1				0.18[*]				0.14[†]
Oxytocin T2 (after massage)	−0.01	0.01	−0.47[*]		−0.02	0.01	−0.48[*]	
Emotional maltreatment	0.18	0.26	0.12		0.05	0.27	0.03	
Step 2				0.14				0.05
Oxytocin T2 x Emotional maltreatment	−0.07	0.06	−0.23		−0.09	0.06	−0.26	

Betas derived from the final block of the regression model.
[†] $p < 0.1$.
[*] $p < 0.05$.

sensitive parent-infant interactions. Massage applied by a massage chair or seat cover may be an easy way of enhancing oxytocin levels in parents and possibly also in infants, which may in turn promote positive parent-infant interactions. Massage combined with intranasal oxytocin or a behavioral intervention may also be effective in stimulating sensitive parenting, for example in mothers with postpartum depression.

Unfortunately, massage attenuated oxytocin level decreases over time only in men with positive childhood experiences, but not in men with experiences of emotional maltreatment. This may indicate that stimulating effects of massage on oxytocin release are hindered in individuals with negative childhood experiences. Moreover, salivary oxytocin levels were lower in individuals with experiences of emotional maltreatment. This is consistent with previous studies showing that adverse childhood experiences lead to a dysregulation of the oxytocin system and reduced sensitivity to intranasal oxytocin (Fan et al., 2015; Meinlschmidt and Heim, 2007; Riem et al., 2013). Thus, individuals with negative childhood experiences do not only show abnormal sensitivity to exogenous oxytocin administration, but also a different response to stimulation of endogenous oxytocin release. It has been suggested that negative childhood experiences change the oxytocin system, possibly through methylation of genetic areas regulating the oxytocin system and different expressions of oxytocin receptors in the brain (Kumsta et al., 2015), or through an increase in the density of vasopressin receptors at the cost of oxytocin receptors. Differences in oxytocin and vasopressin receptor expression may, in turn, lead to differential sensitivity to intranasal oxytocin and decreased sensitivity to stimulation of endogenous oxytocin release. Experiences of affectionate touch during early childhood may also play an important role in shaping the oxytocin system. Animal studies show that maternal tactile stimulation serves to promote development and an efficient endocrine state. Rat pups deprived from maternal contact and stimulation show severely impaired growth and development (Meaney, 2001). These negative consequences of growing up in isolation can be reversed with mimicking maternal licking and grooming by "stroking" the pups with a brush (Kaffman and Meaney, 2007). This converges with the findings of the present study and raises the question whether endocrine effects of negative childhood experiences can also be reversed in humans, for example by stimulating the oxytocin system through repeated massage.

A limitation of our study is that our findings can only be generalized to individuals without children. Massage effects on oxytocin levels should be replicated in future studies in parents and with larger samples. Furthermore, the effects of the massage seat cover were not compared with human massage. Effects of massage with human touch might be more pronounced than effects of massage applied by a seat cover. Third, although we found that massage increased average oxytocin level, we did not find a significant change in the course of oxytocin levels across time in Study 1. In a previous study we found that salivary oxytocin levels remained elevated up to seven hours after intranasal oxytocin administration (Van IJzendoorn et al., 2012). In Study 1 we assessed oxytocin levels up to three hours after the massage, which

might be too short for the oxytocin levels to return to baseline. Future studies should cover a longer period of time in order to understand the duration of the effects of massage. Furthermore, emotional maltreatment was measured with a retrospective self-report questionnaire. Maltreatment may be underestimated in the current study because previous research has shown that abused individuals may provide false negative reports (Fergusson et al., 2000). Future research should examine how early childhood experiences shape the oxytocin system using longitudinal designs. Lastly, a limitation of the current study is that a female sample was examined in the pilot study (Study 1) and a male sample in Study 2. Different populations were examined in order to explore sex differences in the oxytocin-enhancing effects of massage, but no evidence for a sex specific oxytocin response to massage was found. It should be noted that the influence of emotional maltreatment on oxytocin response to massage was only examined in the male sample but not in the female sample. Animal studies indicate that variations in maternal care influence the expression of oxytocin receptors in a gender-specific manner (Francis et al., 2002). A future study with a larger sample should therefore examine whether negative childhood experiences influence sensitivity to endogenous oxytocin release similarly in men and women.

A question that should be addressed in future research is how enhanced oxytocin levels after massage promote a more sensitive response to infant signals. One explanation is that oxytocin promotes affiliative and empathic responses. Alternatively, enhanced oxytocin levels after massage may reflect stress reduction as a result of the anxiolytic effects of oxytocin, which in turn promote a more sensitive response. Ideally, future studies should also examine whether affectionate touch or massage influences subjective and physiological stress responses, for example measured with cortisol. Animal studies have shown that central oxytocin levels inhibit the Hypothalamic-Pituitary-Adrenal (HPA) axis (Neumann et al., 2000), which is in line with research showing that intranasal oxytocin administration results in cortisol decreases in humans (Cardoso et al., 2013; Heinrichs et al., 2003). Thus, oxytocin and cortisol interact in the response to stress and beneficial massage effects on caregiving responses may also be mediated by cortisol decreases. Previous research points to an important role of oxytocin as an underlying biological mechanism for stress-protective effects of positive social interactions. For example, oxytocin enhances positive effects of social support during stress (Heinrichs et al., 2003). Coan et al. (2006) showed that holding a partner's hand during stress reduces neural threat responses, suggesting that touch alleviates distress and improves stress regulation. Thus, oxytocin seems to be a likely candidate underlying the comforting effects of supportive touch during stress.

5. Conclusions

We are the first to examine effects of massage applied by an electric massage seat cover on salivary oxytocin levels in men and women in two exploratory studies. Our findings seem to indicate that massage

stimulates oxytocin release and that enhanced oxytocin levels after massage promote a more sensitive response to infant signals. However, we found that men with experiences of emotional maltreatment showed lower oxytocin levels, which did not increase after massage. These findings indicate that negative childhood experiences are associated with atypical responding to stimulation of endogenous oxytocin release and extends previous research showing a dysregulated oxytocin system after early adversity. Although massage did not increase oxytocin levels in men with experiences of emotional maltreatment, it normalized excessive handgrip force in response to infant crying and laughter in these individuals. This may indicate that, instead of increased oxytocin release, other mechanisms underlie the sensitivity enhancing effects of massage, for example reduced stress. Future studies should examine whether stimulation of endogenous oxytocin release through massage affects parent-infant interactions and explore whether it can be an effective auxiliary intervention targeting insensitive parenting.

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