INFANT JEALOUSY: BEHAVIOURAL AND NEUROPHYSIOLOGICAL CORRELATES

BEREN AVCI

A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS

GRADUATE PROGRAM IN PSYCHOLOGY
YORK UNIVERSITY,
TORONTO, ONTARIO

AUGUST, 2011

Your file Votre référence
ISBN: 978-0-494-80492-6
Our file Notre référence
ISBN: 978-0-494-80492-6

ABSTRACT

Jealousy is defined as the fear of losing a loved one to a rival (Legerstee, Ellenbogen, Nienhuis & Marsh, 2010). Recently, Legerstee et al. (2010) examined jealousy in 3 and 6-month-old infants, and found that infants only became upset when their mothers participated in an active dialogue with a female stranger, but not when the mother simply listened. The present study examined the behavioural and neurophysiological correlates of infants' experiences of jealousy. The behavioral paradigm was a replication and extension of Legerstee et al. (2010) and the brain activity was measured using a dense-array, 128-channel EEG recording cap. Consistent with previous infant research (Legerstee et al., 2010; Fox & Davidson, 1988), infants showed both approach (gazing) and protest behaviours as well as both left and right hemisphere activations during the jealousy condition.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisor Professor Maria Legerstee for giving me the opportunity to work on this project, and for sharing with me her expertise on infancy research and infant jealousy in particular. I am grateful for her continuous mentoring, and for providing me with an amazing research team. Without her help and that of the team, this research would not have been possible. Thank you to the graduate students Monica Caldeira, and Elaine Lam, as well as honours student Vadim Poliansky, and research assistants Magdalena Denenberg and Johanna Robertshaw for assisting me with recruitment, data collection, seeing participants, coding and data analysis. I was delighted to be able to present my findings at the 41st Annual Meeting of the Jean Piaget Society in Berkeley, California (Avci, Legerstee, Haley, Poliansky, 2011), and to discuss the results with various interested international colleagues.

I am also grateful to Dr. David Haley of the University of Toronto and his lab members (Nida Mustafa, Mohana Giruparajah, and Kemi Akano) for providing me with the necessary Electroencephalogram (EEG) equipment and training on EEG methodology and data analysis. I would also like to thank all the mothers and infants who participated in this study. Finally, I am especially grateful to my family and friends for their endless support.

I would also like to thank my committee members for their feedback and guidance.

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Introduction

Jealousy has been a difficult term for researchers to define. Lewis (2010) has categorized it as a self-conscious emotion, thereby differentiating it from basic emotions such as joy and anger. Plutchik (1970) suggests that secondary emotions such as jealousy are combinations of basic emotions. Lewis & Michelson (1983) relate emotions to cognitive development, and suggest that jealousy is a secondary emotion, because it involves an awareness of triadic relationships, which includes an awareness of self and others. Because of this cognitive awareness, they suggest that jealousy cannot emerge until the second year of life. Lewis (2010) also characterizes jealousy as a relational emotion, meaning the infant needs to be self-aware and also be conscious of others in the environment, which he claims cannot occur until the first year of life. Recently, Fivaz-Depeursinge and colleagues have shown that infants are able to differentiate among various types of triangular interactions involving both of their parents (Fivaz-Depeursinge, Favez, Lavanchy, de Noni, & Frascarolo, 2005). Furthermore, Legerstee and colleagues (2010) have exposed infants to triadic interactions involving their mother and an experimenter, and have shown that infants as young as 3 months of age experience negative emotions during jealousy-evocative situations. The main purpose of this thesis was to build on Legerstee et al's work and to demonstrate that infants as young as 3 and 6 months of age were able to experience so called secondary emotions, such as jealousy. This was done by providing evidence for both behavioural and neurophysiological correlates of jealousy in infants.

Definition of Jealousy

Lewis (2010) has categorized jealousy as a self-conscious emotion, requiring the individual to have mental representations of self and others. Jealousy has also been referred to as "a fear of losing a loved one to a rival" (Legerstee, et al., 2010, p. 163). This definition indicates that in addition to being self-aware, the individual needs to have a primary bond with another person, and finally perceive that a third party is somehow a threat to this bond (Legerstee et al., 2010). This makes jealousy triadic in nature, and differentiates it from emotions such as envy which is dyadic in nature and involves individuals lacking something another person possesses (Miceli & Castelfranchi, 2007). Therefore, jealousy is usually referred to as a complex state, which can manifest itself as a blend of other basic emotions such as anger, fear, and sadness (Harmon-Jones, Peterson, & Harris, 2009).

Factors Influencing the Expression of Jealousy

The expression of jealousy depends on situational factors such as the individual's early life experiences, gender and culture. Over the past twenty years or so, researchers have conceptualized jealousy in many different ways. From the evolutionary psychology perspective, jealousy can be viewed as a positive emotion, as experiencing jealousy can be vital in ensuring the survival of one's genes. Research indicates that men become more jealous if their partner engages in sexual infidelity, because if the female becomes pregnant by a rival, the man's genes will not survive (Buss, Larsen, Westen & Semmelroth, 1992). On the other hand, women get significantly more jealous if their partner has an emotional connection with a rival, as this situation poses a threat to the survival of her genes, because the male's resources are invested in rearing the rival's offspring (Buss, et al., 1992). This argument is further supported by findings that jealousy experienced by men decreases when their partner is perceived to be cheating with a same-sex rival (Ben-Ze'ev, 2010). Some theorists also consider jealousy to be a personality trait with different individuals possessing varying degrees of it. Bringle (1981) has found that if individuals are dispositionally jealous, they would also be more self-deprecating, unhappy, and anxious. In addition, some theorists consider self-evaluation to be the main cause of jealousy in adults. In a study that has been performed by DeSteno & Salovey (1996), it has been shown that the intensity of jealousy increases if the domain of the rival's characteristics is relevant to one's self-image. For instance, if intelligence is important to one's self-image, then the individual would feel more jealousy, if the rival is perceived to be intelligent.

Buunk and Hupka (1987) suggested that there could be cultural differences in what behaviours evoked jealousy, and how individuals reacted to jealousy-evocative situations, and that these differences could even be present in cultures that are similar in other societal features such as economy and politics. In their study, conducted in seven industrialized nations, Buunk and Hupka (1987) found that while jealous reactions toward certain behaviours with a third party existed in all nations, there were differences in the intensity of jealousy reactions. For instance, flirting evoked negative reactions in one culture, but elicited a neutral response in another (Buunk & Hupka, 1987). Furthermore, the study also found gender differences in what behaviours elicited jealousy. Regardless of their culture, women reacted negatively to their partner kissing someone else, whereas men reacted strongly if their partner had sexual fantasies about someone else (Buunk & Hupka, 1987). This finding was supportive of the above argument regarding gender differences in jealousy reactions, if it could be assumed that kissing is a more emotional behaviour compared with sexual fantasizing.

Adult Jealousy

Adult jealousy studies have mostly focused on exploring jealousy behaviours in the context of romantic relationships. In adult relationships, jealousy is believed to occur as a result of individuals' fear of losing their exclusivity with a loved one and become inferior (in the eyes of the loved one) to a rival (Ben-Ze'ev, 2010). This social comparison and how an individual expresses jealousy may be influenced by many factors, such as gender, the characteristics of the jealous individual and the characteristics the individual perceives to be possessed by the rival (Ben-Ze'ev, 2010, Sharpsteen & Kirkpatrick, 1997).

It was suggested that when individuals were afraid of losing their loved one to a potential rival, the rival became the main target for social comparison (Buunk & Dijkstra, 2004). In a study performed by DeSteno & Salovey (1996), it was shown that the intensity of jealousy increased if the domain of the rival's characteristics were relevant to one's self-image. For instance, if intelligence was important to one's self-image, then the individual would feel more jealous, if the rival was perceived to be intelligent. Furthermore, research indicated that males and females showed differences in what rival characteristics evoked jealousy reactions when faced with emotional and sexual infidelity (Buunk & Dijkstra, 2004). Buunk and Dijkstra (2004) found that following emotional infidelity, men felt more threatened by the perceived rival's social status or dominance, whereas women became more jealous if they thought the rival was physically attractive. This conclusion seemed plausible, because as evolutionary psychologists suggested men place more emphasis on the rival's potential to provide more resources to their loved one. On the other hand, women could have thought that physical attractiveness was more important because they associated youth with reproductive success (Buunk & Dijkstra, 2004) and assumed that their partner would leave them for someone who they thought was more suitable than them as a partner.

Jealousy in adults could also be seen within the context of parent-child relationships. It could be possible for parents to be jealous when they perceived that their children were spending more time with a different person (e.g. nanny, spouse) (Ben-Ze'ev, 2010). Furthermore, a parent could also express feelings of jealousy about the relationship between the child and the other parent. In this case, the other parent would be considered to be the rival. In a study that was done by Ellestad and Stets (1998) mothers were instructed to read vignettes that placed mothers in either nurturing or playmate roles. The study found that mothers reacted with greater jealousy when they read vignettes that placed the father in a nurturer role (Ellestad & Stets, 1998). These findings once again indicated that individuals were more likely to feel jealousy if the rival possessed a particular characteristic that was important to their self-definition (Ellestad & Stets, 1998).

Jealousy in Childhood

The primary relationships of children are with their parents and their siblings. Therefore, jealousy research with children mostly involves examining sibling jealousy. In this case, the triadic relationship consists of the parent (the object of affection), and the sibling (the rival) (Volling, Kennedy, & Jackey, 2010). Researchers and parents interpret older children's reactions after the birth of their siblings as manifestations of jealousy (Volling et al, 2010). These reactions may involve attempts to disturb the mother-infant interaction, and aggression toward the mother or the infant (Volling et al, 2010). In this case, the sibling is perceived to be a threat to the attachment the child has toward the primary caregiver. Although research on sibling jealousy during middle childhood and adolescence is more limited, jealousy continues to be reported by children and parents (Volling, McElwain, & Miller, 2002). Thompson and Halberstadt (2008) report that the main cause for middle childhood jealousy is diverted parental attention as well as parental favouritism. Sibling rivalry can be related to the experience of jealousy among siblings, as rivalry is found to be associated with differential treatment by parents (Volling et al., 2010).

Another area of jealousy research in children involved studies performed with children with developmental disorders such as Autism Spectrum Disorders (ASD). In order to observe if the development of jealousy in high-functioning autistic children had cognitive or social roots, Bauminger (2004) presented the children with two scenarios. One involved the mother praising another child's drawing (cognitive), and the other involved the mother interacting with a rival, another peer (social). It was found that children with autism were able to express jealousy in both situations (Bauminger, 2004). However, when compared to typically-developing children, there were significant differences in how the feelings of jealousy were manifested. Autistic children showed less gazing toward the mother compared with typically-developing children, but more acting and aggression toward the rival (Bauminger, 2004). Researchers concluded that because children with autism were able to express jealousy, they were aware of themselves in relation to others (Bauminger, 2004). However, it was also suggested that aggressive behaviours displayed by autistic children toward rivals indicated that autistic children were less aware of what behaviours constituted socially acceptable emotional displays (Bauminger, 2004). Nonetheless, autistic children were able to perceive the threat to their primary relationship by a rival, even though their expressions of jealousy were atypical.

Jealousy in Infancy

Until recently, research on jealousy has focused on adults' social connections such as romantic relationships, friendships, and sibling relationships (Harmon-Jones et al., 2009). Jealousy research involving infants and children is scarce. One reason is that experiments involving infants and children rely heavily on identifying facial expressions that correspond to a specific emotion. For instance, sadness is identified when corners of the mouth are drawn downward (Izard, 1979). However, because jealousy can be manifested through a mixture of emotions, facial indices alone may not be enough to explain the expression of jealousy (Bauminger, 2004). As a result, some researchers have added additional behaviours to measure the expression of jealousy in young infants and children. For instance, in their study with 6-month-old infants Hart, Carrington & Tronick (2004) have used approach (defined as gazing at mother) and withdrawal (defined as twisting and turning in chair and away from the mother) behaviours to measure jealousy responses. Proximity-seeking behaviours such as attempting to reach the mother can be added to the approach category when older infants are studied (Mize, 2008).

One of the earliest accounts of infant jealousy came from Gesell (1906), who provided examples of how infants between 3 and 15 months of age reacted toward a rival in various situations. Based on individual case studies, these reports showed that even young infants demonstrated angry and frustrated behaviour when their caregiver paid attention to a rival (sibling, peers) (Gesell, 1906). More recently, jealousy research consisted of creating situations that induced jealousy, and observing behaviours of children and infants in these situations that were indicative of jealousy (Masciuch & Kienapple, 1993). One of the earliest studies that attempted to understand when jealousy was most likely to occur and how it manifested itself was performed by Masciuch & Kienapple (1993). In this study, behaviours of infants and children between the ages of 4.5 months and 4.5 years were observed when their mother paid exclusive attention to a peer. Results indicated that infants and children from all age groups studied showed increased negativity when their mother paid exclusive attention to another child (Masciuch & Kienapple, 1993). However, the authors also concluded that older children demonstrated greater jealousy compared to younger infants. One reason for this finding could be due to a greater range of behaviours observed in older children such as proximity seeking and verbal communication that would not be demonstrated by infants.

Another reason for the preclusion of infants in jealousy research was the notion that infants did not have the cognitive and social skills necessary to experience an emotional state like jealousy. Lewis (2010) suggested that in order for infants to experience jealousy; they needed to have a concept of self-representation, which he claimed did not develop until 15 months of age. In a study performed exclusively with mother-infant dyads; Hart and colleagues (2004) found that infants showed significantly more negative affect and gaze towards the mother when she attended to a lifelike baby doll, than when she attended to a book, which was the control stimulus. Because infants seen in the study were 6 months of age, the results challenged Lewis's (2010) claim that jealousy emerged after the first year of life in infants (Hart, et al., 2004). However, because the study used a doll as the rival, it was not clear whether the infants' reactions were due to the perception of the presence of a rival, or if they wanted to play with the doll (cf. Legerstee et al, 2010). Furthermore, the study did not have a control condition that included a triadic interaction involving the infant, the mother, and another social object such as another person. In fact, the mothers acted toward the baby doll with social behaviors, but in the control condition just read the book. Thus not only did the stimulus change in the control condition but also the mother's behaviors, and therefore, it was not clear what the infants were responding to (M. Legerstee, personal communication, May 20, 2011).

Another study that challenged the belief that jealousy did not emerge in infancy was performed by Legerstee and colleagues. Legerstee et al. (2010) argued that because jealousy involved the fear of losing a loved one to a rival infants needed to show that (1) they were able to distinguish between self and others, (2) had established a primary social bond with another person, and (3) perceived and reacted to the relationships between the rival and the beloved in a social triad. In order to reveal that infants possessed these socio-cognitive abilities, Legerstee et al. (2010) assessed the infants in a paradigm where they were excluded by their loved one (the mother) in favor of a rival. If infants showed negative reactions to being excluded by a loved one in favor of a rival, but not when being excluded in the absence of a rival, then one could assume that infants' reactions were due to jealousy (Legerstee et al., 2010). In the presence of a rival, infants' jealousy reactions could manifest themselves as negative emotionality and approach behaviours, which had been defined as behaviours infants engaged in to get the attention of their loved one. In order to assess for jealousy, Legerstee et al., examined whether 3 and 6-month-old infants were aware of the reason they were ignored, by including various triadic conditions during which infants were excluded in various ways. In one condition infants were presented with a female stranger (the experimenter) during a still-face (the experimenter looked at baby but did not talk) and three modified still-face conditions where the mother sat at the experimenter's side at equal distance of the infant (see figure 1). In one modified still-face condition, the experimenter drank a beverage from a bottle while looking at the infant. In the other modified still-face condition, the experimenter did not talk, but simply looked at the baby. In two additional conditions, the experimenter would ignore the infant while talking to the mother who simply listened (monologue condition), and in the other condition, the experimenter and mother engaged in an animated dialogue while the adults ignored the infants (dialogue condition). Results showed that infants at both ages reacted with sadness and gaze aversions during the still-face condition, but not when mothers were drinking a beverage. Furthermore, infants were less upset during the monologue condition compared to the dialogue condition, during which they reacted with more agitation and intense interest. (Legerstee et al. (2010) concluded that infants as young as 3 and 6 months of age were not upset when mother was drinking a beverage, as she had a reason for breaking her interaction, but they were upset when she refrained from talking without a reason as in the still-face condition. Similarly, infants were not upset when mothers listened to another person, while ignoring their infants, but they were very upset when mothers engaged in an animated conversation with another person while excluding their infants. Legerstee et al., (2010) argued that infants were upset during the dialogue condition because they were able to perceive the threat from a rival to the social bond they had developed with their mother. Given the evidence that infants as young as 3 months of age experience jealousy, the question arises about the corresponding neurophysiological reactions.

Neurophysiological Correlates of Jealousy

Jealousy and brain areas.

Studies examining the specific brain locations that correspond to the experience of jealousy are limited, as it is difficult to associate the emotion of jealousy with a particular brain area. Because most jealousy research has focused on romantic adult relationships, researchers have been interested in how males and females differ in their neurophysiology when it comes to sexual and emotional infidelity. Takahashi and colleagues have presented participants with sentences aimed to arouse sexual or emotional infidelity and have asked them to rate their levels of jealousy (Takahashi, Matsuura, Yahata, Koeda, Suhara, & Okubo, 2006). In addition, they have taken fMRI screenings of their subjects. Their results have indicated that there are no significant gender differences in the ratings of jealousy for the two types of infidelity (Takahashi et al., 2006). However, fMRI results have demonstrated that males and females show differences in brain region activations during jealousy-provoking situations. During the viewing of sexual infidelity-related sentences, males showed greater activation in brain areas implicated in sexual salience, reproduction and negative emotions such as amygdala and hypothalamus; whereas females showed greater activation in areas involved in the detection of deception and trustworthiness such as posterior superior temporal sulcus during the viewing of emotional infidelity-related sentences (Takahashi et al., 2006). These findings seem to be consistent with the evolutionary correlates of jealousy for males and females, which suggest that males are more prone to be upset when faced with sexual infidelity, whereas females are more likely to be more distressed because of emotional infidelity (Panksepp, 2010).

Infant jealousy research was investigated through the use of jealousy-evocative situations such as when the mother paid exclusive attention to a potential rival. Therefore, in the case of infant jealousy it was more plausible for researchers to look at studies that attempted to understand brain structures associated with concepts that were similar to jealousy such as social exclusion. Research indicated that feelings of social loss could be reflected in the circuits of the human brain (Panksepp, 2003). An fMRI study that was performed by Eisenberger and colleagues involving participants being excluded from a virtual ballgame showed that when participants experienced social loss, the brain areas that activated were the same as those of physical pain (Eisenberger, Lieberman & Williams, 2003). It was concluded that the experience of social exclusion could share some of the same neural pathways as physical pain. It should be noted that despite its excellent spatial resolution, fMRI is not an efficient methodology to be used in studies involving infant populations and behavioural paradigms, because it does not allow subjects to move during the recording, and requires them to be in machinery throughout the experiment. A more effective methodology to use with infant populations has been electroencephalogram (EEG). In addition to having temporal resolution, it possesses excellent artifact detection, and movement and eye blinks removal techniques (Teplan, 2002). EEG is also easier to use in studies involving behavioural paradigms, as it does not require subjects to lie motionless inside machinery.

Jealousy and brain asymmetry.

One of the most common methodologies that have been used by researchers to examine the neural correlates of emotion is EEG. EEG is a widely used, non-invasive methodology, which has been in existence for over one hundred years (Teplan, 2002). It works by reading the electrical activity on the scalp, which is generated by firing neurons (Teplan, 2002). In a review that has been completed by Coan and Allen (2004), it has been suggested that over seventy studies have examined the correlates between emotion and EEG asymmetries. Researchers first noticed a relationship between brain laterality and emotion around one hundred years ago, when patients showed varying reactions to left and right brain lesions (Wheeler, Davidson, & Tomarken, 1993). Over the past twenty years, there has been an increase in research examining the neural correlates of emotions (Davidson, 1993). In particular, there has been a growing interest in studying the associations between emotional reactivity and hemispheric reactivity, specifically frontal asymmetry (Wheeler et al., 1993).

A number of studies investigating the hemispheric correlates of emotion using EEG reported that the two frontal hemispheres showed differences when subjects experience positive and negative emotions. Specifically, findings indicated that there is greater left hemisphere activation during the perception or experience of positive emotions or approach behaviours (in this case infant approach was defined as gazing at mother), and greater right hemisphere activation is associated with negative emotions or withdrawal behaviours (in this case infants tend to move away from mother) (Davidson, 1993; Ahern & Schwartz, 1985). However, infancy research showed that right and left hemisphere division according to positive or negative emotions is not as straightforward, because infants' brain and behavioural reactions could vary according to social stimuli presented. For instance, in a study by Fox and Davidson (1988) the brain correlates of discrete facial emotions in 10-month-old infants were examined. The authors hypothesized that those facial signs of positive emotions that accompany approach behaviours (defined as mother or stranger approaching the infant) would be associated with left frontal EEG activation, while facial signs of negative emotion that accompany withdrawal behaviours (defined as crying during maternal separation) would be associated with right frontal EEG activation. Infants were exposed to 3 conditions. They were either approached by their mothers or a stranger, or were separated from their mother. Facial expressions produced during these conditions were compared to their respective EEG recordings taken during these conditions. The results of the study demonstrated that infant smiles during their mothers' approach were larger in duration and were associated with greater left hemisphere activation. On the other hand, smiles accompanying the approach of a stranger were shorter in duration and were associated with greater right hemisphere activation. Furthermore, it was found that while infants demonstrated sad facial expressions without the presence of crying during maternal separation, their brain activity showed greater left hemisphere activation. When infants exhibited sad facial expressions along with crying, greater right hemisphere activation was observed. The authors concluded that infants would show differences in their facial expressions as well as their brain laterality as a function of the changing social context.

To our knowledge, only one study has evaluated EEG in an infant jealousy paradigm so far. Like Hart et al. (2004), Mize (2008), exposed 12-month old infants to jealousy-induced conditions involving their mother attending to a social (a life-size doll) and a non-social item (a book). It was hypothesized that infants with greater left frontal EEG activity during a baseline EEG recording would rate higher on the IBQ-R Approach Scale and also would demonstrate greater jealousy (as indicated by greater approach behaviours such as maternal gazing and proximity-seeking, and greater negativity) when their mother attended to the baby doll (Mize, 2008). The study found a relationship between the infants' baseline EEG recordings and their ratings on the IBQ-R approach scale (infants with greater left hemisphere activation rated higher on the IBQ-R Approach Scale). However, the author did not find a relation between jealousy responses (defined as more approach behaviours like gazing at mother, proximity-seeking, and touching, as well as other behaviours like negative vocalizations and negative affect) and EEG activation. It should be noted that this study had some critical limitations. Like Hart, Mize used a lifelike doll and not a human as the "rival", to which mother paid exclusive attention. However, during the first 6 months of life infants differentiate between people and objects in various paradigms, when important physical differences between the stimuli were controlled (see Legerstee, 2005, Ch. 3; Legerstee, 1992, for reviews). This finding is supported with neurological data. Evidence from behavioral neuroscience revealed that different neural mechanisms underlie the processing of the two classes of stimuli, which supported the notion that a global social-nonsocial distinction is deeply rooted in our categorical thinking. Brains of 7-8 month-old infants responded differently when presented with different stimuli in both social and nonsocial domains (Jeschonek, Marinovich, Hoehl, Elsner & Pauen, 2010). Therefore, in Mize's study, it could be that the negative reactions during the doll condition were due to the 12 month old infants' desire to play with the toy doll (non-social object) to which they were not given access, rather than due to the perception of a rival. Furthermore, Mize did not take EEG recordings were not taken during the jealousy paradigm. Instead, the recordings were taken during a baseline period before the behavioural paradigm started. Consequently, the researchers could not study the brain dynamics while the infant was exposed to a jealousy-inducing condition (excluded by the mother).

Present Study

The purpose of the current study was to examine infant behaviours during jealousy-induced interactions with their mothers and a rival (the experimenter) in various triadic interactions. Infants' gazes, facial expressions, vocalizations, and protest behaviours were observed while their mothers interacted with the experimenter in an animated fashion and one where she simply listened. In both conditions mothers excluded their infants. These behaviours were compared with natural interactions where the infants were not excluded and a still-face interaction where mothers looked at their baby but did not talk. Infants' brain activity during these interaction conditions was measured using a dense-array 128-channel infant recording cap (EEG).

Hypotheses

Behavioural.

- Based on the research by Fox and Davidson (1988), infants are expected to show greater maternal gazing, and positivity during the natural interaction compared to all other conditions.
- Infants as young as 3 months of age should react with more maternal gazing, negative expressions, and protest behaviours in the dialogue condition compared to monologue and still-face conditions.
- It is expected that infants will be able to distinguish between the dialogue and still-face conditions. Specifically, infants are expected to show more negativity

during the still-face condition compared with other conditions, including the dialogue condition.

Neurophysiological.

- It is expected that infants would show differences in frontal EEG activation among all four conditions (natural interaction, dialogue, monologue, and still-face).
- Due to the expectation that both approach and distress behaviours would be observed during the dialogue condition compared to the natural interaction and monologue conditions, both hemispheres would be expected to activate during the dialogue condition compared to the natural interaction condition.
- Infants are expected to demonstrate left hemisphere activations during the dialogue compared to the still-face conditions, because behaviourally they are expected to show greater negativity during the still-face condition.

Method

Participants

Forty-six mother-infant dyads were recruited (25 boys and 21 girls). Participants were seen at the Parent-Infant Research Laboratory of Professor David Haley at the University of Toronto, Scarborough Campus. Seven infants were excluded due to experimental error and ten were excluded due to fussiness. The final sample consisted of twenty-nine full-term infants (15 boys and 14 girls). Two groups of infants were studied. One was between 3-to 5-month-olds (n = 15; M = 4.38 months, SD = 0.81) and the second 6- to 7-month-olds (n = 14; M = 6.53 months, SD = 0.68). Participants were of

Caucasian (62%, Asian 14%, African-Canadian 3%, and mixed 21% ethnicity). Mothers were twenty-five to forty-three years of age at birth (M = 34.42, SD = 4.72), and were of upper-middle socioeconomic class on average (M = 19.60, SD = 2.98) (Kuppuswamy, 1981).

Upon arrival to the Parent-Infant Research Lab, parents were asked to sign an informed consent form. Parents were also presented with a demographics questionnaire to gather information about the infants such as their age, sex, the APGAR score of their infants, and household information such as parents' occupation, and education level.

Participants were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct," (American Psychological Association, 2002). Participants were recruited by phone using commercial mailing lists provided by Z-Retail Marketing Inc. of Toronto, Ontario. Parents were provided with a small gift, in addition to a copy of their baby's video.

Materials and Apparatus

The procedure was based on the research conducted by Legerstee et al. (2010). Infants were seated in a red, foam infant seat, which was placed on a round office table. The mother and the experimenter sat next to each other and faced the infant at eye level. As a result, the infant, the mother, and the experimenter formed a triangle (see Figure 1). The interaction was filmed and recorded on one camera, which was placed behind the experimenter and the mother.

A 128-channel high-density array of Ag/AgCI electrodes embedded in soft sponges and arranged into a net (Geodesic Sensor Net, EGI Inc.) was used to record brain activity. Electrophysiological data was recorded using Net Station 4.0 (EGI. Inc.) (Haley, Akano, & Dudek, 2011).

Design and Procedure

Electrode preparation and application.

Prior to placing the EGI net to the scalp, the net was soaked in a warm potassium chloride (KCl) solution. This solution served as a conductor for electrical currents from the scalp to the electrodes of the net. This solution consisted of 1 teaspoon of KCl (or 14.7 CCs), 1 liter of distilled water, and 5 CCs of Johnson's Baby Shampoo. The EGI net was soaked in this solution for 5-8 minutes. The net was then gently padded on a towel and applied to the infant's head. The impedance was checked and kept under 10 micro/ohms. .

Behavioural Jealousy Paradigm

After the infant and the mother were settled in the room, the session was started. In this paradigm, four types of social interactions were evaluated to elicit social emotions in the infant. Each condition was approximately one minute (sixty seconds) in length and the conditions were counterbalanced. The first condition was a natural interaction, in which the mother was instructed to interact with the infant as she normally would at home. Each condition was followed by a natural interaction, in order to prevent possible carry-over effects and to soothe the infant after potentially upsetting conditions. As a result, infants were presented with a total of three natural interaction conditions. The second condition was the dialogue condition, in which the experimenter engaged the mother in talking about her baby, through questioning, laughing, and speaking in a very animated fashion (Legerstee, et al., 2010). The mother and the experimenter did not look at the baby during this condition. The third condition was the monologue condition, in which the experimenter talked to the mother, once again to the exclusion of the infant. However, during the monologue condition, the mother refrained from replying to the experimenter. The dialogue interaction was defined as the jealousy-induced condition and the monologue and the natural interaction conditions were included as control conditions. The dialogue condition consisted of mothers talking for approximately 70 percent of the time, and the experimenter 30 percent (M_{mother}= 68.16, M_{Exp}= 31.84), while during the monologue condition mothers responded to the experimenter for less than 5 percent of the time (M_{mother}= 4.63, M_{exp}=95.37). The fourth condition was a still-face condition, during which the mother was asked to look at the infant with a neutral expression, but refrained from smiling, talking or touching the infant. This condition was included in order to differentiate it from other social exclusion conditions, such as the monologue and dialogue, where mothers and the experimenter did not look at the baby (Legerstee et al. (2010).

It should be noted that infant behaviours were only recorded if they were able to maintain a calm and alert state (stage 4) (Wolff, 1966). Interactions were terminated in the case of significant agitation or upset.

Behavioral Coding Measures

The behavioural coding was completed by viewing the video records of the paradigm. Coding was performed second by second to determine the duration and frequency of each behavioural measure. Although the filming of the infants had begun as soon as infants, mothers and the experimenter were seated, the coding did not commence until infants gazed at the stimulus (eyes turned toward the stimulus face). During the natural interaction and still-face conditions the stimulus was considered to be the mother, whereas during the dialogue and the monologue conditions the stimulus was either the mother or the experimenter. Behavioural coding was divided into the following five categories: Gazing at the stimulus face, gaze aversion, facial expression, vocalization and protest.

Gazing consisted of: (1) gazes at mother (2) gazes at experimenter and (3) gaze aversions to mother or experimenter. Gazes at the mother were defined as approach behaviours (Weinberg & Tronick, 1994).

Facial expression categories were as follows: (1) positive expression, (2) negative expression, (3) neutral expression.

Vocalizations included positive/neutral and negative vocalizations.

Protest behaviours were defined as infants twisting in the chair and raising their arms in a distressed fashion. (See table 1 for summary of measures).

Reliability

Inter-rater reliability measures were calculated by having two separate coders code 20% of the data and calculating Kappa values. Cohen Kappas were calculated on agreement of the durations and frequencies of each behavior and their values ranged from .71 to 1.0. Please refer to table 2 for kappa values for each measure in each condition.

Electroencephalogram Acquisition Procedure

All electrodes (channels) were initially referred to vertex (Cz) during data collection and then re-referenced to an average reference for data analyses. EEG signals were analog filtered using a 0.1 Hz high pass filter 100 Hz low pass filter.

EEG data analysis.

EEG data was measured in microvolts-squared. EEG recordings of each participant were put through two types of filters, in order to eliminate activity in frequencies that are not of interest. A Highpass Filter was set to 0.1 Hz and a Lowpass Filter was set to 100 Hz. Once the filtering was completed, the data was segmented into one-second epochs, giving sixty epochs for each behavioural condition. Segmentation was performed for each of the behavioural conditions, in order to organize the EEG data into categories (natural interaction, dialogue, monologue, still-face), which would allow the data to be averaged.

Artifact detection.

The Artifact Detection was performed to eliminate noise that could have been created as a result of bad channels, eye movements, and eye blinks. A channel (electrode) was marked as "bad" (containing too many artifacts), if it contained more than 50 percent eye blinks (as measured by ocular electrodes), eye movements, or artifacts (a change in amplitude greater than 200 μV). A segment was considered "bad", if more than 70 percent of it contained bad channels. If a segment was marked as "bad", it was not used in the averaging for that condition. If the remaining segments contained channels marked as "bad", then the Bad Channel Replacement tool was used to replace those bad channels with the data interpolated from the remaining channels. The Montage tool of the Net

Station program allowed for re-referencing of all the channels that had initially been referred to the vertex, to the overall average of all channels.

Frequency and channel selection.

For the remaining segments that were not marked "bad", a single average segment was calculated for each condition. The Wavelet tool was used as a bandpass filter to specify the data into the frequency interval of interest (4-9 Hz, with 0.5 Hz step) to perform a wavelet transformation. The 4-9 Hz range was chosen because previous research showed that this range contains the majority of alpha activity in infants (Santesso, Schmidt & Trainor 2007; Schmidt, 2008). The Statistic Extraction tool was used to obtain the power (average amplitude squared of the wavelet data) for the F3 and F4 region (using a mean of 3 channels in each) in each condition. The channels analyzed were chosen to correspond to the 10-20 system of EEG. For the channels used please refer to the appendix and for the correspondence areas in the 10-20 system, please refer to table 3. Power was expressed in units of microvolts-squared and the data was transformed using the natural log (Ln) to obtain a normal distribution. It should be noted that EEG power numbers are inversely related to activity, as low alpha power indicates higher cortical processing (Coan & Allen, 2004). As a result, lower power numbers were taken to represent higher activity, and higher power numbers represented lower activity (Santesso, et al., 2007).

Results

Hypotheses 1 and 2: Infants are expected to show greater maternal gazing and positivity during the natural interaction compared to all other conditions. They

are expected to show greater maternal gazing, negativity, and protest behaviours during the dialogue compared to monologue condition. Infants will also show differences between the still-face and all other conditions.

Maternal gazing.

For all dependent measures, the data was transformed by taking the square root of each value, in order to satisfy the normality assumptions of ANOVA. A repeated 2 X 4 measures ANOVA with age (3-5 months vs. 6-7 months) as the between subjects factor and condition (natural interaction, monologue, dialogue, and still-face) as within subjects factors was conducted and a significant main effect $F(1,25)=29.63$, $p=0.01$ for gaze at mother was shown. Post-hoc analysis indicated that infants of both age groups gazed at their mothers more during natural interaction followed by still-face ($p=0.01$), dialogue ($p=0.01$) and monologue ($p=0.01$). Furthermore, infants gazed at their mothers significantly longer during the dialogue condition than monologue condition ($p=0.01$). Please refer to table 4 for the mean and standard deviation values for the maternal gazing measure.

Stranger gazing.

A repeated 2 X 4 measures ANOVA with age (3-5 months vs. 6-7 months) as the between subjects factor and condition (natural interaction, monologue, dialogue, and still-face) as within subjects factors was conducted and a significant main effect $F(1,25)=31.53$, $p=0.00$ for gaze at stranger was shown. Post-hoc analysis indicated that infants gazed at the stranger more during the monologue condition compared to the natural interaction ($p=0.01$), and still-face ($p=0.01$) conditions. There were no significant differences between the dialogue and the monologue condition for the stranger gazing measure. Please refer to table 4 for the mean and standard deviation values for the stranger gazing measure.

Gaze aversions.

The analyses did not reveal a significant effect with respect to the measure of gaze aversion.

Expressions.

A repeated measure ANOVA was not performed on the expression variable, because the data violated the normality assumptions of ANOVA. Therefore, the data was analyzed using Wald Chi-square test, and a significant condition main effect was found for positive expression c^2 (3, N= 29) = 24.87, p = 0.01. Post-hoc analysis indicated that infants at both ages showed more positive expression in natural interaction than dialogue (p=0.04), monologue (p=0.01), and still-face (p=0.01) conditions.

Wald Chi-square analysis showed a significant condition effect c^2 (3, N= 29) = 16.36, p = 0.01 for the negative expression measure. Post-hoc analysis showed that 3-5-month-olds demonstrated significantly greater negative expressions during the still-face condition compared with the monologue (p=0.001), dialogue (0.002), and natural interaction (p=0.01) conditions. 6-7-month-olds also demonstrated significantly greater negative expressions during the still-face condition compared with the monologue (p=0.01), dialogue (0.004), and natural interaction (p=0.003) conditions.

Vocalizations.

A repeated 2 X 4 measures ANOVA with age (3-5 months vs. 6-7 months) as the between subjects factor and condition (natural interaction, monologue, dialogue, and still-face) as within subjects factors indicated that there was a significant main effect of total vocalization $F(1,25)=8.22$, p=0.001. Post-hoc analysis showed that infants in both age groups showed significantly less vocalization during the dialogue condition compared to the natural interaction and still-face conditions (p=0.034 and 0.003, respectively). There were no significant differences with respect to positive/neutral and negative vocalizations.

Protest behaviours.

Wald Chi-square analysis showed a significant condition X age interaction c^2 (3, N= 29) = 9.63, p = 0.022. Post-hoc analysis showed that 3-5-month-old infants showed more protest behaviours (defined as twisting in chair in distress) during the dialogue than the monologue condition (p=0.01).

As predicted, infants showed greater maternal gazing, and protest behaviours when their mothers paid exclusive attention to the experimenter and was engaged in an active dialogue with the experimenter than when she simply listened to the experimenter. On the other hand, infants simply gazed at the experimenter and were quiet and calm during the monologue condition compared to the dialogue condition.

Hypothesis 3: Differences in frontal EEG activation among all four conditions

A 2x2x4 repeated measures ANOVA with age (3-5 months vs. 6-7 months) as the between subjects factor and hemispherity (left and right) and condition (monologue, dialogue, natural interaction, still-face) as within subjects factors was conducted. The results showed that there was a significant condition main effect $F(1,25) = 5.86$, $p=0.002$ and a significant condition X hemispherity interaction $F(1,25) = 3.34$, $p=0.023$. Post-hoc analysis indicated that there was significantly less frontal alpha power in the left hemisphere (i.e. greater activation) for both ages in the dialogue condition compared to the natural interaction ($p=0.003$), monologue (0.017) and still-face ($p=0.005$) conditions. Post-hoc analysis further revealed that there was also significantly less frontal alpha power in the right hemisphere (i.e. greater activation) for both age groups in the dialogue condition compared to the natural interaction ($p=0.001$) and still-face ($p=0.003$) conditions. There were no significant differences with respect to the right hemisphere activations between dialogue and monologue conditions. (see figures 2 and figure 3 for the frontal EEG activations for each hemisphere during each condition).

In addition to comparing left and right frontal hemisphere EEG activation for each condition, region was added as a variable, in order to determine whether more EEG activation was present in the prefrontal or parietal regions of the brain. A 2x2x2x4 repeated measures ANOVA with age (3-5 months vs. 6-7 months) as the between subjects factor and hemispherity (left and right), region (front and back) and condition (monologue, dialogue, natural interaction, still-face) as within subjects factors was conducted. Results showed that there was a significant condition X hemispherity X region interaction $F(1,27)=3.34$, $p=0.023$. Post-hoc analysis indicated that there was significantly less left hemisphere alpha power (i.e. greater activation) in the front region compared to the back during the natural interaction (p=0.008), dialogue (p=0.003) and still-face conditions (p=0.003) (see figures 4 and 5). Results also showed that there was less right hemisphere alpha power (i.e. greater activation) in the front region compared to the back during the monologue condition (p=0.002). Therefore, it can be concluded that for all conditions there was greater activation in the front region of the brain compared to the back region.

In summary, the findings revealed that behaviourally infants showed greater maternal gazing, and more protest behaviours during the dialogue condition compared with the monologue condition, and showed less positivity compared with the natural interaction condition. Furthermore, they also showed greater negativity during the still-face condition compared to all other conditions. These behavioural findings were consistent with the predictions of the study and the findings of Legerstee et al., 2010).

With respect to the neurophysiological correlates of jealousy, it was hypothesized that infants would show greater right and left hemisphere activation during the dialogue (distress) compared to the natural interaction and monologue conditions, and greater left hemisphere activation (approach) compared to the still-face condition. The findings revealed both greater left and right hemisphere activations during the dialogue, supporting the behavioral data that infants showed more distress (protest) as well as approach, (gazes at mother) compared to the natural interaction and still-face conditions. There was also a difference between the dialogue and monologue conditions. Infants had greater left hemisphere activation in the dialogue (approach) compared to the monologue condition.

Discussion

Lewis (2010) referred to jealousy as a secondary emotion. He argued that the triadic nature of jealousy required infants to have certain cognitive abilities such as having an awareness of the self, and forming mental representations of others (Lewis, 2010). Lewis further claimed that self-awareness and having an understanding of triadic interactions did not emerge until infants are 15 months of age. This notion was recently challenged by Fivaz-Depeursinge et al. (2005) who showed that infants were able to differentiate among different triangular contexts such as when both parents paid attention to the infant compared with when one parent presented a still-face and the other played with the infant. Furthermore, research conducted by Legerstee and colleagues (2010) demonstrated that during a jealousy-evocative triadic situation, in this case the mother paying exclusive attention to and engaging in a lively dialogue with a female experimenter, infants showed more vocalizations, and greater vocalizations compared to when the mother simply listened to the experimenter. These findings led the researchers to conclude that infants perceived the stranger as a rival to the bond the infants had with their mother and thus were experiencing jealousy during the first year of life. The goal of the present study had been to replicate and build on Legerstee et al.'s behavioural paradigm by examining the neurophysiological correlates of jealousy through measuring EEG alpha power.

Behavioural results of the present study were mostly consistent with Legerstee et al. (2010)'s findings, and confirmed the hypothesis that infants as young as 3 months of age experience jealousy. As predicted, infants showed greater maternal gazing, and protest behaviours when their mothers paid exclusive attention to the experimenter and was engaged in an active dialogue with her than when she simply listened to the experimenter. In contrast, when she simply listened, and the experimenter engaged in a monologue, infants were quiet and calm. Interestingly, although infants gazed longer at the experimenter during the monologue condition than the dialogue condition, the gazes were not accompanied by protest behaviors, or other emotional expressions, suggesting that perhaps infants were looking at the stranger during this condition, because she was doing most of the talking. Thus, the results indicated that infants did not mind being ignored by their mother, as long as she did not show an interest in the other person, thereby not giving the infants any reason to assume that the stranger was a rival.

A second goal of this study was to examine the neurological correlates of jealousy in infants. In order to accomplish this, infant EEG activation was measured throughout the behavioural paradigm. In a study by Fox and Davidson (1988), EEG activation patterns were measured while observations of infant facial expressions were taken during maternal separation and reunion situations. It was found that when infants smiled at their mothers, they showed greater left than right hemisphere activation. However, when they smiled at the stranger, they showed greater right hemisphere activation. Thus although infants smiled behaviorally in both conditions, their EEG measures suggested that different emotions supported these smiles. In addition, when infants were upset, but did not exhibit crying, they showed greater left hemisphere activation, whereas facial expressions during crying were found to be related to right hemisphere activation. Thus, the Fox and Davidson study indicated that there were differences in brain activations depending on the type of positive and negative expressions infants produced. The findings of the present study revealed that there were significantly greater left and right hemisphere activations during the jealousy condition compared to the natural and still-face conditions, which was consistent with the findings of the Fox and Davidson (1988) study. Behaviourally, infants showed greater positivity and maternal gazing during natural interaction than the dialogue condition, which would predict greater left hemisphere activation during the natural interaction, and this was one of the findings of the EEG analyses. In addition, the jealousy condition also showed greater right hemisphere activation compared to the natural interaction. This could be due to the increased protest behaviours exhibited by infants during the jealousy condition. On the other hand, infants showed greater negativity during the still-face condition compared to the dialogue condition, which suggests that that dialogue condition should have greater left hemisphere activation compared to the still-face condition. EEG results of the study were supportive of this prediction and indicated that there was greater left hemisphere activation during the dialogue compared to still-face condition, which was consistent with the hypothesis. There was also greater right hemisphere activation found in dialogue compared to still-face. This could be due to infants not exhibiting significantly greater positivity during the jealousy condition compared to still-face condition. Furthermore, greater right hemisphere activation was related to the presence of crying in infants (Fox

& Davidson, 1988). However, in this study, infants did not cry during the still-face condition, which could be the reason for the lack of right hemisphere activation during this condition. EEG findings of the present study also showed that there was greater relative left frontal EEG activation during the jealousy condition compared to the control (monologue) condition. Even though infants showed greater protest behaviours during the dialogue condition, they also showed behaviours aimed at regaining their mothers' attention such as gazing. In addition, infants' protest behaviours were not coupled with crying, which might have contributed to the greater left hemisphere activation in this condition compared to the monologue condition. These findings suggested that infants' experiences of jealousy-like feelings may not necessarily be maladaptive or negative as previously thought. Instead, the results of this study could be interpreted as infants showing both hostility (protest behaviours) and restorative behaviours (gazing) toward the mother when she paid exclusive attention to a rival. When faced with the fear of losing a loved one to a potential rival, infants could be engaging in behaviours aimed at regaining their loved one's attention from the rival, and re-establishing their primary relationship with their mother (Campos et al., 2010). Like the Fox & Davidson study, the EEG findings of this study showed that brain hemisphere activation and the expression of emotions are influenced by the social environment.

It has been argued that it may not be possible to find a specific brain structure that corresponds to the experience of a state like jealousy, because jealousy is a blend of many other basic emotions (Panksepp, 2010). However, fMRI studies have shown that dACC is activated during the feeling of pain related to social exclusion (Eisenberger, 2003). It should be noted that EEG is a better methodology to utilize with infants because it allows the infants to move whereas fMRI does not, although one of its disadvantages is that it can only provide information about hemispheric activity. Thus, the findings of this study were not able to reveal a specific brain location of activity during jealousy-evocative situations. However, back and front channel activation comparisons were performed, and the results showed that there was greater hemispheric activation in the frontal regions of the brain during the jealousy condition. Furthermore, findings showed that there were equally high left and right hemispheric activations during the jealousy condition, suggesting that both hemispheres may be involved during the experience of this emotion. This might indicate that for infants, jealousy-like emotions are processed in the prefrontal cortex. Anterior cingulate cortex (ACC) has two functional parts: cognitive and affective (Bush, Luu, & Posner, 2000). Findings of Eisenberger's (2003) fMRI study indicate that dorsal part of ACC (dACC), which is located in the prefrontal cortex and is part of cognitive component of ACC, is linked to social exclusion. Although the results of this study cannot tell whether or not ACC is activated when infants are exposed to jealousy-evocative conditions, greater activation of frontal regions of the brain indicate that the experience of jealousy may take place in the same area where ACC is located.

Limitations

EEG is an effective methodology to utilize during studies involving infants, as it allows for movement and has high spatial resolution (Teplan, 2002). During the current study, it was observed that younger infants (ages 3-7 months) did not protest to the EEG cap. However, when the study was tried with infants who were 9-months or older, they reacted strongly to the cap and demonstrated distressed behaviours such as attempting to pull the cap and fussiness during the paradigm. Therefore, the study was not continued with older infants. Another possible disadvantage of taking EEG recordings during the behavioural paradigm could be that infants' reactions to the different behavioural conditions may have been subdued as a result of the cap, in case infants felt uncomfortable with having to wear the cap. However, subdued reactions may also be due to exposing infants to laboratory controlled conditions, as opposed to observing their behaviours at home. Nonetheless, EEG continues to be an effective methodology to be used during studies examining infant brain reactions.

Future studies

This study did not find significantly more negative expressions during the jealousy condition compared with the natural interaction condition. In a study performed by Legerstee and Varghese (2001), maternal interaction style was measured according to the level of attention maintenance, warm sensitivity and social responsiveness. Researchers concluded that infants whose mothers ranked high on affect mirroring measures, also ranked higher on prosocial behaviours (Legerstee & Varghese, 2001). This implied that there might be differences in infant reactions depending on the maternal interaction style. It could be possible that some mothers recruited in the current study were better able to elicit positive reactions from their infants during natural interactions. Adding maternal interaction style as a variable could yield more accurate distinctions between the jealousy condition and the natural interaction condition.

The findings of the present study suggest that jealousy has its foundation early on in life. According to Panksepp (2010) separation anxiety is part of the old mammalian brain. Jealousy may be related to separation anxiety, but it is influenced by experience with the social world and as this study has shown becomes present very early on in life. It could be interesting to explore genetic and environmental influences and how they interact to affect the experience of jealousy.

Conclusion

Research had shown that infants behaviourally exhibited jealousy-like behaviours at 3-6 months of age (Legerstee et al., 2010). This study sought to examine the neurophysiological correlates of jealousy in 3 and 6-month-old infants. Results from twenty nine mother-infant dyads indicated that when faced with a jealousy-evocative condition, infants reacted with greater maternal gazing, and protest behaviours compared with control conditions, supporting the Legerstee et al. 2010 findings.

This was the first study to find support for neurophysiological correlates of jealousy and showed that the experience of jealousy in infants was associated with greater left and right frontal EEG activation reflecting the infants' approach and protest behaviours.

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Table 1

Description of behavioural measures

Measure	Description
Gaze at mother	any look at the mother's face
Gaze at stranger	any look at the experimenter's face
Gaze aversion	infants are looking down and to the side (away) from the stimulus (mother or the experimenter)
Positive expressions	infants demonstrate happiness, smiles, makes cooing sounds (eyebrows and lips turned up)
Negative expressions	infants show anger, sadness, fear, disgust, contempt. The baby may furrow eyebrows, press lips together or turned down
Neutral expressions	the absence of positive or negative expressions
Positive/Neutral vocalizations	coded when infants vocalized with happy or neutral faces (eyebrows and lips turned up)
Negative vocalizations	coded when infants vocalized with unhappy faces (frowning, lowering corners of the mouth)
Protest behaviours	infant is twisting in chair and raising arms in a distressed fashion

Table 2

Inter-rater reliability: kappa values for each measure

	Natural interaction	Dialogue	Monologue	Still-face
Gaze at mom	0.92	0.95	0.94	0.97
Gaze at stranger	0.95	0.87	0.93	0.72
Gaze at other	0.90	0.87	0.92	0.96
Gaze aversion	1.00	1.00	1.00	1.00
Neutral expression	0.81	1.00	0.80	0.87
Positive expression	0.81	1.00	0.80	0.86
Negative expression	1.00	1.00	1.00	0.88
Pos/neutral vocalizations	0.83	0.80	0.75	0.80
Negative vocalizations	1.00	1.00	1.00	0.85
Protest behaviours	0.75	0.71	0.75	0.87

Table 3

The corresponding 10-10 electrode sites for those electrode channels picked

EGI Electrode Number	10-10 Electrode Site
9	Fp2
22	Fp1
24	F3
33	F7
52	P3
58	P7
70	O1
83	O2
92	P4
96	P8
122	F8
124	F4

Table 4

Mean and standard deviation values (in seconds) for all behavioural measures for each condition

(Note. Nat: natural interaction, dial: dialogue, mono: monologue, and SF: still-face)

Behavioural Measure		Condition			
Maternal Gazing		Nat	Dial	Mono	SF
3-5m					
	M	20.05	13.31	2.31	14.35
	SD	13.10	15.48	4.96	17.78
6-7m					
	M	24.51	12.50	6.11	12.00
	SD	13.69	10.62	6.87	14.53
Total					
	M	22.36	12.89	4.28	13.13
	SD	13.34	12.93	6.22	15.90
Stranger Gazing					
3-5m					
	M	12.79	26.92	32.46	8.83
	SD	10.15	19.03	20.64	11.28
6-7m					
	M	8.43	25.71	27.12	7.87
	SD	9.50	13.66	16.53	8.62
Total					
	M	10.53	26.30	29.69	8.33
	SD	9.88	16.15	18.46	9.80
Gaze Aversion					
3-5m					
	M	0.18	0.31	0.23	0.77
	SD	0.46	0.63	0.83	1.30
6-7m					
	M	0.14	0.43	0.14	1.26
	SD	0.53	0.94	0.53	3.00
Total					
	M	0.16	0.37	0.19	1.02
	SD	0.49	0.79	0.68	2.31

Behavioural Measure		Condition			
Neutral Expression		Nat	Dial	Mono	SF
3-5m					
	M	52.99	57.15	59.92	47.86
	SD	7.33	7.38	1.89	16.42
6-7m					
	M	50.98	58.00	57.42	46.97
	SD	9.55	6.66	5.60	18.39
Total					
	M	51.95	57.59	58.63	47.40
	SD	8.45	6.89	4.35	17.14
Positive Expression					
3-5m					
	M	5.79	1.31	0.38	0.38
	SD	4.89	2.50	1.12	1.39
6-7m					
	M	7.81	0.93	1.50	0.71
	SD	9.62	3.47	4.05	1.64
Total					
	M	6.84	1.11	0.96	0.56
	SD	7.64	2.99	3.02	1.50
Negative Expression					
3-5m					
	M	1.18	2.23	0.38	12.60
	SD	4.25	7.19	1.39	16.46
6-7m					
	M	2.22	2.07	2.19	10.59
	SD	3.98	6.03	4.77	13.76
Total					
	M	1.72	2.15	1.32	11.56
	SD	4.07	6.48	3.62	14.86
Total Vocalizations					
3-5m					
	M	3.32	2.92	1.54	7.59
	SD	3.22	3.80	1.94	7.02
6-7m					
	M	5.36	3.64	5.80	8.54
	SD	5.07	4.94	6.75	6.13
Total					
	M	4.38	3.30	3.75	8.08
	SD	4.33	4.36	5.41	6.46

Behavioural Measure	Condition			
Positive Vocalizations	Nat	Dial	Mono	SF
3-5m				
M	2.64	1.92	1.15	1.96
SD	2.97	2.14	1.52	2.63
6-7m				
M	3.71	2.79	4.62	5.31
SD	3.96	3.95	5.72	5.89
Total				
M	3.20	2.37	2.95	3.70
SD	3.50	3.18	4.53	4.84
Negative Vocalizations				
3-5m				
M	0.68	1.00	0.38	5.63
SD	1.24	2.77	0.77	6.32
6-7m				
M	1.60	0.86	1.18	4.16
SD	2.64	2.66	2.41	3.77
Total				
M	1.15	0.93	0.80	4.87
SD	2.10	2.66	1.83	5.11
Protest Behaviours				
3-5m				
M	0.65	1.62	0.38	5.69
SD	0.75	2.33	0.65	4.82
6-7m				
M	1.01	1.43	1.72	3.75
SD	1.53	1.83	3.05	3.01
Total				
M	0.84	1.52	1.08	4.68
SD	1.21	2.05	2.30	4.03

Figure 1. A representation of the triadic seating arrangement

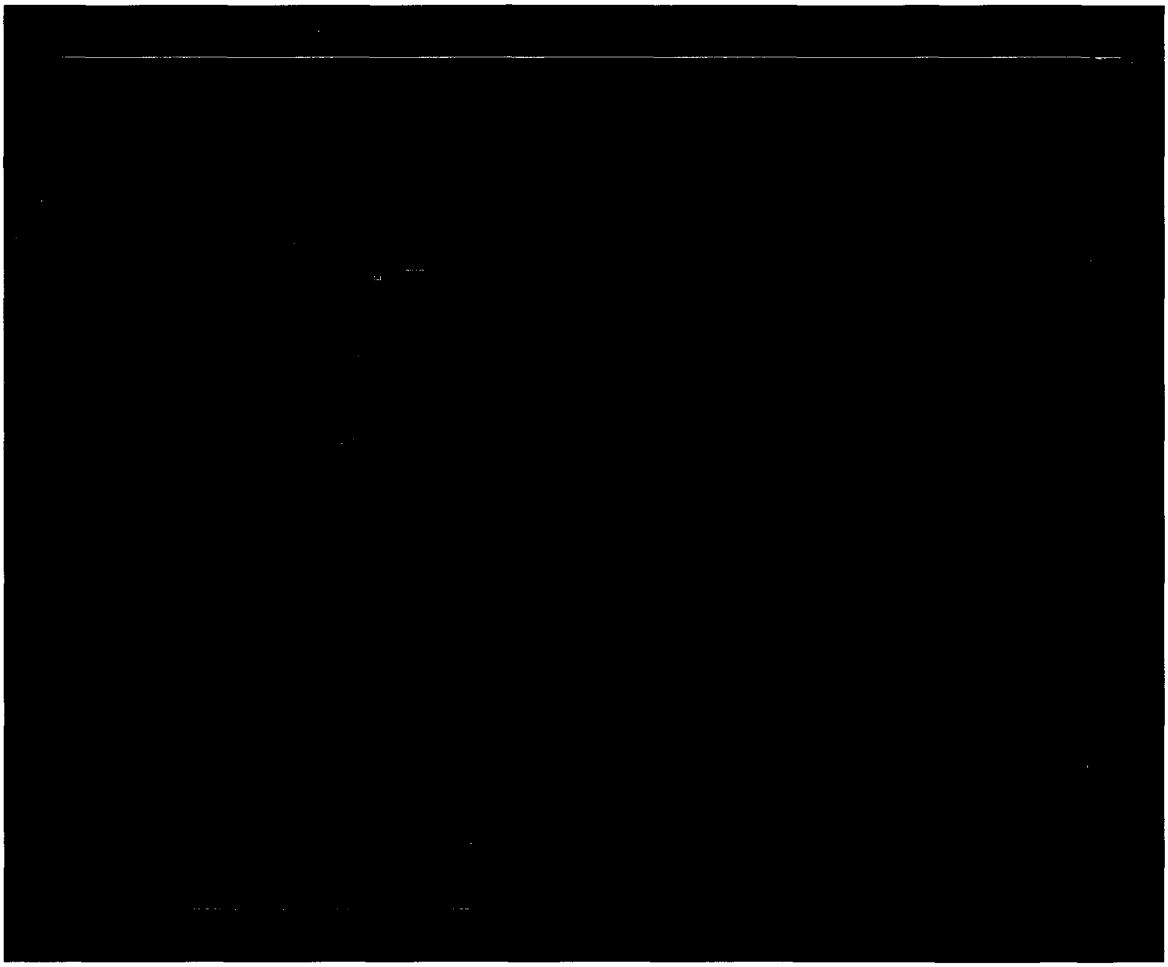


Figure 2. Frontal EEG activation for left and right hemispheres in each condition (note: lower power numbers indicate greater activation).

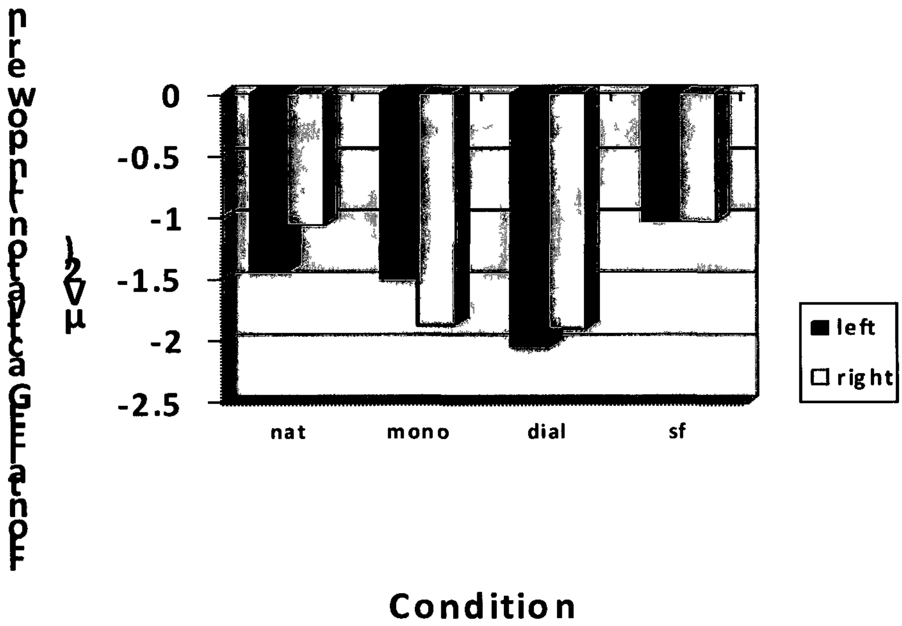


Figure 3. Frontal EEG activation for left and right hemispheres in each condition using raw power numbers.

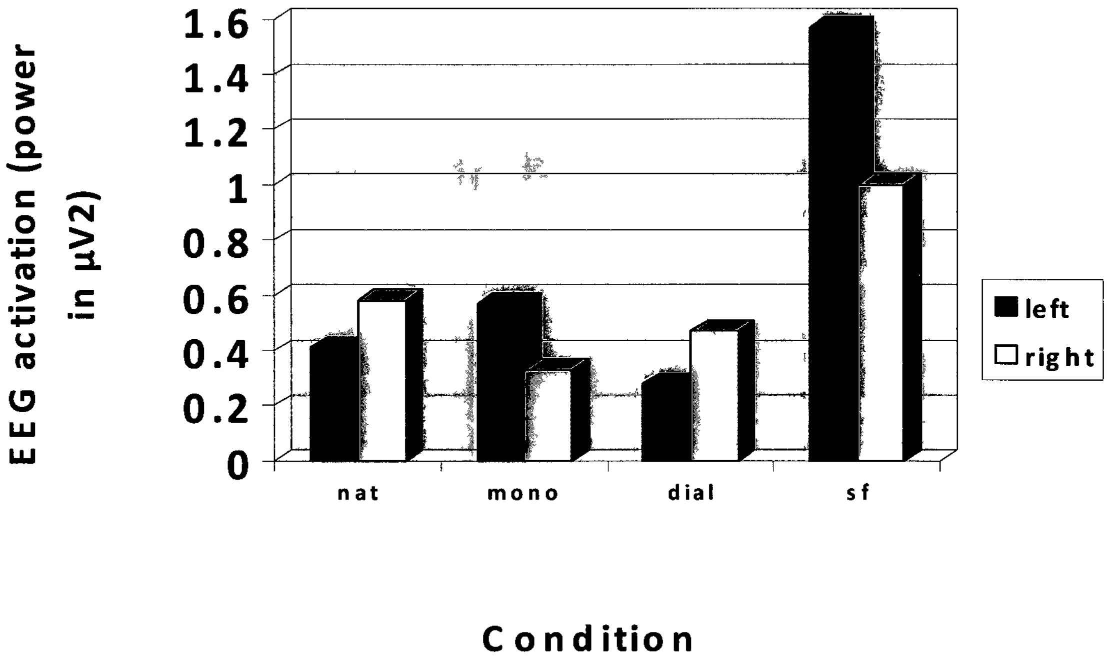


Figure 4. Front and back EEG activation for all conditions (note: lower power numbers indicate greater activation).

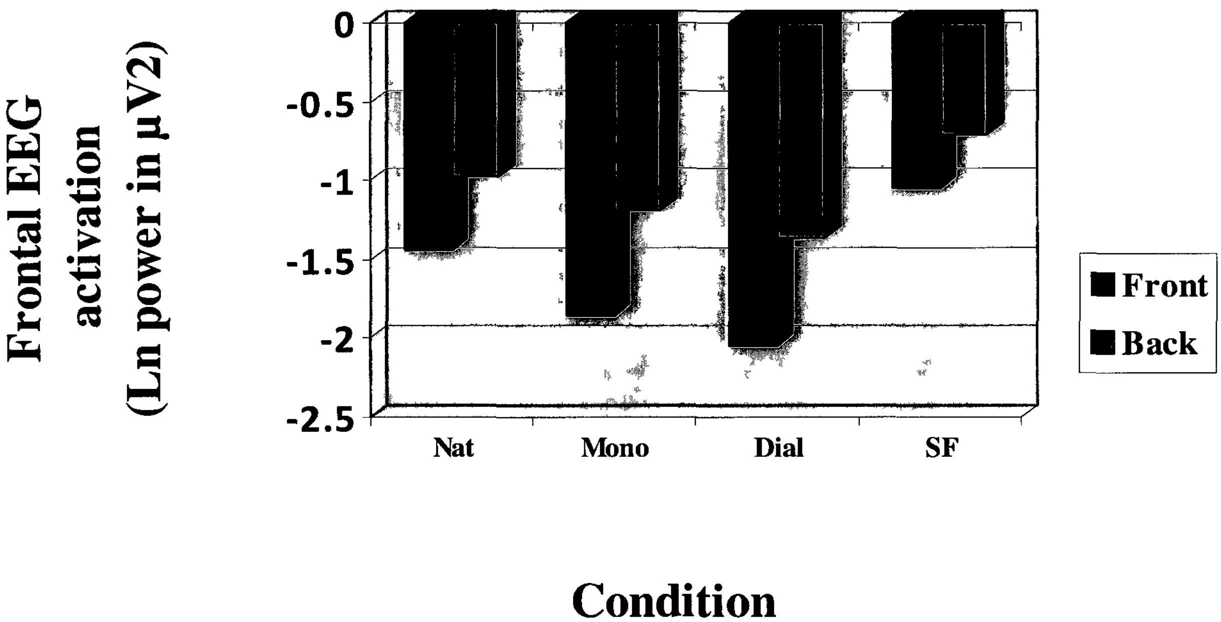
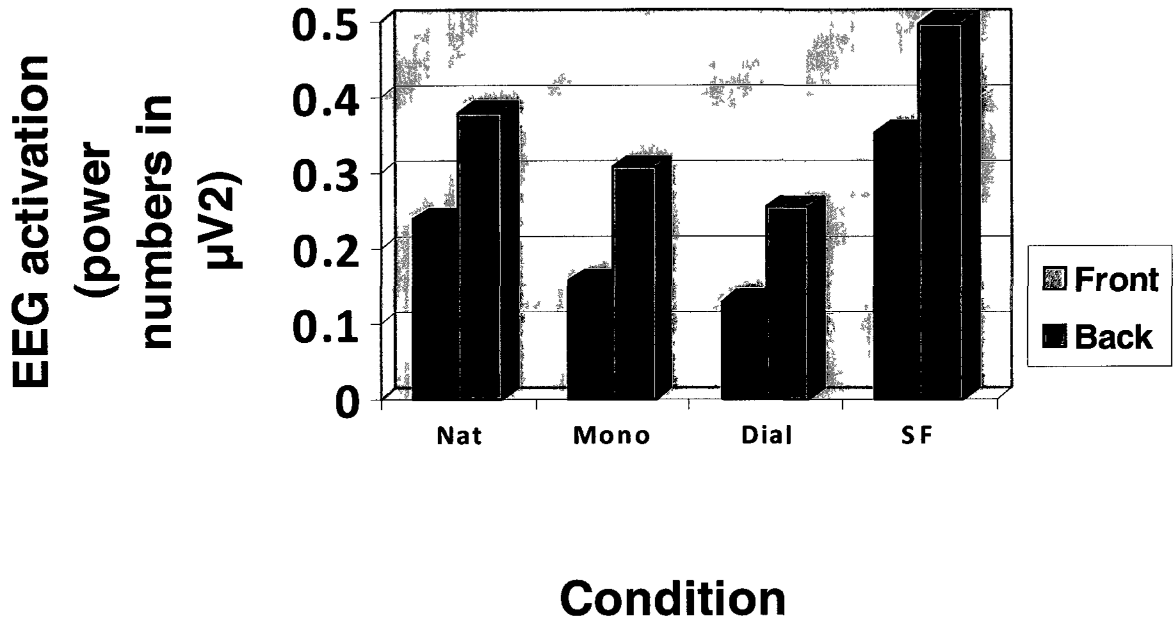
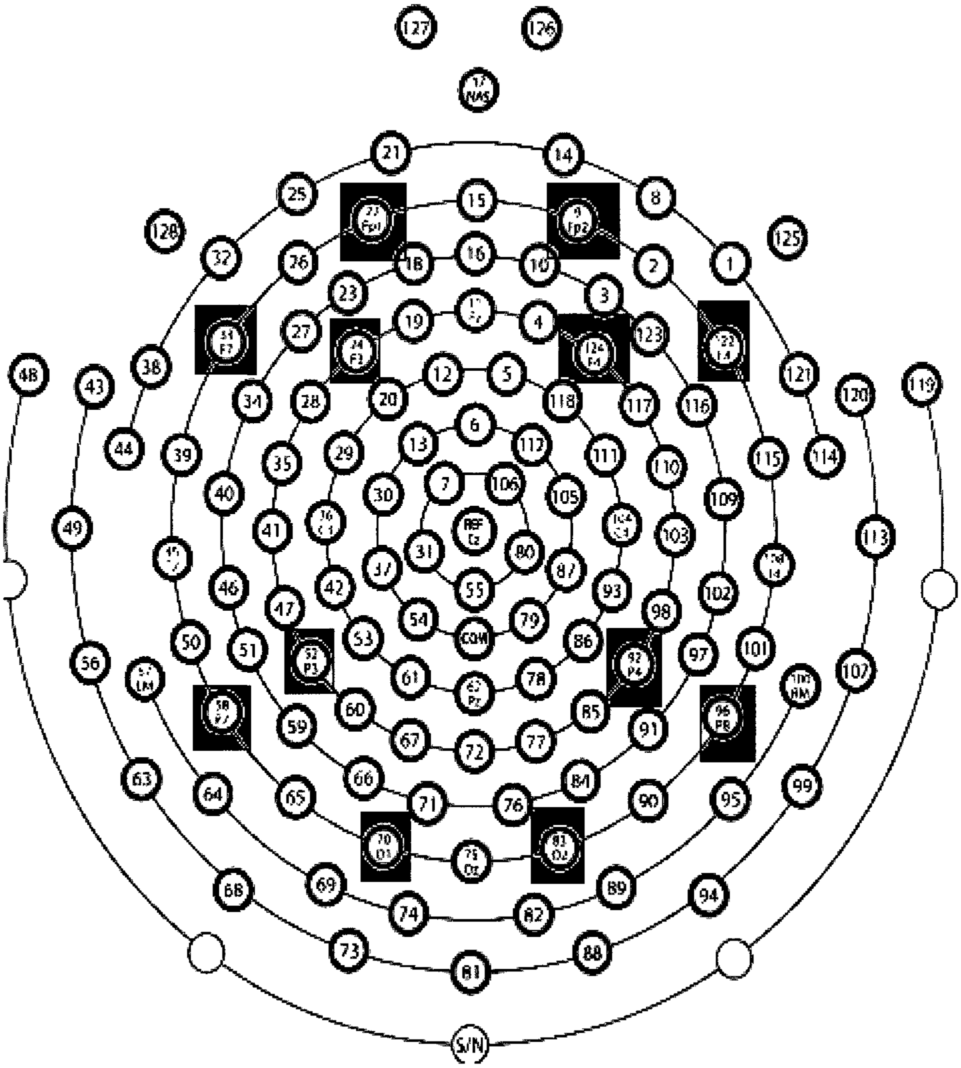


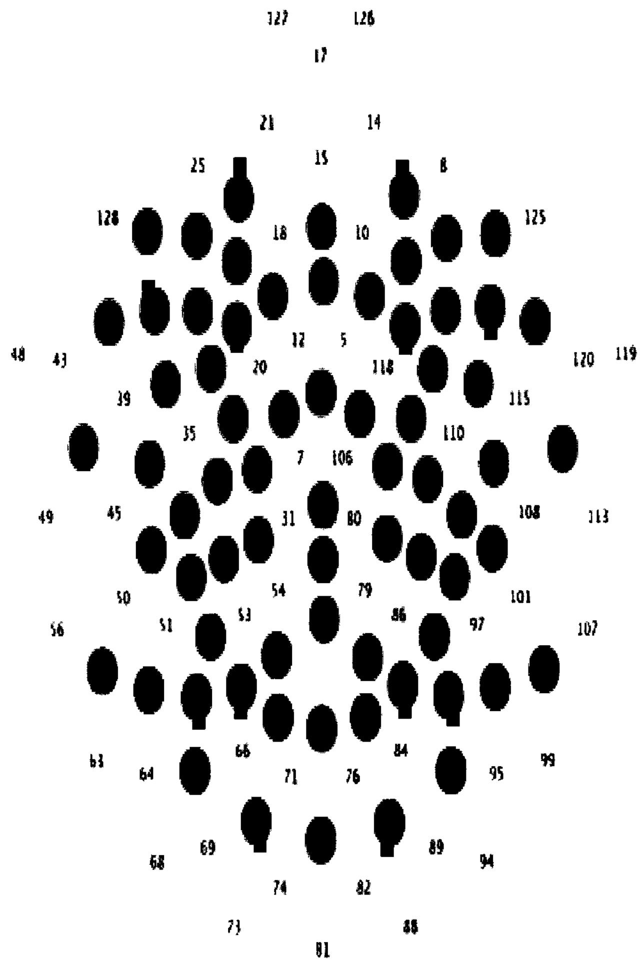
Figure 5. Front and back EEG activation for all conditions using raw power numbers.



Appendix

EEG channels picked for analysis: A map of 128-channel EGI nets and the corresponding 10-10 equivalent electrodes

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