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"Impact of Oxytocin Reactivity on Infant Social Gaze at Four Months"

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## Introduction

Face-to-face interactions play an essential part in the early mother-infant relationship, which has been found to have a bearing impact on the either favorable or adverse cognitive and socio-emotional development of the child (Bowlby, 1969). Research shows that certain factors, such as maternal sensitivity have a key influence on the quality of mother-infant bonding and dyadic behaviors (Ainsworth, Blehar, Waters, & Wall, 1978). As animal studies and recent research in humans suggest a moderating effect of the hormone oxytocin on variations of maternal behavior (Bakermans-Kranenburg & van Ijzendoorn, 2008; Champagne, Diorio, Sharma, & Meaney, 2001; Feldman, Weller, Zagoory-Sharon, & Levine, 2007) as well as pro-social behaviors like trust or attachment (Carter, 1998; Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005; Young, Lim, Gingrich, & Insel, 2001), oxytocin might shape the characteristics of mother-infant interactional patterns too. Especially during the first moths of life, mutual gaze is one of the most dominant and fundamental behaviors for establishing a conversational context and initiating a communication between mother and child (Nelson, 1987). Direct eye contact has been proven to be influenced by oxytocin as well and can be specifically related to the duration of maternal eye gaze towards her child (Kim, Fonagy, Koos, Dorsett, & Strathearn, 2014). As a possibly similar impact of oxytocin on infant gaze behaviors has yet to be researched, the present study aims to enhance the current state of knowledge, by investigating the influence of oxytocin on infant social gaze.

During the first months of life infants rapidly develop increasingly complex socio-emotional competence such as emotion recognition, affective understanding and forms of communication with others (Nelson, 1987). Within this dynamic process the social and emotional conversation during face-to face interactions with the mother serves as the most fundamental learning environment and, therefore, the foundation of the child's healthy development (Okabe, Nagasawa, Mogi, & Kikusui, 2012). The infant's ability to regulate their emotions, attention, and behavior is highly shaped by the interactive emotional exchange during face-to-face conversations with the mother (Greenspan, 2003; Tronick, Als, Adamson, Wise, & Brazelton, 1978). By attending to the emotional expressions and underlying needs of the infant, a mother's reactions help the infant to organize and shape their own reaction, encouraging desired emotions and helping the infant overcome unwanted ones. Ideally, this learning process is fostered by an empathic and nurturing relationship, with the mother meeting the child's needs in a sensitive and appropriate way (Stern, 1974), creating a safe environment for the child, the essential prerequisite for a favorable development.

Even though the mother naturally has the greater emotional and behavioral competence or flexibility, the relationship with the infant is highly interactive, with the infant initiating and/or avoiding engagement (Beebe, 2000). Moreover, the early interactions show a highly bidirectional communicative pattern (Cohn & Tronick, 1983) allowing each participant to modify their own behavior and to be modified by the other's behavior. By understanding the meaning of their own behavior or that of the others, infants associate reactions to those actions and, therefore, learn the rules/concept of social interactions (Tronick et al., 1978). Through this mutual engagement, routines and behavior anticipations are formed in each mother-infant dyad including expectations to the response of the other.

Social gaze plays an important role in these early mother-infant face-to-face interactions. Eye contact is one of the most powerful foundations of human communication and social interaction and usually the first impression of a face to be noticed (Bindemann, Scheepers, & Burton, 2009). In addition, social gaze not only serves to gather information about social cues such as emotions or intentions, but also plays an essential role in initiating and maintaining a conversational context with others (Bremner, 2014). While direct or mutual gaze indicates an attempt to establish contact, the aversion of eye contact implies the avoidance of interaction (Itier & Batty, 2009). Beyond giving a glimpse to others' minds, mutual gaze has a vital significance in early mother-infant interactions (Stern, 1974), since it is central for a favorable manifestation of secure attachment (Bowlby, 1969; Dickstein, Thompson, Estes, Malkin, & Lamb, 1984) and relevant to a normative socio-emotional development of the child. The ability to detect and distinguish human gaze is inherent and direct gaze is a powerful social stimulus for infants from birth (Farroni, Csibra, Simion, & Johnson, 2002). Moreover, it represents the very first possibility for infants to initiate or attend social interactions, and human gaze activates, even in young infants, neural areas associated with processing communicative signals (Grossmann et al., 2008).

While eye-to-eye contact during the first weeks of life reflects merely infants' ability to distinguish between direct and averted gaze, 2-months-old infants are already able to react and respond to it more precisely (Bremner, 2014). Until the third month of life, this skill develops into a sophisticated ability of enriched communication and social encounters through eye contact (Lavelli & Fogel, 2005). Therefore, within the first months of life infant gaze and gaze cueing evolve from their basic key functions of detecting another person's focus of attention and defining the affective information implied into a complex competence concerning interactive communication (Jessen & Grossmann, 2014; Neath, Nilsen, Gittsovich, & Itier, 2013). Thus, for infants gaze represents a powerful pre-linguistic tool to communicate and connect with their environment, particularly during early face-to-face interactions where infants' comprehension of socio-emotional concepts like emotion recognition, perception of other's minds and social coordination is formed (Itier & Batty, 2009). The importance of mutual gaze and reciprocity in face-to-face interactions can be shown by the voluntary violation of his/her anticipation of interaction. In the *still face* paradigm (Tronick et al., 1978) infants display a severe stress reaction as soon as the mother "freezes" and withdraws from social engagement, ignoring all infant attempts to re-initiate an interaction. The strong effect this paradigm elicits in infants shows the central significance of bidirectional conversation in social relationships, precisely, infants are displayed as active participants of those interactions with a sensitive response to the lack of fulfillment of their expectations. In addition, the research with the *still face* paradigm reveals a connection between variations of maternal care and infant response, as well as predictive findings regarding future development and attachment (Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009; Moore, Cohn, & Campbell, 2001). While traditional research has focused on infants' gaze attention or their reaction to violations in face-to-face interactions, the present study additionally attempts to uncover the underlying situational and biological influences that modify gaze in different social contexts and, therefore, have an impact on the fundamental foundation of social engagement in mother-infant dyads.

Maternal sensitivity is known to influence the quality of those important early face-to-face interactions. The sensitivity of a mother reflects her capability to react empathetic and attentive to the communications of an infant. In particular, it defines a mothers ability to discern the meaning of her infants signals and her consistency to respond caringly, promptly and appropriately to her infants needs (Ainsworth et al., 1978). Research over the past decades revealed an essential impact of this maternal competence on infants' healthy development with respect to affect regulation (Bowlby, 1969), and secure attachment (Ainsworth et al., 1978; Belsky & Fearon, 2002). In addition, longitudinal studies show that maternal warmth and affection during childhood are the most powerful predictors for a happy and fullfilled life (Vaillant, 2012). Furthermore, research suggests an impact of low maternal sensitivity on infant feeding problems (Hagekull, Bohlen, & Rydell, 1997), whereas high maternal sensitivity predicts the ability to coordinate attention at the age of ten months (Legerstee, Markova, & Fisher, 2007) and, later, adds to the ability of language acquisition (Baumwell, Tames-LeMonda, & Bornstein, 1997).

Behavioral studies like the *still face* paradigm have shown that maternal sensitivity has a great impact on the child's stress reaction. For instance, evidence suggests that higher maternal sensitivity relates to better infant affect regulation (Braungart-Rieker, Garwood, Powers, & Wang, 2001) and more positive attempts of initiating re-engagement by the infant in the reunion phase of the *still face* paradigm (Kogan & Carter, 1996). Furthermore, maternal warmth and empathetic behaviors predict longer attempts by the infant to establish eye contact with the mother during the paradigm (Carter, Mayes, & Pajer, 1990) and significantly less avoidant behavior during the reunion phase (Kogan & Carter, 1996; Mastergeorge, Paschall, Loeb, & Dixon, 2014). In contrast, children of less sensitive mothers have shown less eye gaze at the mother and a less distinguished reaction during the *still face* paradigm compared to the natural interaction (Haley & Stansbury, 2003). While mutual gaze seems to be predicted by maternal sensitivity, especially for infant behaviors during stress reactions, direct eye contact is also shown to have a smothering effect when it occurs during a paradigm such as the *still face* and, for that reason, may directly influence the affect regulation ability of an infant even when the mother seems to be emotionally unavailable (MacLean et al., 2014).

Behavioral stress responses of infants have been studied for the past decades, additionally, recent research started to focus to physiological responses, leading to an enhanced understanding of the biological foundations of mother-infant reciprocity. Several studies concerning infants' physiological regulation provide evidence that maternal affectionate behavior has an impact on infant physiological stress responses as well. For instance, infants' bio-behavioral reactivity to stress, such as vagal tone and heart rate reactivity appear to be related to maternal sensitivity. In particular, after confrontation with a social stressor higher maternal sensitivity is related to decreases in infants' heart rate (Conradt & Ablow, 2010; Haley & Stansbury, 2003) and Respiratory Sinus Arrythmia (Moore et al., 2009). Furthermore, levels of the stress hormone cortisol can be linked to behavioral observations and the infant's stress reactivity (Haley & Stansbury, 2003; Lewis & Ramsay, 2005). Those findings lead to the suggestion, that infants of more sensitive mothers have a greater ability to regulate their behaivoral and physiological reaction in response to a social stress.

Next to cortisol, oxytocin is another hormone that has been recently linked to natural variations of maternal sensitivity and the onset of maternal behavior (Bakermans-Kranenburg & van Ijzendoorn, 2008; Feldman et al., 2007; Shahrokh, Zhang, Diorio, Gratton, & Meaney, 2010), the establishment of attachment (Carter, 1998; Uvnäs-Moberg, 1996; Young et al., 2001) as well as human conversational gaze behaviors (Guastella, Mitchell, & Dadds, 2008; Kim et al., 2014; Nagasawa, Kikusui, Onaka, & Ohta, 2009). In addition, oxytocin plays an important role in trust (Kosfeld et al., 2005), social behaviors (Lee, Macbeth, Pagani, & Young, 2009), and psychological disorders with distinct social deficits (Kanat, Heinrichs, & Domes, 2014; Mercedes

Perez-Rodriguez, Mahon, Russo, Ungar, & Burdick, 2014; Meyer-Lindenberg, Domes, Kirsch, & Heinrichs, 2011), such as autism spectrum condition (Guastella et al., 2010; Modahl et al., 1998), schizophrenia (Rosenfeld, Lieberman, & Jarskog, 2011; Rubin et al., 2010; Sasayama et al., 2012) and affective disorders (Costa, Pini, Gabelloni, et al., 2009; Costa, Pini, Martini, et al., 2009; Jokinen et al., 2012).

Recent research has also established a link between processes during mother-infant interaction and oxytocin. Studies with mammals display plenty of evidence that variations in maternal care are predicted by levels of oxytocin and the number of oxytocin receptors in relevant neural regions (Champagne et al., 2001; Francis, Champagne, & Meaney, 2000; Shahrokh et al., 2010), and furthermore, that these characteristic levels of oxytocin are transmitted to the next generation (Champagne, Francis, Mar, & Meaney, 2003). Similar studies with humans replicated these findings (Apter-Levy, Feldman, Vakart, Ebstein, & Feldman, 2013; Feldman, Gordon, Influs, Gutbir, & Ebstein, 2013; Feldman, Gordon, Schneiderman, Weisman, & Zagoory-Sharon, 2010; Feldman, Gordon, & Zagoory-Sharon, 2010; Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010). Higher levels of the hormone, for instance, seem to be connected with secure attachment in infants (Chen, Barth, Johnson, Gotlib, & Johnson, 2011) and with more positive communication of the mother while engaged with her child (Feldman, Gordon, Schneiderman, et al., 2010; Nagasawa, Okabe, Mogi, & Kikusui, 2012). Additionally, with higher levels of oxytocin more mutual gaze and sensitive parental care are displayed (Feldman et al., 2012), and these behaviors can be increased when oxytocin is administred (Naber, van Ijzendoorn, Deschamps, van Engeland, & Bakermans-Kranenburg, 2010). Besides the behavioral mother-infant reciprocity, oxytocin release establishes a second, endocrine, bidirectional mother-infant relationship. Sensitive maternal behavior stimulates the release of oxytocin in the infant and, therefore, activates more trust and bonding behaviors. Consequently, the infant's bonding behavior stimulates the maternal oxytocin system while simultaneously activating additional nurturing behavior by the mother (Feldman, Gordon, Schneiderman, et al., 2010; Ross & Young, 2009). Biological and behavioral factors that influence the mother-infant interaction, therefore, seem to mutually regulate each other, predicting the quality of early socio-emotional relationships.

Even though much evidence points towards a connection between social gaze as a central foundation of pro-social behaviors and the pro-social hormone oxytocin, thus far only few studies addressed this relationship (Guastella et al., 2008; Nagasawa et al., 2009), and only one study specifically during mother-infant interactions (Kim et al., 2014). In this study, authors found a positive correlation between more maternal gaze and higher levels of maternal oxytocin, but failed to address infant hormone levels or gaze behaviors (Kim et al., 2014). Because mother-infant relationships are highly bidirectional, it could be hypothesized that infant social gaze is affected by oxytocin levels as well.

For infants, eye-to-eye contact in face-to-face interactions is one of the most important possibilities to establish a conversational context and, moreover, the most influential learning environment for social interactions. Studies suggesting that social deficits in psychological disorders are connected to oxytocin as well as a distinguished gaze pattern, raise the question whether different levels of oxytocin already reflect patterns of social behavior in infants as young as four months. The goal of the present study was to examine infant gaze behaviors in regard to factors such as oxytocin and maternal sensitivity, which may influence this essential part of mother-infant interactions. Therefore, we investigated whether these factors have an impact on infant gaze towards the mother in three different situations.

## Hypotheses

Is there a relationship between infant social gaze behavior and maternal sensitivity?

$H_{1.1}$: Maternal sensitivity has an impact on infant social gaze.

$H_{1.2}$: Higher maternal sensitivity predicts more infant gaze towards the mother.

Is there a relationship between infant social gaze behavior and oxytocin levels?

$H_{2.1}$: Infant oxytocin levels have an impact on infant social gaze.

$H_{2.2}$: Maternal oxytocin levels have an impact on infant social gaze.

$H_{2.3}$: Higher levels of oxytocin predict more infant gaze towards the mother.

# Method

## Participants

Recruitment took place in prenatal childbirth and mother-infant activity classes. A total of 24 mother-infant dyads (14 girls) participated in the study. Infants were between 105 to 204 days old (*M* = 139.54 SD = 19.969), all of European Caucasian origin as well as born full term (min. 36 weeks) and healthy (APGAR-10 Score = 9 or higher). The majority of the sample were first-time mothers (91.7%), breast-fed their infants (91.7%) and had an average age of 31.08 years (*SD* = 3.134). All mother infant dyads came from middle class homes (average years of education: *M* = 4.81 *SD* = 3.010) and received a small present for their participation.

## Procedures

To ensure reliable measures of salivary oxytocin, testing took place in the afternoon (between 1pm and 4pm) and at least one hour after the consumption of food or drinks as well as 30 minutes after breastfeeding. After arrival at the infancy laboratory, mothers were informed about procedure, salivary oxytocin extraction, and the informed consent was signed. Infants were placed on a booster seat on a table; the mothers were facing their infants on eye-level from a chair with an approximate distance of 30 cm. The experiment was videotaped by two digital video cameras, one facing the infant, one directed towards the mother and were later combined into a split screen image.

All mother-infant dyads completed three different parts in a fixed order: Baseline, Natural Interaction and Modified Interactions. (1) *Baseline*. There was an initial 10 minutes separation phase, with no interaction between mother and infant. While mothers completed a demographic questionnaire and a screening for depression, infants watched a Baby Einstein® DVD at the same time. (2) *Natural Interaction*. For a 10 minutes period mothers were instructed to interact with their child as they do day to day at home. Toys were not provided. (3) *Modified Interactions*. The original study included three different experimental modifications (a) speech to child, (b) speech to adult, and (c) imitation. All modified interactions were performed in a randomized order. The present study analyzes only (3a) and (3b). In each *Modified Interaction* the mother was asked to perform an objective and emotionless "speech" about facts (e.g. reciting details of her résumé) in the manner of a news anchor. In (3a) the speech was delivered to the child with the underlying intention to create a paradigm that disrupts the natural interaction between mother and child such as the *still face* paradigm (Tronick et al., 1978) but embed it in a more "natural" scenario. Mothers were instructed to give their talk without engagement with, or reaction to the infant. While (3b) served as a control paradigm, with the same "news anchor"-speech, but this time given to another adult sitting next to the infant. The mothers were again instructed to give their speech without engagement with, or reaction to the other adult (or the infant). Paradigm (3b) was theoretically founded on a modified *still face* study, reporting that the infant's reaction to the paradigm was influenced by presented context (e. g., mother drinking during the still face task; Legerstee & Markova, 2007).

**Measures**

**Questionnaires.** Demographic data was collected to determine data concerning socio-demographic status, infant age, health and maternal feeding style. All mothers were screened for symptoms of depression using Beck Depression Inventory II (Beck, Steer, & Brown, 1996), a self-report questionnaire. The scale ranges from 0 to 63 and results are partitioned into four dimensions (minimal, mild, moderate and severe depression). The majority of mother's (83.2%) showed no or minimal signs of depression, three mothers (12.5%) described mild and one mother (4.2%) moderate symptoms of depression.

**Behavioral coding.** *Infant Gaze* behavior was encoded via Datavyu® through event sampling. Each gaze shift was considered as long as it occurred for at least one second. Gaze was divided into two dimensions (1) *at* mother and (2) *away*. To establish inter-rater reliability about 30% of the data was randomly selected and evaluated by two coders. Cohen's kappa was calculated to determine inter-rater reliability and reached ICC = .980 for gaze at mother and ICC = .994 for gaze away. For further analyses the relative duration and the relative frequency of infants' gaze were considered.

*Maternal Sensitivity* was encoded via Datavyu® through interval sampling (one interval = one minute) during the *Natural Interaction*. Maternal sensitivity was composed out of three dimensions: Positive Affect, Warm Concern and Social Responsiveness (Landry, Smith, Miller−Loncar, & Swank, 1998; Legerstee et al., 2007; Markova & Legerstee, 2006). A five-point rating-scale was used, from minimal occurrence (1) and high presence (5) of the behavior, for each dimension the average was calculated to determine the global value. Again, 30% of the data was randomly selected and evaluated by two coders in order to establish inter-rater reliability. Cohen's kappa was calculated to determine inter-rater reliability and reached ICC = .789 for maternal sensitivity.

**Assessment of oxytocin.** Saliva samples were collected for each dyad using Salimetrics© oral swabs for mothers and infants. Samples were obtained before *Baseline* $OT_1$ and after each of the three parts of the procedure, in detail $OT_2$ after *Baseline*, $OT_3$ after the *Natural Interaction*, and $iOT_4$ after the *Modified Interactions*. Research assistants instructed mothers how to place the swabs and held infants' swabs to guarantee correct usage. The collected swabs were stored in the swab storage tube, cooled in an icebox during the procedure and later frozen at -20°C.

An enzyme immunoassay kit (Oxytocin EIA kit, ADI-901-153, Enzo Life Science) was used to determine the concentration of oxytocin. Swabs were centrifuged to obtain saliva (4°C, 2500x g, 10 min) and used for analyses without any modification. Concentrations of oxytocin (pg/mL) were calculated via Softmax Pro 5.2.

The $OT_4$ sample was excluded from further analyses, as it was obtained after three different modified interactions that were assigned randomly. Therefore, the $OT_4$ sample had no distinct predictive value. Additionally, recent literature concerning oxytocin levels in mother-infant interactions usually analyzes measures pre and post of settings (Feldman, Gordon, & Zagoory-Sharon, 2010), which represents the samples $OT_2$ and $OT_3$ in the present study. In order to guarantee comparability to related research, only these two samples were used for the primary analyses.

**Statistical analyses.** IBM™ SPSS® was used for all analyses. Possible correlations between demographic data and the variables of the primary hypotheses were explored. The primary hypotheses were analyzed through a three-way ANOVA, additional analyses through a three-way ANOVA with repeated measures. Hypothesis testing was performed in one model to avoid an alpha-cumulation error, while the critical *alpha*-error was *alpha* = .05 for the analyses. Gaussian distribution, homoscedasticity, sphericity and homogeneity were given.

## Results

### Preliminary Data Analyses

Prior to analyses, all data was screened for possible outliers ($z \geq \pm 3.25$) and normal distribution, and no deviation was found. In addition, missing values were explored in relevant variables. For maternal oxytocin missing values were found for $mOT_2$ ($N = 2$; 8.3%) and $mOT_3$ ($N = 3$; 12.5%), while infant oxytocin showed no missing data for the samples $OT_2$ and $OT_3$. Missing values were replaced by the mean of the variable. Descriptive statistics for all relevant variables are displayed in Table1. Exploration of possible correlations between oxytocin and relevant variables revealed a negative relational trend between maternal $OT_2$ and sensitivity ($p = .052$).

Table 1

*Descriptive Statistics for Relevant Variables*

| | *Mean* | *SD* | *Range* | *N* |
|---|---|---|---|---|
| $iOT_2$ | 194.664 | 123.882 | 29.72 – 485.15 | 24 |
| $iOT_3$ | 179.083 | 123.265 | 11.50 – 440.98 | 24 |
| $mOT_2$ | 181.841 | 115.524 | 17.39 – 387.43 | 24 |
| $mOT_3$ | 172.945 | 112.392 | 12.77 – 410.38 | 24 |
| M. Sensitivity | 4.305 | .263 | 3.81 – 4.86 | 24 |
| Gaze at Mother | | | | |
| Natural Interaction | .371 | .244 | .066 – .817 | 24 |
| MI: Child | .356 | .287 | .000 –.920 | 19 |
| MI: Adult | .443 | .282 | .000 –.910 | 18 |

Note: Oxytocin in pg/mL; iOT = infant oxytocin level; mOT = maternal Oxytocin level; $OT_2$ = pre Natural Interaction; $OT_3$ = pre Modified Interaction. Values of Gaze at Mother represent relative duration. MI: Child = Modified Interaction: Speech to Child; MI: Adult = Modified Interaction: Speech to Adult.

In order to assess the individual oxytocin reactivity, the *area under the curve* with respect to increase ($AUC_i$) was calculated for the time interval before and after the *Natural Interaction* in order to access the intensity of changes over time (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). While calculations with ANOVA in regard to oxytocin reactivity compares only the changes between means over time, the $AUC_i$ allows comparing individual changes in reactivity, and, therefore, represents a more advantageous approach to assess interpersonal differences. Infants and mothers $AUC_i$ showed that oxytocin levels either increased or decreased from before to after the *Natural Interaction*. Consequently, two groups were indentified, splitting the AUC by either higher or lower than zero: a total of 12 infants were classified as infant oxytocin increase ($iOT_i$) group ($M$ = 31.536; $SD$ = 20.23) while infants whose oxytocin levels decreased over time were identified as infant oxytocin decrease ($iOT_d$) group ($M$ = –47.116; $SD$ = 48.541, $N$ =12). In addition, mothers were classified by the same procedure in maternal oxytocin increase ($mOT_i$) ($M$ = 20.702; $SD$ = 18.456, $N$ = 12) and maternal oxytocin decrease ($mOT_d$) ($M$ = –29.598; $SD$ = 30.747, $N$ = 12). Furthermore, two sub-groups of maternal sensitivity were classified while performing a median split: low maternal sensitivity ($MS_L$) ($M$ = 4.078; $SD$ = .142; $N$ = 10), and high maternal sensitivity ($MS_H$) ($M$ = 4.468; $SD$ = .199; $N$ = 14). For further exploration, correlations for all relevant data were calculated. Maternal and infant $AUC_{i/d}$ displayed a significant negative correlation ($r$ = – .473; $p$ = .02), in addition there was a significant relationship between infant gaze at mother and maternal sensitivity during the natural interaction ($r$ = .612; $p$ = .001) (see Table 2). Additional analyses revealed that neither of the relevant variables correlated to demographic or health-related variables (maternal age, years of education, infant gender, birth weight, APGAR-10, or feeding).

Table 2

*Correlations Between Relevant Variables*

| | Gaze at (NI) | Mat. Sensitivity | Maternal AUC $_{i/d}$ | Infant AUC $_{i/d}$ |
|---|---|---|---|---|
| Gaze at (NI) | | $r$ = .612** | $r$ = .132 | $r$ = .344 |
| Mat. Sensitivity | | | $r$ = .252 | $r$ = .202 |
| Maternal AUC $_{i/d}$ | | | | $r$ = –.473* |
| Infant AUC $_{i/d}$ | | | | |

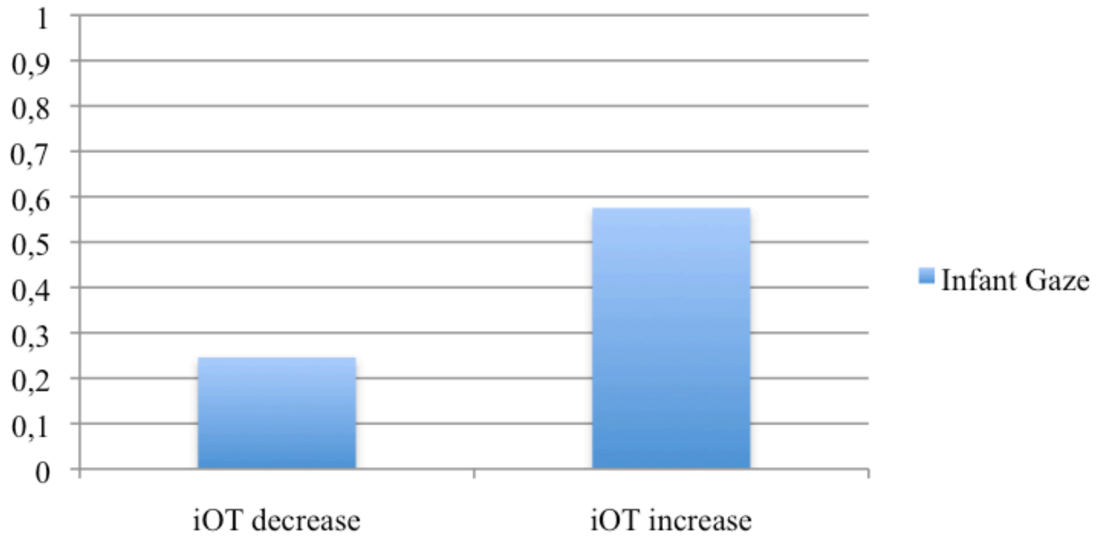
Note: Gaze at (NI) = gaze at mother during Natural Interaction, values represent relative duration; Mat. Sensitivity = Maternal Sensitivity; AUC $_{i/d}$ = area under the curve with respect to increase/decrease. * $p$ < .05; ** $p$ < .01; *** $p$ < .001.

**Analysis of the Natural Interaction**

A three-way ANOVA was calculated in order to test the hypotheses whether oxytocin variability or maternal sensitivity have an effect on infant social gaze. The ANOVA was performed on infant gaze at mother during the natural interaction with infant oxytocin $AUC_{i/d}$, maternal oxytocin $AUC_{i/d}$ as well as maternal sensitivity ($MS_{L/H}$) as factors. There was a significant main effect of infant oxytocin $AUC_{i/d}$ on the infant gaze behavior, $F$ (1, 17) = 25.460, $p$ < .001, $\eta_P^2$= .600 (see Figure 1a). In particular, infants with an increase in oxytocin ($AUC_i$) displayed significant more gaze at their mother than infants with a decrease of oxytocin ($AUC_d$). In addition, a significant main effect of maternal sensitivity on the gaze behaviors of the infant, $F$ (1, 17) = 7.897, $p$ = .012, $\eta_P^2$= .317 (Figure 1b) was found, revealing that infants of $MS_H$ mothers gazed significantly more towards their mothers than infants of $MS_L$ mothers. No significant main effect was found for maternal oxytocin $AUC_{i/d}$ on infant gaze behavior ($p$ = .325). Furthermore, no interaction effect between infant oxytocin $AUC_{i/d}$ and maternal oxytocin $AUC_{i/d}$ ($p$ = .364), infant $AUC_{i/d}$ and maternal sensitivity ($p$ = .639), or maternal oxytocin $AUC_{i/d}$ and maternal sensitivity ($p$ = .136) were found.

Figure 1a

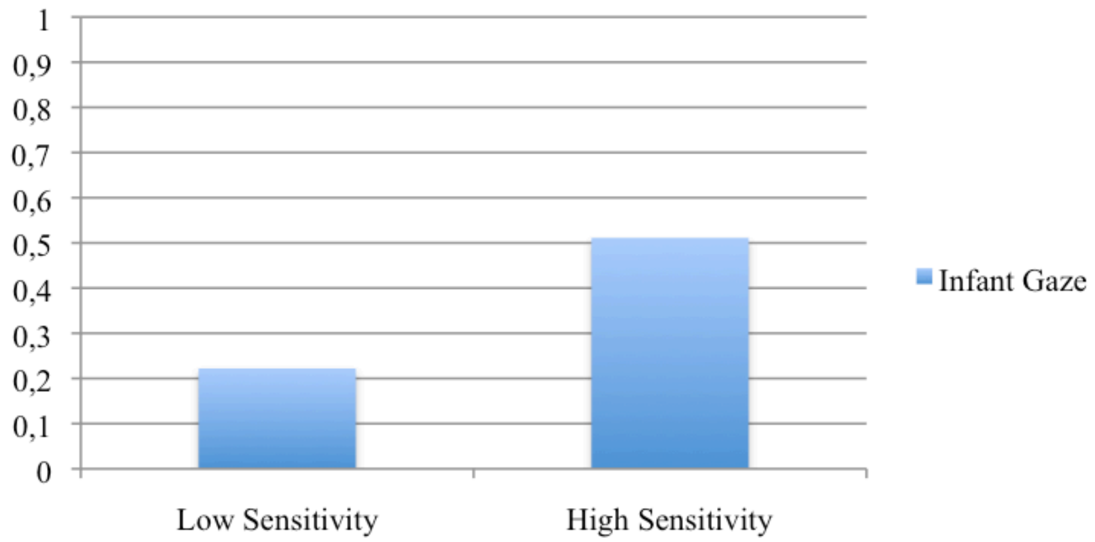
*Infant Gaze at Mother with respect to Infant Oxytocin*




Note: Infant Gaze = gaze at mother in relative duration with regard to iOT (infant oxytocin) in pg/mL.

Figure 1b

*Infant Gaze at Mother with respect to Maternal Sensitivity*




Note: Infant Gaze = gaze at mother in relative duration with regard to maternal sensitivity (high or low).

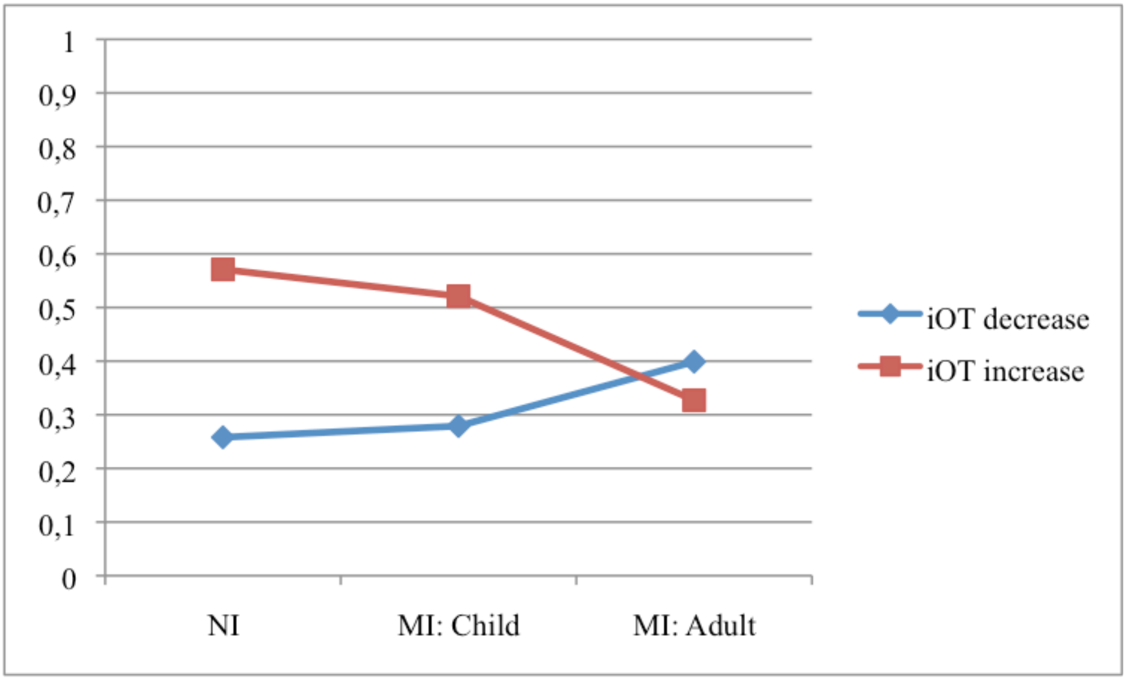
**Analysis of the Modified Interactions**

In order to further explore whether oxytocin variability or maternal sensitivity have an effect on infant gaze behavior during the *Modified Interactions* an additional three-way ANOVA with repeated measures was performed. The ANOVA was calculated for infant gaze at mother in the three conditions (1) *Natural Interaction* (2) *Modified Interaction: Speech to Child*, and (3) *Modified Interaction: Speech to Adult*, with infant oxytocin $AUC_{i/d}$, maternal oxytocin $AUC_{i/d}$ as well as maternal sensitivity ($MS_{L/H}$) as factors. This analysis revealed no significant main effect. A trend was visible for an interaction effect between gaze condition and infant oxytocin $AUC_{i/d}$ ($F$ (1.976, 21.733) = 3.181, $p$ = .062, $\eta_P^2$ = .224; $N$ = 18). The Bonferroni *post-hoc* test and a simple contrast calculation revealed that there was a significant effect of infant oxytocin $AUC_{i/d}$ on infant gaze at mother during the first condition (*Natural Interaction*) $p$ = .001, displaying that $AUC_i$ infants showed significant more gaze at mother during this condition, while $AUC_d$ infants showed significant less gaze. Furthermore, the post hoc test revealed no further effect for the *Modified Interactions* (condition 2 and 3).

Further exploration of the ANOVA displays a significant within-subject contrast, $F$ (1, 11) = 5.703, $p$ = .036, $\eta_P^2$ = .341; $N$ = 18), revealing a significant effect of infant oxytocin variability on the change of gaze pattern between condition 1 (*Natural Interaction*) and condition 3 (*Modified Interaction: Speech to Adult*). Infants whose oxytocin increased ($AUC_i$) displayed a decrease in gaze duration from condition 1 to 3, while infant with oxytocin decrease showed an increase of gaze at their mothers between condition 1 and 3 (see Figure 2).

Figure 2

*Infant Gaze at Mother during Natural and Modified Interactions*




Note: Gaze at mother in relative duration with regard to iOT (infant oxytocin) increase or decrease (in pg/mL), during three conditions, NI = Natural Interaction, MI: Child = Modified Interaction: Speech towards Child, and MI: Adult = Modified Interaction: Speech to Adult.

## Discussion

The results of the present study demonstrate that infant oxytocin and maternal sensitivity have a significant effect on infant social gaze, suggesting an impact of oxytocin on social behaviors as early as of 4 months of age. The present findings reveal that higher maternal sensitivity and an increase in infant oxytocin ($iOT_i$) independently elicit a longer duration of infant gaze at the mother during a natural interaction. In contrast, decreases in infant oxytocin ($iOT_d$) or lower maternal sensitivity were found to account for shorter eye-to-eye contact initiated by the infant. While infant oxytocin variability appears to have a main effect on the duration of gaze towards the mother, maternal sensitivity seems to moderate the intensity of this effect. That is, lower maternal sensitivity alleviates the impact of $iOT_i$ while higher maternal sensitivity elevates gaze in $iOT_d$ infants.

Furthermore, a significant effect of infant oxytocin on infant gaze behaviors during the *Modified Interaction* (*MI*) underpins the assumption of its influence on early social competence. We found that infants with increasing levels of oxytocin displayed longer gaze at the mother during the *Natural Interaction* and a decrease of gaze during the *MI: Speech to an Adult*. This pattern was reversed in infants whose oxytocin decreased. These findings suggest that $iOT_i$ infants are able to adjust more easily to a social context than $iOT_d$ infants. In particular, a face-to-face interaction such as the natural interaction in the present study is supposedly highly interactive (Itier & Batty, 2009; Lavelli & Fogel, 2005) while a situation such as the mother talking to another adult does not require the main attention of the infant. The results display a significant influence of oxytocin variability on infants' ability to match their own behavior to both of those situations at an early age.

The results of the present study correspond to recent evidence showing a significant relationship between maternal oxytocin and maternal gaze during the *still face* paradigm (Kim et al., 2014). In addition, oxytocin increase has been connected to eye contact between dogs and their owners (Nagasawa et al., 2009), and intranasal administration of the hormone has been shown to increase eye gaze in healthy adults and individuals with autism (Guastella et al., 2010; Guastella et al., 2008). Eye-to-eye contact builds an important part of communication, emotion recognition, and empathy; an involvement of oxytocin in such behaviors underpins its importance for the development of pro-social behaviors.

Several psychological disorders display a connection with oxytocin and, interestingly, are not only characterized by impairments in social skills and emotion understanding (Heinrichs, von Dawans, & Domes, 2009), but also display a distinct pattern of gaze behaviors. For instance, children with autism spectrum condition show significant lower oxytocin levels compared to a healthy control group (Modahl et al., 1998). Higher levels of oxytocin are significantly related to more pro-social behaviors in schizophrenic patients (Rubin et al., 2010), and lower levels of the hormone have been linked to a higher suicide risk in depression (Jokinen et al., 2012). Accordingly, a downward gaze appears to be characteristic for patients with depression and schizophrenia (Segrin, 1990, 2000). Additionally, in autism spectrum condition a diminished ability to initiate eye contact and impairment in mutual gaze during interactions is observed (Bal et al., 2010). These specific gaze patterns in autism spectrum condition are displayed as early as 12 months (Zwaigenbaum et al., 2005), while behavioral studies find further evidence of impairment in eye contact and psychopathological traits in infants as young as 4 to 8 years (Dadds, El Masry, Wimalaweera, & Guastella, 2008; Dadds et al., 2006)

The present study adds to the current state of knowledge by demonstrating that infant oxytocin reactivity seems to moderate specific gaze patterns. In particular, an increase or decrease in oxytocin predicts how well an infant adjusts their gaze and attention within different social situations. $OT_i$ infants showed increased gaze when their mothers' attention was directed towards them, while they decreased their gaze when their mothers' attention was directed to another adult. In contrast, $OT_d$ infants showed a reverse pattern of eye contact. These results suggest that infants whose oxytocin increases during a natural interaction, may have in general an endocrine system that enables them to better discern the social context they are surrounded by, which allows them to match their behavior in a more appropriate way. Findings of the present study add to previous research and suggest that infant gaze behaviors may serve as an important variable to study social competence and impairments at an early stage of development.

In addition to its main results, the present study reveals a negative relationship between maternal $OT_2$ levels and maternal sensitivity as well as a strong negative correlation between infant and maternal oxytocin variability ($AUC_{i/d}$) even though an impact of maternal oxytocin on infant gaze can be excluded, at least for the natural and modified interaction of the present study. These results support the findings of Elmadih et al. (2014), by displaying a negative relationship between maternal oxytocin and sensitivity and, therefore, disagreeing with a well reported positive correlation of affectionate maternal behaviors and oxytocin in humans (Bakermans-Kranenburg & van Ijzendoorn, 2008; Feldman et al., 2012) and mammals (Champagne et al., 2001). In general, higher levels of maternal oxytocin have been connected with secure attachment in infants (Chen et al., 2011), more positive interaction initiated by the mother (Feldman, Gordon, & Zagoory-Sharon, 2010), and sensitive parental care in general (Feldman et al., 2012). In addition, studies suggest that affective engagement can even be increased by intranasal administration of the hormone (Naber et al., 2010). These controversial results indicate that oxytocin plays a more complex role than its interplay with bonding behavior, emphasizing its involvement in the HPA-axis next to stress-hormones such as vasopressin and cortisol (Heinrichs et al., 2009; Meyer-Lindenberg et al., 2011). Even though it is well known that the hormone is released as a stress-response (Carter, 1998) and forms an important part inhibiting stress-induced activity in the human body (Ditzen et al., 2008; Markus Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Neumann & Landgraf, 2012), its specific role in the moderation of stress-responses has yet to be investigated (Heinrichs et al., 2003).

The present finding of a negative correlation between maternal sensitivity and oxytocin levels is in line with studies reporting a relationship between high oxytocin and relationship anxiety and distress in adults (Taylor et al., 2006; Turner, Altemus, Enos, Cooper, & McGuinness, 1999), mothers in particular (Feldman, Gordon, & Zagoory-Sharon, 2011), and research suggesting a positive relationship between oxytocin and cortisol (Taylor et al., 2006; Tops, Van Peer, Korf, Wijers, & Tucker, 2007). The ambiguity in describing oxytocin on the one hand as a hormone of trust and bonding, alleviating anxiety (Heinrichs et al., 2003), and, on the other hand, as a hormone elevated in states of anxiety and distress (Taylor et al., 2006; Turner et al., 1999) needs to be addressed in further reseach.

In addition to a negative relationship between maternal oxytocin and sensitivity, the present study found a strong negative correlation among maternal and infant oxytocin variability, showing, that mothers OT decreased while infants OT increases, and vice versa, thus suggesting an interplay between the hormonal variability of the dyad. This finding contradicts recent literature reporting positive correlations between maternal and infant OT levels (Apter-Levy et al., 2013; Feldman et al., 2013). However, while most studies compared the group-means of hormone levels, in the present study we focused on individual differences instead by applying the AUC. While the present study is the first to report this negative correlation between maternal and infant oxytocin levels, Moore et al. (2009) found a similar negative relationship between maternal and infants vagal tone during a disrupted interaction. Considering the bi-directional nature of early mother-infant interactions, the present findings provide new insight and more detailed information about the neurobiological foundations of this reciprocity.

Results of the present study have several implications for studying the role of oxytocin in early mother-infant interactions. First, the complex interplay of oxytocin with stress-responses remains yet to be explained (Heinrichs et al., 2009). Furthermore, the present findings imply that a negative correlation between mothers and infants' oxytocin variability may bring out the most favorable behavior. Secondly, previous research suggests a positive correlation of oxytocin and cortisol release (Carter, 1998) which may imply that mothers' displaying an $AUC_d$ experienced less stress during the laboratory situation, which may lead to a more comfortable interaction with their infants and therefore enabling them to better adjust to the given context. In contrast, an increase of distress caused through a decrease in oxytocin may imply that mothers were possibly more alert and, therefore, responded more sensitively towards their infants, leading to a better adjustment of infants' gaze behavior in different social contexts. That is $AUC_i$ infants adjust to social situations in a more competent way, particularly if their mothers were well attuned and sensitive, as reflected in maternal $AUC_d$. However, further research is needed to explain the specific impact of oxytocin variability on mother-infant interactions and mutual regulation.

**Strength and Limitations**

Even though the present study reveals groundbreaking results in regard to the impact of oxytocin on social competence in four months old infants, the final sample size of 24 dyads was relatively small. A replication of the experimental procedure with a larger group of mother-infant pairs is needed to strengthen the findings and to further explore controversies revealed by the present results. Additionally, the approach of collecting saliva samples to measure oxytocin is often criticized in the literature (Horvat-Gordon, Granger, Schwartz, Nelson, & Kivlighan, 2005), even though several studies find strong correlations between salivary, urinary and plasma samples of the hormone (Apter-Levy et al., 2013; Feldman et al., 2011). Furthermore, the $OT_4$ sample of this study could not be employed as it was collected after three different *Modified*

*Interactions*, which were randomly applied. A more precise collection of samples as well as different methods of measurements should be advised for future studies examining this topic.

Despite the above mentioned limitations, the effect sizes of the present study display strong and stable results that improve the current state of knowledge and emphasize the moderating role of oxytocin in social competencies, as well as its importance for a favorable development. As maternal sensitivity has an important impact on the quality of the early mother-infant relationship and future development of the child as well, it is important to gain a better understanding of the physiological foundation of sensitive parenting. Therefore, the negative relationship between oxytocin and maternal sensitivity may be addresses in further research in regard to its interplay with cortisol. This may lead to a better understanding of the involvement of oxytocin during stress responses and how those relate to variations in parenting behaviors. Furthermore, the exploration of the subjective parenting experience and its relationship to bio-behavioral markers may add to the current state of knowledge.

In addition, the possible impact of oxytocin reactivity on early social competence, that this study revealed, may gain importance for future research. The present study adds to the current state of knowledge by demonstrating that infant oxytocin reactivity seems to moderate infants ability to adjust their social gaze behaviors more easily to different social contexts. In detail, infants who showed an $OT_i$ displayed an increase in gaze during an interactive situation such as a context when the maternal attention was directed to them, and a decrease in gaze when the mothers' attention was directed towards another adult. In contrast, $OT_d$ infants showed a significantly reverse gaze behavior in each of those social situations.

When those results can be replicated, oxytocin may not only serve as a biomarker for social competencies, but related psychological vulnerability and resilience in an early stage of development. An early detection of possible deficits may lead to early interventions for infants at risk for psychological impairments and in particular conditions such as autism spectrum condition. In conclusion, the present results raise new research questions and enable a more distinct approach to study the neurobiological foundations of mother-infant interaction as well as the development of infants social competences in favor and adverse.

## Abstract

Face-to-face interactions play an essential part in early mother-infant relationships, which have been found to have a bearing impact on the either favorable or adverse cognitive and socio-emotional development of the child. Within those early interactions mutual gaze is one of the most dominant behaviors for establishing a conversational context and initiating a communication between mother and child. As recent research suggests an impact of oxytocin on human social and gaze behaviors, it may shape the characteristics of mother-infant interactional patterns too. Therefore, it is investigated whether oxytocin has a moderating impact on infant social gaze and, therefore, may influence the healthy development of the child. Behavioral data from 24 mother-infant dyads during natural and modified interactions was coded for maternal sensitivity and infant gaze. Additionally, oxytocin samples were collected at four different points of time from mother and infant. Maternal oxytocin displayed a negative relationship with maternal sensitivity, while maternal oxytocin reactivity had a strong negative correlation with infant oxytocin reactivity. Maternal Sensitivity and infant oxytocin reactivity had a significant effect on infant gaze during the natural interaction. Furthermore, infant oxytocin reactivity was related to infants gaze adjustments in different social contexts. In particular, an increase in infant oxytocin predicted a better social adjustment of infants. While infant oxytocin reactivity and maternal sensitivity jointly influence infant gaze direction in natural face-to-face interactions, infant oxytocin predicts infant gaze adjustment in different social situations and therefore may indicate infant social competence as early as four month of age.

## Zusammenfassung

Interaktionen mit direktem Blickkontakt haben eine zentrale Bedeutung für die frühe Mutter-Kind Interaktion und einen entscheidenden Einfluss auf die zukünftige sozial-emotionale Entwicklung des Kindes. Direkter Blickkontakt stellt dabei eine wichtige Verhaltensweise dar, die es dem Kind ermöglicht eine Kommunikation und Interaktion mit der Mutter zu initiieren. Forschungsergebnisse deuten auf einen entscheidenden Einfluss von Oxytocin auf das Sozial- und Blickverhalten hin. Die vorliegende Studie prüft, ob Oxytocin bereits einen Einfluss auf das kindliche Sozial- und Blickverhalten hat und damit eine wichtige Rolle für die Entwicklung des Kindes spielt. Das Verhalten von 24 Mutter-Kind Paaren wurde während einer natürlichen und zwei experimentellen Situationen auf mütterliche Sensitivität sowie kindliches Blickverhalten analysiert. Zudem wurden von jedem Mutter-Kind Paar zu vier verschiedenen Zeitpunkten Oxytocinproben entnommen. Mütterliche Sensitivität und mütterliches Oxytocin zeigten eine negative Korrelation. Zudem gab es einen negativen Zusammenhang zwischen der Reaktivität von mütterlichem und kindlichem Oxytocin. Mütterliche Sensitivität und kindliche Oxytocinreaktivität zeigten einen signifikanten Einfluss auf das Blickverhalten des Kindes in der natürlichen Interaktion. Zudem wurde ein signifikanter Effekt von kindlicher Oxytocinreaktivität auf die Fähigkeit des Kindes gefunden, sich entsprechenden sozialen Situationen anzupassen. Die Ergebnisse zeigen, dass mütterliche Sensitivität und kindliche Oxytocinreaktivität einen Einfluss auf das Blickverhalten in der natürlichen Interaktion haben. Kindliche Oxytocinwerte sagen zudem die kindliche Fähigkeit vorher, das Blickverhalten einer sozialen Situation anzupassen und deuten darauf hin, dass kindliche Oxytocinreaktivität bereits im Alter von vier Monaten einen Einfluss auf die soziale Kompetenz des Kindes hat.

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# Curriculum Vitae
# Isabelle Müller
10. Mai 2015

## Akademische Laufbahn

**Universität Wien**
Psychologie **2008–2015**
Biologie **2006–2009**

**Hochschule Bonn-Rhein-Sieg**
Biologie **2005–2006**

**Altes Gymnasium Oldenburg** **06/2005**
Allgemeine Hochschulreife

## Auslandsaufenthalte im Rahmen des Studiums

**Harvard University** **07/2012–08/2012**
Praktikum im Rahmen eines Kooperationsprojektes mit der Universität Wien.

**University of California, Berkeley** **05/2010–09/2010**
Auslandssemester

## Publikationen

Chorpita, B. F., Weisz, J. R., **Müller I.** & Sprung M. **Voraussichtlich 2015**
“MATCH-ADTC: Modularer Therapieansatz für Kinder mit Angst, Depression, Trauma oder Verhaltensauffälligkeiten.“ PracticeWise. LLC, Satellite Beach, FL.

## Ehrenamtliche Tätigkeit

**Vortragende an der Kinderuniversität Wien 2014** **07/2014**
Vortrag: Sport, Yoga und Psychologie (PSY-202)
Workshop: Mindfulness Meditation für Kinder (PSY-197)

**Vortragende an der Kinderuniversität Wien 2013** **07/2013**
Vortrag: Einführung in die Psychologie (PSY-300)
Workshop: Nur ein Spiel? (PSY-327)

**Formative Evaluation eines Schulprojektes** **10/2011–06/2012**
Projekt: „Praktische Implementierung von Lesenkompetenzstufen für Sachtexte“. Im Rahmen einer Initiative des Österreichischen Ministeriums für Bildung, Kunst und Kultur.
Volksschule Dr.-Karl-Renner, Kapfenberg. Betreuer: Professor Dr. Barbara Hanfstingl, Universität Klagenfurt.

**Testleiter** **06/2011**
Testleiterfunktion bei der Evaluierung der englischen Version des AID 2, Universität Wien.

## Konferenzen

**Games for Health Europe** **2013**
28. – 29. Oktober 2013, Amsterdam, Niederlande
Posterpresentation: "Mind Book: A computer-game based cognitive behavioral training for children with low mood".

**F.R.O.G. Future and Reality of Gaming** **2012**
12. – 13. Oktober 2012, Wien, Österreich
Posterpresentation: "Alien Ranger Game: Promotion of executive function in children with an computer game".

**12th European Conference on Posttraumatic Stress** **2011**
30. Mai – 5. Juni 2011, Wien, Österreich
Studentische Hilfskraft bei Organisation und Durchführung

## Berufstätigkeit

**Studienassistentin** **10/2014–08/2015**
Universität Wien, Klinische Psychologie
Prof. DDr. Kristina Hennig-Fast

**Studienassistentin** **03/2012–09/2014**
Universität Wien, Klinische Kinder- und Jugendpsychologie
Prof. Dr. Manuel Sprung

**Fitnesstrainerin** **11/2011–02/2012**
Mrs. Sporty Sportclub für Frauen
Wien Rudolfsheim-Fünfhaus I

**Angestellte im Verkauf** **01/2008–09/2011**
IKEA – Möbelhaus Wien Nord

## Sprachen

| | |
|---|---|
| Deutsch | Muttersprache |
| Englisch | Level C2 |
| Latein | Großes Latinum |

## Weitere Qualifikationen

MS Office
Mac OS
SPSS
Datavyu
EPOC Emotiv EEG Headset