The Neurobiology of Adult Attachment

By

Martha Bailey

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ABSTRACT

Attachment styles and the experiences of parenting that underpin attachment styles have important effects throughout the lifespan. Research on the neurobiology of human attachment has begun to identify neural correlates of attachment styles. The present study adds to that body of research and confirms previous findings on correlations between attachment style and memories of parenting.

My main goal was to test the first time the hypothesis that baseline neural activity in the left dorsolateral prefrontal cortex (DLPFC) would be correlated adult attachment security. Previous research has identified: 1) a correlation between baseline neural activity in the left DLPFC and approach motivation; 2) a correlation between baseline neural activity in the left DLPFC and infant attachment style; and 3) a correlation between the willingness of toddlers to freely explore a new environment when in the presence of their attachment figures and attachment style. Based on these previous findings, I hypothesized that adult attachment security, as indicted by “confidence” scores on the Adult Attachment Questionnaire (ASQ), and parenting memories, as measured by the EMBU questionnaire, would be positively correlated with baseline neural activity in the left DLPFC.

I also explored correlations between responses to the ASQ and to the EMBU, hypothesizing that attachment security, as measured by confidence scores on the ASQ, would be positively correlated with memories of parental emotional warmth and negatively correlated with memories of parental rejection.
As hypothesized, I found a significant positive correlation between confidence, the ASQ factor reflecting a secure attachment orientation, and neural activity in the left DLPFC. Because the same correlation between attachment security and neural activity in the left DLPFC has been found in infants, my finding suggests that this may be one of the mechanisms by which attachment styles developed in infancy persist into adulthood. The left DLPFC has also been associated with approach motivation. Therefore my finding suggests that more confident, or securely attached, adults have higher approach motivation.

I also found that adult attachment style as measured by the ASQ was correlated with memories of parenting as measured by the EMBU. “Memories of father emotional warmth” was the most significant EMBU factor relating to attachment style.
ACKNOWLEDGMENTS

In addition to his generous and timely supervision, Professor Mark Sabbagh provided very concrete help by creating the EEG paradigm and the Matlab and sLORETA protocols used in this study. Samantha Drover and Jeannette Benson kindly helped me with EEG and Matlab and, along with the other members of the Early Experience Lab, were wonderfully supportive colleagues. My research assistants, Beth Power, Lauren Brandys and Linay Repath, assisted with cleaning EEG files, and Beth also helped with data input. Members of my thesis committee, Professors Janet Menard and Tom Hollenstein provided helpful feedback on my thesis proposal and an earlier draft of this thesis. Professor Tara Macdonald offered guidance on attachment theory and allowed me to use the result of her pre-screening instrument for recruitment. Professor Robert Bailey offered helpful comments on an early draft of this thesis. Faculty and staff at the Centre for Neuroscience Studies and the Department of Psychology have been very helpful, and I am particularly grateful to Lucy Russo-Smith and Kelly Moore.
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CHAPTER 1: INTRODUCTION

Attachment refers to the stable patterns of behavior that characterize intimate relationships in humans (Bowlby, 1969). A given attachment “style” is thought to have its roots in the early experiences that children have with their caregivers (Bowlby, 1973; Simpson & Belsky, 2008). These early experiences are then thought to provide the basis for a template for how subsequent intimate relationships are approached (Hazan & Shaver, 1987). Although originally conceptualized as being a specific factor affecting intimate relationships, it is now clear that attachment styles have important effects on social functioning and health throughout the lifespan (Shonkoff et al., 2009). For these reasons, researchers have turned their attention to understanding the neurobiological correlates of different attachment styles, in hopes of better understanding the role that neural systems associated with cognitive and emotional processing may have in maintaining attachment styles over time (Coan, 2008). To date, what little is known about the baseline neural correlates of attachment has come from brain encephalographic (EEG) research with infants and children (Dawson et al., 2001). The goal of my project is to use EEG measures to identify possible developmental similarities in the baseline neural correlates of attachment styles in adults.

In this introductory section, I will review the extant literature on attachment theory and the long-range developmental implications of attachment styles that are developed in infancy. I will then turn to a review of the literature on the neurobiological concomitants of attachment styles, with a particular focus on the findings using EEG
methods with infants and young children. Finally I will discuss in detail my hypotheses and predictions regarding the EEG correlates of attachment styles in adults.

**Attachment**

Attachment theory posits that infants are biologically predisposed to form attachment relationships with their caregivers (Bowlby, 1969). Using her “strange situation” protocol, Ainsworth and her colleagues identified three patterns of infant attachment: “secure,” “anxious-resistant,” and “avoidant” (Ainsworth et al., 1978). For this protocol, the parent and child are left in an experiment room with toys, a stranger enters, the parent leaves, the parent returns, the child is then left alone, and finally the parent again returns. The key points of interest are the amount the child explores, the child’s reaction to the parent’s departure, and the child’s behaviour on reunion with the parent.

Children classified as securely attached freely explore their environment when their “secure base” is present, welcome their parent’s return after a separation and, when distressed, seek proximity to and are readily comforted by the parent. Infants classified as anxious-resistant are reluctant to explore a new environment even when parents are present, and show ambivalent behaviour toward parents and an inability to be comforted on reunion. Infants classified as avoidant do not freely explore a new environment, and they avoid proximity or interaction with parent on reunion, although physiological measures indicate a strong reaction to the event (Ainsworth et al., 1978; Gunnar et al., 1996). Later researchers, noticing that some infants did not fit within any of the three patterns, classified as “disorganized/disoriented” infants who display
conflicted behaviours in the parent's presence, e.g., by averting the face after initial approach, freezing with a trance-like expression, or going to greet the parent but then falling prone (Main & Soloman, 1990).

Supporting the child’s growing independence while providing a secure base of comfort and safety is the parenting style most associated with secure attachment. Inconsistently responsive parenting is associated with anxious attachment style. Cold, rejecting, or insensitive parenting is associated with avoidant attachment style (Bowlby, 1973; Simpson & Belsky, 2008).

From the 1980s, researchers extended attachment theory to adult relationships, arguing that the attachment style developed in infancy in response to the degree of sensitivity and responsiveness of the primary caregiver is carried forward into romantic and perhaps other relationships (Hazan & Shaver, 1987). Kaplan and Main designed the Adult Attachment Interview (AAI), which is intended to reveal internalized representations of the self and attachment figures and implicit strategies for emotion regulation, resulting in the classification of adults as “secure/autonomous,” “avoidant/dismissing,” “anxious/preoccupied,” or “unclassifiable” (Fonagy & Target, 2007; Kaplan & Main, 1996). As well, various self-report measures of adult attachment were developed to measure dimensions of attachment anxiety and attachment avoidance (Brennan et al., 1998).

The terminology and theoretical underpinnings of the various self-report instruments vary to some degree, but they generally result in classifications of secure, avoidant and anxious attachment styles (Ravitz et al., 2010). The characteristic voice of
these classifications is well captured by Hazan and Shaver:

**Secure:** I find it relatively easy to get close to others and am comfortable depending on them and having them depend on me. I don't often worry about being abandoned or about someone getting too close to me.

**Avoidant:** I am somewhat uncomfortable being close to others; I find it difficult to trust them completely, difficult to allow myself to depend on them. I am nervous when anyone gets too close, and often, love partners want me to be more intimate than I feel comfortable being.

**Anxious/Ambivalent:** I find that others are reluctant to get as close as I would like. I often worry that my partner doesn't really love me or won't want to stay with me. I want to merge completely with another person, and this desire sometimes scares people away. (1987)

Depending on the instrument used, about 60% of adults are considered secure, 25% avoidant, 10% anxious and 5% unclassified (Mickelson et al., 1997).

Because human infants are born in a relatively underdeveloped state, their survival depends on forging bonds with their caregivers. Maintaining proximity to the caregiver (the “attachment figure”), turning to the attachment figure as a “safe haven” for comfort and support, and using the attachment figure as a “secure base” from which to explore are adaptive behaviours that improve chances of survival and reproduction (Simpson & Belsky, 2008). Maturing into adolescence and adulthood, individuals gradually diminish their reliance on parents and increasingly turn to peers and romantic partners as attachment figures, and this shift is important for reproductive success (Simpson & Belsky, 2008).

The attachment behavioural system is not only central to human survival and reproductive success. Individual attachment styles and early life experiences have major effects on adult mental and physical health (Shonkoff et al., 2009). Secure attachment is important for the formation and maintenance of positive and supportive relationships,
emotion regulation and optimal physical health (Maunder & Hunter, 2001). Insecure attachment increases the risk of disease, in part because of the associated alteration in stress physiology (Maunder & Hunter, 2001). For example, attachment avoidance is associated with differences in physiological regulation of heart rate, and in particular with vagal influence on heart rate (Maunder & Hunter, 2006). Unfortunately, insecure attachment styles formed during the early years of development are generally maintained over time (Hazan & Shaver, 1987). Insecure attachment styles may be adaptive in the context of adverse early parenting. For example, inconsistently responsive parenting is associated with anxious attachment style, which is characterized by hyper-vigilance, rumination on potential rejection, and demanding behaviour. This attachment style may be an adaptive response to erratic parenting, designed to increase proximity to caregivers, solicit more responsive care and increase chances of survival (Simpson & Belsky, 2008). But the continuation of insecure attachment style into adolescence and adulthood is problematic because it hinders the formation and maintenance of positive relationships and contributes to mental and physical disorders, particularly stress-related disorders and depression (Besser & Priel, 2003).

The neurobiology of human attachment is not completely understood (Insel, 2001). Researchers have identified various neural systems are implicated in the attachment behavioural system, including neural systems underlying incentive motivation, emotional response, emotion regulation, and social behaviours such as establishment of familiarity and preferences, proximity seeking, separation distress and social affect regulation (Coan, 2008, at pp. 243-244). As Coan (2008) has emphasized,
the attachment behavioural system in not a unitary neural construct, and each of the neural systems involved contributes to the attachment behavioural system. Currently, therapists tend to focus on behaviour and self-reported experience for diagnosing and developing treatment plans for attachment problems (Brisch, 2012). But attention should be given to the various attachment neural systems as well. For example, although avoidantly attached individuals generally report lower levels of subjective stress, both anxious and avoidant attachment are associated with heightened autonomic nervous system reactivity to stress, and this heightened reactivity has negative effects on health (Maunder & Hunter, 2006; Diamond & Fagundes, 2010).

**Brain Imaging Research on Attachment**

The present study is situated within a growing body of research on the neural systems underlying the attachment behavioural system. Mark et al. (2012) posed the question: “are the brains of individuals with different attachment styles fundamentally different from each other?” Research to date suggests that in fact they are. Below is a selected portion of brain imaging research that particularly highlights the distinctive neural correlates of attachment styles.

Much of the research on the neurobiology of human attachment style, particularly brain imaging research, has focused on how various neural systems respond to socially threatening and other attachment-related stimuli. Examples of this “response to stimuli” research include work of functional magnetic resonance imaging (fMRI) researchers, who use blood-oxygen-level-dependent (BOLD) contrast as a measure of neural activity, operating on the experimentally validated assumption that changes in
oxygenation in a particular region of the brain indicate changes in neuronal activation in that region (Harmon-Jones & Beer, 2009).

Using fMRI, DeWall et al. (2012) found that, in response to a simulated social exclusion experience, anxious attachment was associated with greater activity in the dorsal anterior cingulate cortex and anterior insula, regions previously associated with rejection-related distress. They also found that avoidant attachment was associated with less activity in these regions.

Several researchers have used fMRI to examine links between attachment style and amygdala activation in response to various stimuli. The strong links between the amygdala and responses to emotionally salient stimuli, along with the amygdala’s high density of receptors for oxytocin (OT), the neuropeptide most strongly linked to parental-child bonding, have made it an obvious focus for this kind of fMRI research. The results indicate stronger activation of the amygdala in response to stress stimuli in individuals with insecure attachment style (Lemche et al., 2006; Riem et al., 2012).

As well, some studies have focused on the mesocortico-limbic pathways, which are dopamine pathways in the brain that play an important role in reward, motivation, learning, memory, and movement (Yamaguchi et al., 2011). Researchers have found that insecure mothers compared to secure mothers show relatively less activity in the mesocortico-limbic region in response to cues from their own infants. These same insecure mothers showed reduced peripheral OT production when interacting with their own infants, and the OT response was correlated with brain activation in the hypothalamus and the ventral striatum, important oxytocinergic and dopaminergic
reward-processing regions. Altogether this research suggests that insecure mothers have impaired OT production and a suboptimal reward system, which may account for the reduced brain activity in response to their own infants (Strathern, 2011).

Gillath et al. (2005) conducted fMRI scans on women who were instructed to think about and then stop thinking about negative relationship scenarios. The researchers found that the negative relationship scenarios resulted in increased activation of the dorsal anterior cingulate but lower levels of activation in the orbitofrontal cortex among those with an anxious attachment style, suggesting a suboptimal emotion-regulation system.

Warren et al., (2010) used fMRI to examine adult neural activity during an emotion-word Stroop test. In this test participants are asked to name the colour of emotional words. The researchers found that less secure individuals performed the task less efficiently and demonstrated more activity in pre-frontal cortical regions associated with emotion regulation (the right orbitofrontal cortex) and top-down cognitive control (the left dorsolateral prefrontal cortex, anterior cingulate cortex, and superior frontal gyrus). Their results suggest that adults with insecure attachment style are vulnerable to distraction by attachment-related emotional information and emotional reactions that require greater increased cognitive resources to manage.

EEG studies also have found distinctive brain activity associated with human attachment in response to attachment-related stimuli. EEG recordings from electrodes mounted in an electrode cap tightly connected to the human scalp result from electrical voltages generated inside the brain, mostly from postsynaptic potentials (voltages that
occur when a neurotransmitter binds to receptors on the membrane of a postsynaptic cell). The EEG waveform can be analysed in the temporal or frequency domain (Harmon-Jones, 2009).

Some attachment-related EEG studies involve analysis in the temporal domain using event-related potential methodology (ERP), which means that they have measured brain response resulting from a specific sensory, cognitive or motor event. ERP waveforms consist of a series of positive and negative voltage deflections that are related to a set of underlying components. Most components are referred to by the letter N, indicating negative polarity, or the letter P, indicating positive polarity, followed by a number indicating either the latency in milliseconds or the component’s ordinal position in the waveform (Harmon-Jones, 2009).

ERP was used by Fraedrich et al. (2010) in a study involving mothers who were presented with infant faces showing positive, negative or neutral facial expressions within an oddball paradigm. This paradigm involves asking the participant to react to particular stimuli that are rare occurrences among a series of more common stimuli. Generally the P300 component of the ERP is larger after the rare occurrence. Insecure mothers showed a more pronounced negative response in the N170 component and a smaller N200 amplitude. Secure mothers showed a stronger response to face stimuli in the P300 component. Overall, the results showed an association between attachment style and neuropsychological functioning.

Mark et al. (2012) presented students with angry, fearful or neutral faces in an oddball paradigm and found that those with a more secure rather than anxious
attachment style showed larger N100 and smaller P300 amplitudes, while those with more anxious attachment showed smaller N100 and larger P300 amplitudes. Their results suggested that secure individuals are highly attuned to threats but do not dwell on them, whereas those with an anxious attachment style demonstrate less early attention to threat but may dwell on it later. Dan and Raz (2012) also used ERP methodology to demonstrate that adult attachment style may influence the perception of angry and neutral facial expressions. Their findings suggest that adults with avoidant attachment style more quickly identify potential sources of threat.

In the study of White et al. (2012), adolescents were excluded by their peers in Cyberball, a computer toss-ball game. The toss-ball procedure involves a group of three people tossing a ball back and forth, with a pre-arranged script involving exclusion of the participant after a few tosses. A few minutes of exclusion are generally sufficient to produce anger and sadness in the participant (Williams & Sommer, 1997). Those with an avoidant (dismissive) attachment style showed more negative left anterior slow wave on experiencing rejection. As well, they showed a pattern of underreporting distress relative to the neural measure, which is a pattern consistent with previous research on the cognitive-affective strategy related to avoidant attachment. White et al. interpreted their ERP data to suggest that avoidant adolescents had greater expectations of rejection during the game than did their secure counterparts.

In a 2013 study, White et al., inspired by the “strange situation” protocol of Ainsworth and her colleagues (1978), added a reunion component to a social exclusion task. Using ERP, the researchers found that being included by their peers after an initial
period of exclusion more strongly violated the expectations of avoidant adolescents than secure adolescents. Their findings suggest that it is more difficult for avoidant adolescents to abandon negative expectations about future interactions.

**Baseline EEG and Attachment**

Research on the neurobiology of attachment has also used frequency analysis of EEG specified in hertz (cycles per second). There are five EEG frequency bands related to behavioural outcomes: delta (1-4 Hz); theta (4-8 Hz); alpha (8-13 Hz); beta (13-20 Hz); and gamma (>20 Hz). Alpha activity is the dominant EEG pattern during relaxed but alert wakefulness.

Most social and personality research using EEG in the frequency domain has looked at asymmetries in right and left frontal cortical activity in relation to emotional and motivation processes, using alpha power values (Harmon-Jones, 2009). The present study builds on this previous research, particularly the work done on approach motivation, which is “the impulse to go toward” (Harmon-Jones et al., 2013). Many of the approach motivation studies measure motivational direction using the behavioural inhibition/behavioural activation system scales developed by Carver & White (1994). A sample item from their approach-oriented scale is: “I go out of my way to get things I want,” and from their withdrawal-oriented scale is: I worry about making mistakes.”

Emotions associated with approach motivation, e.g., happiness and anger, have been associated with relatively high neural activity in the left frontal cortex, while emotions associated with withdrawal motivation, e.g., fear and sadness, have been linked to relatively high neural activity in the right frontal cortex (Tullett et al., 2012;
Harmon-Jones et al., 2013). This pattern of lateralized neural activity applies to right-handed individuals only – stronger approach motivation is associated with more left-hemisphere activity in right-handers, but with more right-hemisphere activity in left-handers (Brookshire & Casasanto, 2012).

Individuals may demonstrate relatively stable lateralized alpha activity, but asymmetries can also result from a situation, such as an emotion-evoking stimulus (Ischebeck et al, 2014). Some EEG asymmetry research relating to attachment has examined responses to stimuli. For example, Rognoni et al. (2008) presented participants with emotional video-clips that aroused happiness, fear and sadness with attachment-related content and found clear differences between attachment styles in frontal asymmetry and fluctuating asymmetry changes as measured by EEG. They found that avoidant individuals were less aroused by both pleasant and unpleasant stimuli and showed right frontal asymmetry, while individuals with an anxious attachment style showed greater neural activation in response to pleasant and unpleasant stimuli and wider left frontal activation.

In addition to identifying responses to stimuli, EEG has been a particularly useful tool to assess potentially trait-like aspects of the neurobiology of attachment by identifying correlations between baseline neural activity and trait-like characteristics. Traits are relatively enduring general characteristics that are consistent across situations. Approach motivation is changeable in response to stimuli such as social threats. But in the absence of such stimuli, there is evidence of a relatively stable, or “trait-like,” tendency to approach or withdraw (Harmon-Jones et al., 2013). Although
there is evidence of context-specific variability in the attachment state (Fraley, 2009), EEG studies that have identified baseline neural activity correlated with attachment style in the absence of any attachment-related stimuli suggest that attachment style includes as well some stable, trait-like features.

Tarullo et al. (2011) used the frequency domain in a study comparing the relative EEG power in 18 month old, internationally adopted children who had been in institutions versus age-matched non-adopted children and children who had been in foster care prior to adoption. The researchers found that post-institutionalized children had higher relative theta power and lower absolute alpha power than the non-adopted children, and that the relative EEG power of the post-institutionalized children predicted indiscriminately friendly behaviour (a sign of uninhibited attachment disorder). The study of Tarullo et al. adds to the body of research showing distinctive neural patterns associated with attachment style.

Sloan et al. (2007) found that anxious attachment was correlated with the “α-EEG” (alpha EEG) anomaly, a biological measure of sleep disturbance. Alpha EEG activity, the predominant EEG frequency recorded during passive wakefulness, is normally replaced by theta activity as sleep begins and by delta activity as sleep deepens. The persistence of alpha activity during sleep – the α-EEG anomaly – is associated with chronic pain, indicating a more vigilant state during sleep for those who suffer from that condition (Sloan et al. 2007). Sloan et al. found that the association of the α-EEG anomaly with anxious attachment was not due to a higher degree of anxiety or depression in those with anxious attachment style. Their findings suggest that
individuals with anxious attachment style have trait-like hyper-vigilance that increases sensitivity to stimuli during sleep.

Most germane to the present study is the work of Dawson et al. (2001), who found differences in right and left frontal cortical activity in relation to the attachment security of 13-15 month old infants. They found that insecurely attached infants had lower baseline neural activity in the left dorsolateral prefrontal cortex (DLPFC) than securely attached infants. When considered in light of the approach motivation research, which has demonstrated that relatively high levels of resting-state activity in the left DLPFC indicates approach-related tendencies (e.g., Harmon-Jones et al., 2013; Pizzagalli et al., 2005), the findings of Dawson et al. may indicate that securely attached infants have a trait-like approach tendency. This would be consistent with the attachment research showing that secure infants who are not threatened by separation from their attachment figure freely move to explore their environment while insecure infants do not (Ainsworth et al., 1978; Gunnar et al., 1996).

**Goals of this Research**

The main goal of this study was to test the hypothesis that adults who are securely attached would demonstrate left-lateralized baseline neural activity in the DLPFC. To test this hypothesis, I recorded adults’ resting EEG and investigated the connections between source-localized alpha power and responses on two questionnaires. The focal questionnaire was the Attachment Style Questionnaire (ASQ), scored on five scales: discomfort with closeness, need for approval, preoccupation with relations, viewing relationships as secondary to achievement, and confidence. Of
particular interest for my hypothesis is the “confidence” scale, which specifically assesses secure attachment behaviors. For instance, participants are asked to indicate on a six-point scale the extent to which they agree with the statement: “I feel confident that other people will be there for me when I need them.” Thus, my specific hypothesis was that scores on the confidence scale of the ASQ would be related to greater activity in the left DLPFC.

The second questionnaire was the Memories of Upbringing scale, which is called the EMBU because of the acronym that is formed by the Swedish title of the measure. The EMBU is a self-report measure that includes 23 questions and is scored on three scales: parental warmth, parental over-protection and parental rejection. Inclusion of the EMBU allowed me to address two auxiliary questions. Considerable research shows that early parenting experiences are connected with adult attachment style (Beckwith et al., 1999). By including this measure, I sought to determine whether these connections might also be seen at both the behavioural level and the neurological level. At the behavioural level, I hypothesized that positive memories of parenting would be associated with evidence of more secure attachment as indicated by higher scores on the confidence scale of the ASQ. At the neurobiological level, I hypothesized that positive memories of parenting would be associated with evidence of increased baseline neural activity associated with the left DLPFC.
CHAPTER 2: METHOD

Participants

Recruitment

Eighty right-handed participants aged 18-25 with no brain injury or current psychoactive medication use were recruited for the study. Fifty were recruited through posters distributed around the Queen’s University campus. Thirty were recruited through email solicitation to members of the pre-screened Psych100 database whose scores on the Experiences in Close Relationships questionnaire (one of the pre-screening instruments administered to those in the database) indicated that they were relatively insecure. The targeted recruitment was done because poster recruitment had yielded mostly participants who were relatively secure, and I wanted to test participants with a range of attachment styles. Because the study used self-selected (poster solicitation) and targeted (email solicitation) subjects, it did not represent a random sample of people in this age range and geographic area.

ASQ/EMBU correlations

One participant was dropped from the EMBU/ASQ association analysis because no data were available on memories of the participant’s father. Thus, for this analysis there were 79 participants aged 18-25 (mean age 20.43). Forty-nine (62.03%) were female. Forty-seven (60.5%) identified as White, 28 (35.44%) as Asian/Indian subcontinent, three (3.8%) as two or more races, and one (1.27%) as Native Canadian. Thirty-two (40.5%) reported that they were in a romantic relationship. Sixty (76%)
reported that their parents were married. The remainder said that their parents were separated, divorced, cohabiting or widowed.

_EEG correlations_

Fifteen participants were dropped because of insufficient artifact-free data. Thus, for this analysis there were 65 participants aged 18-25 (mean age 20.4.). Thirty-seven (57%) were female. Forty-one (63%) identified as White, 20 (30.1%) as Asian/Indian subcontinent, three (4.7%) as two or more races, and one (1.5%) as Native Canadian. Twenty-six (40%) reported that they were in a romantic relationship. Forty-eight (74%) reported that their parents were married. The remainder said that their parents were separated, divorced, cohabiting or widowed.

In comparison, the 15 dropped participants had a mean age of 20.4. Thirteen (87%) were female. Six (40%) identified as White, and 9 (60%) Asian/Indian subcontinent. Six 40% reported they were in a romantic relationship. 12 (80%) reported that their parents were married. For correlations involving father data from the EMBU, one additional participant was dropped because no data were available on memories of the participant’s father.

_Questionnaire results for retained versus dropped participants_

In Table 1, the mean scores on the ASQ and on the EMBU of retained versus dropped participants are given.
Table 1. Comparison of mean scores on ASQ and EMBU of retained versus dropped participants

a) ASQ

<table>
<thead>
<tr>
<th>Mean scores on ASQ</th>
<th>Participants used for ASQ/EMBU correlations (n=79)</th>
<th>Participants dropped because of insufficient EEG (n=15)</th>
<th>Participant dropped because no data on father (n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>3.57</td>
<td>3.34</td>
<td>3.5</td>
</tr>
<tr>
<td>NA</td>
<td>3.59</td>
<td>3.77</td>
<td>5.14</td>
</tr>
<tr>
<td>PR</td>
<td>3.59</td>
<td>3.62</td>
<td>4.13</td>
</tr>
<tr>
<td>RS</td>
<td>2.43</td>
<td>2.32</td>
<td>2</td>
</tr>
<tr>
<td>AV</td>
<td>6</td>
<td>5.67</td>
<td>5.5</td>
</tr>
<tr>
<td>AX</td>
<td>7.19</td>
<td>7.39</td>
<td>9.28</td>
</tr>
<tr>
<td>INS</td>
<td>13.18</td>
<td>13.05</td>
<td>14.77</td>
</tr>
<tr>
<td>CF</td>
<td>4.18</td>
<td>4.18</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Note: ASQ = Adult Attachment Questionnaire; DC = Discomfort with Closeness; NA = Need for Approval; PR = Preoccupation with Relationships; RS = Relationships as Secondary; AV = Avoidant (DC + RS); AX = Anxious (NA + PR); INS = Insecure (DC + NA + PR + RS); CF = Confidence (Secure)

b) EMBU

<table>
<thead>
<tr>
<th>Mean scores on EMBU</th>
<th>Participants used for ASQ/EMBU correlations (n=79)</th>
<th>Participants dropped because of insufficient EEG (n=15)</th>
<th>Participant dropped because no data on father (n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR</td>
<td>1.38</td>
<td>1</td>
<td>2.2</td>
</tr>
<tr>
<td>MOP</td>
<td>2.33</td>
<td>2.44</td>
<td>2.33</td>
</tr>
<tr>
<td>MEW</td>
<td>3.7</td>
<td>4</td>
<td>2.66</td>
</tr>
<tr>
<td>FR</td>
<td>1.39</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>FOP</td>
<td>2.15</td>
<td>2.22</td>
<td></td>
</tr>
<tr>
<td>FEW</td>
<td>3.19</td>
<td>3.67</td>
<td></td>
</tr>
</tbody>
</table>

Note: EMBU = My Memories of Upbringing Questionnaire; MR = Mother Rejection; MOP = Mother Over-protection MEW = Mother Emotional Warmth; FR = Father Rejection; FOP = Father Over-protection; FEW = Father Emotional Warmth.

Procedure

Each participant visited the Early Experience Lab once. At the outset of each appointment, the selection criteria were reviewed, and demographic information and informed consent were obtained from the participant, all of which took about 10 minutes. The participant then completed an EEG recording session, which took about an hour. Several brain imaging studies have looked at neural activity in response to attachment-related stimuli (e.g., Fraedrich et al., 2010), but this study aimed at
identifying distinctive resting-state neural correlates of attachment style and parenting memories in the absence of any such stimuli. Therefore, the EEG recording took place prior to the questionnaires in order to avoid triggering memories or emotions relating to the questionnaire items. After completing the EEG recording, each participant then completed the two questionnaires, in random order, which took about 15 minutes. Finally, there was a debriefing session. The participant had an opportunity to comment on the process and to ask questions. The participant was thanked for participating and given either $20 or course credit for Psych100.

**EEG Collection and Analysis**

*EEG recording*

Each participant first completed an EEG recording session. These sessions were scheduled at various times of the day – morning, afternoon and evening – and at various times of the year – summer, fall and winter. Each participant’s alpha-band activity was measured with a “Hydrocel Geodesic Sensor Net.” This net contains 128 silver/silver chloride (Ag/AgCl) electrodes encased in sponges, packed into plastic pedestals, and knitted into a geodesic tension structure net. Before the net was placed on the participant’s head, it was soaked in a mild and harmless electrolyte solution made of one litre of filtered water, 1.5 teaspoons of potassium chloride, and one drop of baby shampoo. While the net was soaking in the electrolyte solution, the participant’s vertex was marked using a soft, washable crayon. The net was then removed from the electrolyte solution and placed on the participant’s head so that all of the sponge-electrodes were properly positioned and made contact with the scalp.
evenly. Additional electrolyte was applied to electrodes that became dried out in the process in order to lower impedance and ensure good scalp contact. Impedances at most electrode sites were below 30kΩ by the end of the net placement and adjustment period. The room lights were then lowered for the recording process.

Data were recorded at 250 Hz, with a bandpass filter between .1-100 Hz (time constant = 1 sec.). During EEG recording, participants were seated alone in a quiet room and instructed to relax but remain alert throughout 10 contiguous 3-minute trials (30 min. total). On the odd numbered trials, participants were asked to keep their eyes open, and on the even numbered trials, participants were asked to keep their eyes closed. Following standard practice (see Harmon-Jones & Beer, 2009), only data from the eyes-closed trials were considered for further analysis. Throughout the EEG procedure, electrode impedances were monitored and maintained below 50 kΩ to ensure high quality recordings.

**EEG data reduction and analysis**

The EEG data were submitted to computer algorithmic analysis for evidence of eye blink and movement artifact that can contaminate EEG. Eye blink was detected anytime the supra- and infra-orbital electrodes showed sharp transient activity of opposite polarity. Movement artifact was defined as transient voltage exceeding 200 µV across multiple channels.

To prepare the raw EEG data for sLORETA analyses, I computed the cross-spectral matrices for each subject across the EEG alpha band (8-13 Hz) in discrete .5 Hz bands. For this step, the time frames per epoch was 1000, and the sampling rate (Hz)
was 250, thus alpha power was estimated in each discrete band for continuous 4 sec. segments. The resulting cross-spectral matrices were then submitted to sLORETA analysis for current source estimation.

The sLORETA algorithms computed a distributed cortical electrical current density from scalp electrodes, using optimal smoothing to estimate a direct 3D solution for the electrical activity distribution (Cannon, 2012). The cortical space is parcelled into 6,239 5 mm\(^3\) voxels within cortical gray matter and hippocampi. Using a minimum-norm tomographic analysis, each voxel is considered as a possible source for the scalp electrical activity and assigned a current-source density value. The result is a “blurred” probabilistic map of potential cortical sources that fits the brain-electrical data recorded from the electrodes at the scalp, given principles of electromagnetic conduction. The sLORETA technique has been used extensively and critically validated in studies that have combined sLORETA and fMRI (Pascual-Marqui, 2002; Harmon-Jones, 2009).

Each subject’s sLORETA estimates were then normalized (z-score) and log-transformed. Normalizing was done to reduce the effects of individual differences in overall alpha power due to artifacts relating to particular recording conditions. The log-transformation was done because the distribution of the sLORETA results is strongly positively skewed, which can reduce the sensitivity of the individual differences analyses to find meaningful correlations within regions that play a relatively small (but nonetheless important) role in accounting for the scalp electrical activity.

Recent research suggests that the alpha band may be divided into two functionally specific bands, alpha 1 (8.5-10 Hz) and alpha 2 (10.5-12 Hz) (REF). Therefore,
I created two different sLORETA variables for each subject. One averaged the discrete frequency bands from the sLORETA that fell within the alpha1 range, and the other for alpha 2.

**Attachment Style Questionnaire**

Each participant completed the ASQ (attached, Appendix A). The ASQ was designed to assess respondents’ tendencies to engage in behaviors that are characteristic of particular attachment styles (Feeney et al., 1994). The ASQ includes 40 items that comprise 5 separate scales: 1) discomfort with closeness, 2) need for approval, 3) preoccupation with relations, 4) viewing relationships as secondary to achievement, and 5) confidence. The first four scales discriminate different varieties of insecure attachment. The discomfort with closeness and viewing relationships as secondary to achievement scales are thought to index behaviors that are typically associated with avoidant attachment. Need for approval and preoccupation with relations assess behaviors that are typically associated with preoccupied or anxious attachment. The confidence factor captures behaviors that are associated with secure attachment (Karantzas et al., 2010; Brennan et al., 1998).

Although it is possible to design classification criteria based upon these scales, the original authors of the questionnaire advise against doing so in favor of keeping a behaviorally based dimensional assessment. Thus, I will be focusing my analyses on the scales on the questionnaire rather than attempt to group individuals into attachment classifications on the basis of their responses.
The ASQ is considered a reliable and valid measure of the following dimensions of attachment: discomfort with closeness, need for approval, preoccupation with relations, viewing relationships as secondary to achievement, and confidence (Ravitz et al., 2010). Psychometric studies have confirmed that the factor structure of the ASQ captures key elements of attachment style (Karantzas et al., 2010).

Each item is rated on a 6-point scale. Discomfort with closeness is measured by questions 4, 5, 16, 17, 20, 21, 23, 25, 26 and 34; need for approval by questions 11, 12, 13, 15, 24, 27 and 35; preoccupation with relations by questions 18, 22, 28, 29, 30, 32, 39 and 40; viewing relationships as secondary by questions 6, 7, 8, 9, 10, 14 and 36; and confidence by questions 1, 2, 3, 19, 31, 33, 37 and 38. The total scores are the sum of the respective item values, reversed when necessary, with higher scores on discomfort with closeness, need for approval, preoccupation with relations, and viewing relationships as secondary to achievement indicating more insecure attachment, higher scores on confidence indicating more secure attachment, and scores on particular dimensions indicating whether insecure attachments are more avoidant or anxious.

Parenting Memories Measure

Each participant completed the short form EMBU Questionnaire (attached, Appendix B, under heading “My Memories of Upbringing,” which is a translation of the Swedish words for which EMBU is an acronym). The short form of the EMBU measures rejection, emotional warmth and over-protection on the part of the father and of the mother. There are 7 questions relating to rejection, 6 to emotional warmth and 9 to protection (plus one unscaled item). Separate ratings are given for each parent. Each
item is rated on a 1-4 point Likert-type scale. The total scores are the sum of the respective item values, reversed when necessary, with higher scores indicating more problematic practices. The short form EMBU is the recommended questionnaire for measuring parental memories, based on repeated studies on its factorial validity, internal reliability and correlations among scales (Arrindell et al., 1999; Arrindell et al., 2001).
CHAPTER 3: RESULTS

My main research questions centered on the connection between source-localized baseline EEG activity and participants responses on the ASQ and EMBU questionnaires that assessed adult attachment behaviors and memories of their parents’ parenting styles, respectively. In particular, I predicted that baseline activity within the left prefrontal regions would be associated with the confidence scale from the ASQ, as this scale is associated with secure attachment behaviours. More open questions concerned the extent to which baseline EEG activity was connected with other aspects of the ASQ or the EMBU. Finally, I explored whether there were meaningful associations between the ASQ and the EMBU.

Neural Activity, Attachment Style and Parenting Memories

For all focal analyses, I performed whole-brain correlation analyses in which the sLORETA data (for both alpha 1 and 2) were correlated voxel-by-voxel with the responses from the questionnaire. Because there are obviously a large number of tests, results were judged to be significant when voxel-wise tests were associated with p<.01, and voxels reaching that criterion were found within a spatially-contiguous cluster of at least 20 other voxels showing the same effects. This criterion was developed using monte-carlo simulations of similar data, and found to be associated with an acceptable family-wise error rate (.05).
Using these criteria, I found no significant correlations between alpha 2 current density and any of the ASQ or EMBU factors. The analysis discussed below relates to alpha 1 only.

Several results were apparent using the above criterion for alpha 1. Most relevant to the main hypotheses of the study, I found a negative association between participants’ responses on the confidence scale of the ASQ and sLORETA estimates of alpha 1 attributable to the left dorsolateral prefrontal cortex (DLPFC) (109 voxels) and the right middle temporal gyrus (60 voxels) (see Figure 1). Alpha power is an inverse measure of neural activity. Because higher alpha current density reflects lower cerebral activity, my results suggest that higher baseline activity in these regions is associated with confidence (Coan & Allen, 2004; Pizzagalli et al., 2005).
Figure 1: Negative Correlations between Alpha 1 Current Density and Confidence

a) Left Dorsolateral Prefrontal Cortex (DLPFC) (109 voxels)

Figure 1 a). Statistical map and scatterplot of correlations measuring the relation between confidence and sLORETA estimates of current density at left DLPFC. Only significant voxels (p < .01) are shown (in yellow). Voxels in all figures are shown projected onto a template structural MRI to illustrate their neuroanatomical locations. Note: sLORETA = standardized low-resolution electromagnetic tomography; DPFC = dorsal medial prefrontal cortex; MRI = magnetic resonance imaging.
b) Right Middle Temporal Gyrus (60 Voxels)

Figure 1 b). Statistical map and scatterplot of correlations measuring the relation between confidence and sLORETA estimates of current density at right MTG. Only significant voxels (p < .01) are shown (in yellow). Voxels in all figures are shown projected onto a template structural MRI to illustrate their neuroanatomical locations. Note: sLORETA = standardized low-resolution electromagnetic tomography; MTG = middle temporal gyrus; MRI = magnetic resonance imaging.

Although my focal hypotheses were with respect to negative correlations with confidence, I did also find a significant positive correlation between alpha 1 current density and confidence. The one identified cluster contained 40 voxels and was localized in the left middle temporal gyrus/uncus, as shown Figure 2. Because higher
alpha current density reflects lower cerebral activity, my findings suggest that lower baseline cerebral activity in the left uncus is associated with confidence.

**Figure 2: Positive Correlation between Alpha 1 Current Density and Confidence**
Left Middle Temporal Gyrus/Uncus (40 Voxels)

*Figure 2.* Statistical map and scatterplot of correlations measuring the relation between confidence and sLORETA estimates of current density at right MTG. Only significant voxels (p < .01) are shown (in yellow). Voxels in all figures are shown projected onto a template structural MRI to illustrate their neuroanatomical locations. Note: sLORETA = standardized low-resolution electromagnetic tomography; MTG = middle temporal gyrus; MRI = magnetic resonance imaging.
In summary, my findings indicate that confidence is associated with higher baseline cerebral activity in the left DLPFC and the right middle temporal gyrus and lower baseline cerebral activity in the left middle temporal gyrus.

Additional analyses: ASQ

Although not specifically hypothesized in the present context, I explored the extent to which other scales on the ASQ might be associated with baseline EEG activity. Using the same analytic strategy as above, I found that participants’ responses on the discomfort with closeness scale, which is associated with avoidant attachment style, showed a positive correlation with alpha 1 activity in the right posterior superior temporal gyrus (see Figure 3). Though an exploratory analysis, this finding suggests low baseline activity in this region may be associated with feelings of discomfort with relationship intimacy.
Figure 3: Positive Correlation between Alpha 1 Current Density and Discomfort with Closeness

Right Posterior Superior Temporal Gyrus (30 Voxels)

Figure 3. Statistical map and scatterplot of correlations measuring the relation between discomfort with closeness and sLORETA estimates of current density at right pSTG. Only significant voxels (p < .01) are shown (in yellow). Voxels in all figures are shown projected onto a template structural MRI to illustrate their neuroanatomical locations. Note: sLORETA = standardized low-resolution electromagnetic tomography; pSTG = posterior superior temporal gyrus; MRI = magnetic resonance imaging.
Additional analyses: EMBU

Final exploratory analyses were conducted to examine the relation between alpha 1 and responses on the EMBU. Here, I found one notable association – a cluster within the right middle prefrontal cortex/anterior cingulate cortex was associated with mother emotional warmth (see Figure 4). Again, because higher alpha current density reflects lower cerebral activity, my results suggest that higher baseline cerebral activity in this region is associated with mother emotional warmth.
Figure 4: Negative Correlation between Alpha 1 Current Density and Mother Emotional Warmth

Right Middle Prefrontal Cortex/Anterior Cingulate Cortex (82 voxels)

Figure 4. Statistical map and scatterplot of correlations measuring the relation between mother emotional warmth and sLORETA estimates of current density at right MPFC/ACC. Only significant voxels (p < .01) are shown (in yellow). Voxels in all figures are shown projected onto a template structural MRI to illustrate their neuroanatomical locations. Note: sLORETA = standardized low-resolution electromagnetic tomography; MPFC/ACC = middle prefrontal cortex/anterior cingulate cortex; MRI = magnetic resonance imaging.
Summary of the EEG findings

The main prediction that participants’ scores on the confidence scale of the ASQ would be associated with increased baseline EEG activity in the left DLPFC was confirmed. In addition, I found that discomfort with closeness, which indexes behaviors associated with avoidant attachment was associated with decreased activity in the right posterior MTG. Finally, participants responses on the maternal warmth scale of the EMBU was associated with increased activity in the right VMPFC. A summary of these correlations and their characteristics is presented in Table 2.

Table 2: Summary of Correlations between ASQ and EMBU Factors and Baseline Cerebral Activity

<table>
<thead>
<tr>
<th>Questionnaire Factor</th>
<th>+/- activity</th>
<th>Region (BA)</th>
<th>cluster centroid (x,y,z)</th>
<th>cluster size (voxels)</th>
<th>max./mean r</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASQ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confidence</td>
<td>+</td>
<td>Left DLPFC (6, 9)</td>
<td>-40, 5, 45</td>
<td>109</td>
<td>-.368/- .329</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>Right MTG (21, 22)</td>
<td>60, -45, -5</td>
<td>60</td>
<td>-.366/- .339</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Left STG/Uncus (34, 35, 36, 38)</td>
<td>-25, -1, -30</td>
<td>40</td>
<td>.354/.331</td>
</tr>
<tr>
<td>Discomfort with closeness</td>
<td>-</td>
<td>Right pSTG (19, 22, 39)</td>
<td>45, -60, 20</td>
<td>30</td>
<td>.384/.352</td>
</tr>
<tr>
<td>EMBU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother emotional warmth</td>
<td>+</td>
<td>Right MPFC/ACC (10, 11, 24, 25, 32)</td>
<td>5, 40, -10</td>
<td>82</td>
<td>-.407/.360</td>
</tr>
</tbody>
</table>

Note: BA = Brodmann’s area; r = correlation coefficient; DLPFC = dorsolateral prefrontal cortex; MTG = middle temporal gyrus; pSTG = posterior superior temporal gyrus; MPFC = middle prefrontal cortex; ACC = anterior cingulate cortex
Attachment Style and Parenting Memories

As shown in Table 3, I found a significant negative association between rejection by the mother and by the father and confidence. Conversely, I found a significant positive association between emotional warmth of the mother and of the father and confidence. As well, Table 3 shows a significant positive association between rejection by the mother and by the father and insecure attachment. And there is a significant negative association between emotional warmth of the mother and of the father and insecure attachment.

As is evident in Table 3, emotional warmth of the father is the EMBU factor most correlated with ASQ factors. The largest effect sizes and most significant correlations were between father emotional warmth on one hand and insecurity and confidence on the other. Over-protection by neither the mother nor the father was significantly associated with any ASQ factor. “Relationships as secondary” was not significantly associated with any EMBU factor.
Table 3: Correlations between ASQ scores and EMBU Scores (Pearson’s r, n = 79)

<table>
<thead>
<tr>
<th>EMBU:</th>
<th>MR</th>
<th>MOP</th>
<th>MEW</th>
<th>FR</th>
<th>FOP</th>
<th>FEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASQ:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>0.31 **</td>
<td>0.03</td>
<td>-0.33 **</td>
<td>0.25 *</td>
<td>0.19</td>
<td>-0.32 **</td>
</tr>
<tr>
<td>NA</td>
<td>0.08</td>
<td>0.14</td>
<td>-0.13</td>
<td>0.10</td>
<td>0.16</td>
<td>-0.24 *</td>
</tr>
<tr>
<td>PR</td>
<td>0.07</td>
<td>0.08</td>
<td>-0.19</td>
<td>0.25 *</td>
<td>0.03</td>
<td>-0.35 **</td>
</tr>
<tr>
<td>RS</td>
<td>0.21</td>
<td>0.09</td>
<td>-0.16</td>
<td>0.07</td>
<td>0.11</td>
<td>-0.19</td>
</tr>
<tr>
<td>AV</td>
<td>0.31 **</td>
<td>0.06</td>
<td>-0.30 **</td>
<td>0.20</td>
<td>0.18</td>
<td>-0.30 **</td>
</tr>
<tr>
<td>AX</td>
<td>0.09</td>
<td>0.14</td>
<td>-0.19</td>
<td>0.20</td>
<td>0.12</td>
<td>-0.35 **</td>
</tr>
<tr>
<td>INS</td>
<td>0.24 *</td>
<td>0.12</td>
<td>-0.30 **</td>
<td>0.25 *</td>
<td>0.18</td>
<td>-0.40 ***</td>
</tr>
<tr>
<td>CF</td>
<td>-0.30 **</td>
<td>-0.14</td>
<td>0.30 **</td>
<td>-0.29 **</td>
<td>-0.22</td>
<td>0.38 ***</td>
</tr>
</tbody>
</table>

* = p < 0.05; ** = p < 0.01; *** = p< 0.001

Note: ASQ = Adult Attachment Questionnaire; DC = Discomfort with Closeness; NA = Need for Approval; PR = Preoccupation with Relationships; RS = Relationships as Secondary; AV = Avoidant (DC + RS); AX = Anxious (NA + PR); INS = Insecure (DC + NA + PR + RS); CF = Confidence (Secure); EMBU = My Memories of Upbringing Questionnaire; MR = Mother Rejection; MOP = Mother Over-protection; MEW = Mother Emotional Warmth; FR = Father Rejection; FOP = Father Over-protection; FEW = Father Emotional Warmth
CHAPTER 4: DISCUSSION

The main goal of this study was to provide an initial investigation of whether adults with a secure attachment style and positive parenting memories would have left-lateralized baseline neural activity in the DLPFC. My results show that left-lateralized baseline neural activity in the DLPFC is correlated with confidence, the ASQ dimension that tracks secure attachment. Previous research has shown that left-lateralized baseline neural activity in the DLPFC is correlated with approach motivation. Therefore, my findings suggest that one aspect of secure attachment is a trait-like bias to approach rather than withdraw.

The secondary goal of this study was to look at whether attachment style would be related to memories of parenting. As expected based on previous research, I found significant negative associations between parental rejection and confidence, and significant positive associations between parental emotional warmth and confidence. In the next sections I will discuss the findings of the present study in light of previous research and consider future directions for research.

Neural Activity, Attachment Style and Parenting Memories

My hypothesis that confidence scores on the ASQ would be positively correlated with left-lateralized baseline cerebral activity in the DLPFC was supported by my findings. Because left-lateralized cerebral activity in the DLPFC is associated with approach motivation, my finding suggests that confident (securely attached) adults have a trait-like propensity to engage in approach behaviour (Dawson et al., 2001; Pizzagalli et al., 2005; Coan, 2008).
Although many psychological researchers have assumed that approach motivation must be triggered by stimuli, Harmon-Jones et al. (2013) have shown that approach motivation may result from internal processes at the trait level. The link between confidence and approach motivation is consistent with robust behavioural research showing that secure infants in the presence of their attachment figure (and therefore not experiencing any social threat or other attachment-related stimuli) freely approach and explore a new environment, whereas insecure infants do not (Ainsworth et al., 1978; Gunnar et al., 1996).

Baseline differences in neural activity among those with different attachment styles, such as those identified in the present study, suggest trait-like differences that exist in the absence of any stimulus leading to the generation or evaluation of alternative plans of action. Such baseline differences have been shown in infants (Dawson et al., 2001), and the present study shows the same baseline differences in adults. Thus my study may provide evidence of developmental continuity in the baseline neural correlates of attachment styles from infancy through adulthood.

It is not clear, however, when or how the lateralized baseline differences in neural activity in the DLPFC develop. An additional question is whether these baseline differences developed in infancy persist into adulthood, despite the massive reorganization of the PFC as the brain matures (Lewis, 2005). Dawson et al. (2001) correlated baseline neural activity in the left DLPFC with attachment security in 13-15 month old infants. The present study made the same finding in relation to 18-25 year old adults. Longitudinal studies are needed to determine whether baseline differences
in DLPFC neural activity developed in infancy do persist into adulthood.

The present study also identified correlations between confidence and higher baseline neural activity in the right middle temporal gyrus and lower baseline neural activity in the left middle temporal gyrus/uncus. Growing research implicates this region in emotion processing (Pohl et al., 2013) and in attachment behaviours (Atzil et al., 2012). As research on this region of the brain develops, the correlation between neural activity in this area and confidence, or attachment security, should be further explored.

Because of the extensive research implicating early parenting experiences with attachment style, I decided to investigate correlations between memories of parenting and baseline neural activity. Sensitive and emotionally responsive parenting is associated with secure attachment style and, in infants, a tendency to freely explore new environments while the attachment figure is present. Therefore, I hypothesized that positive memories of parenting would be correlated with left-lateralized neural activity in the DLPFC signaling approach motivation. I did not find any such correlation.

I did find a fairly prominent correlation (82 voxels) between mother emotional warmth and neural activity in the right middle prefrontal cortex/anterior cingulate cortex. This area of the brain has been implicated in reward monitoring (Kringelbach & Rolls, 2004). Pizzagalli et al., (2005) found that higher baseline cerebral activity in this region may increase readiness to develop approach tendencies. Thus, my findings do suggest a correlation between memories of mother emotional warmth, a key factor in the development of secure attachment, and approach motivation.
Attachment Style and Parenting Memories

I found significant negative associations between memories of parental rejection and confidence, and highly significant positive associations between memories parental emotional warmth and confidence. Because attachment style is formed in the context of interactions with early caregivers, these results were not surprising. My findings largely confirm previous research.

Gittelman et al. (1998) looked at the correlation between attachment style and parenting memories among married adults. They found that men and women with a secure attachment style recalled higher levels of maternal care than did those with an anxious/avoidant attachment style; and men with a secure attachment style recalled higher levels of paternal care than did men with an anxious/avoidant attachment style. Gittelman et al. used the Parental Bonding Instrument (PBI) to measure parenting memories. Problems with the psychometric properties of the PBI were subsequently identified (Sato et al., 1999; Arrindell & Perris (1999), and later studies did not use this instrument.

Perris & Andersson (2000) used the EMBU to measure the parenting memories and three different attachment questionnaires (the ASQ, the Adult Attachment Scale and the Reciprocal Attachment Questionnaire) to measure the attachment style of 361 participants with a mean age of 24.2. They found a significant positive correlation between memories of parental emotional warmth and indicators of secure attachment, and a significant negative correlation between memories of dysfunctional parenting and measures of insecure attachment.
Hinnen et al. (2008) also used the EMBU to measure the parenting memories and the Experience of Close Relationships questionnaire to measure the attachment style of 437 participants who had an average age of 37. They found that those who reported more parental rejection, less parental support, less family warmth and harmony and more adverse events in childhood were more insecurely attached.

In addition to largely confirming the general conclusions of previous research, the present study provides evidence of sex differences not previously reported. I found that the largest effect sizes and most significant correlations were between memories of father emotional warmth on one hand and insecurity and confidence on the other. Because much attachment research focuses on the importance of mothers as the usual primary attachment figure, I was surprised by this result. It may result from increasing involvement of fathers in parenting. Or it may suggest an important role of fathers in attachment security that has been under-examined. Additional research on this issue is warranted.

A weakness in this part of the study is the reliance on self-report measures of attachment and parenting memories. In future studies, screening for depression or anxiety on the part of participants would address the possibility of those factors affecting questionnaire responses.

Future Directions

We are at an early stage of understanding the various neural systems underlying the human attachment behavioural system. Additional research in this area will contribute to the effort to address the negative consequences of insecure attachment.
In relation to the specific neural system that was the focus of this study, additional research is needed to determine when and how lateralized baseline differences in neural activity in the PFC correlated with attachment style develop. And determining whether baseline differences in PFC neural activity developed in infancy do persist into adulthood will contribute to the understanding of how attachment style developed in infancy persists over time.

To strengthen my conclusion that left-lateralized neural activity in the DLPFC is correlated with attachment confidence (security) in adults, future research could replicate this study with a larger sample size and use different attachment measures. My findings on the correlations between parenting memories and attachment style suggest that additional research is needed on the role of fathers in attachment security.

**Conclusions**

My findings show for the first time in adults that left-lateralized baseline neural activity in the DLPFC is correlated with confidence, a factor that underpins attachment security. This same neural signature has been associated with approach motivation. Therefore one aspect of secure attachment may be a trait-like bias to approach rather than to withdraw. Left-lateralized baseline neural activity in the DLPFC has also been correlated with attachment security in infants. This may be one of the mechanisms by which attachment styles developed in infancy persist into adulthood. Additional research on when and how these neural patterns develop in infancy and their stability or variability over time is needed.
I also found significant negative associations between memories of parental rejection and confidence, and significant positive associations between memories of parental emotional warmth and confidence. These findings confirm the importance of parenting to attachment security. My findings also offer suggestive new evidence on the importance of fathers to attachment security.
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Appendix A: Attachment Style Questionnaire

Show how much you agree with each of the following items by rating them on this scale: 1=totally disagree; 2=strongly disagree; 3=slightly disagree; 4=slightly agree; 5=strongly agree; 6=totally agree.

1. Overall, I am a worthwhile person. _____
2. I am easier to get to know than most people. _____
3. I feel confident that other people will be there for me when I need them. _____
4. I prefer to depend on myself rather than on other people. _____
5. I prefer to keep to myself. _____
6. To ask for help is to admit you’re a failure. _____
7. People’s worth should be judged by what they achieve. _____
8. Achieving things is more important than building relationships. _____
9. Doing your best is more important than getting on with others. _____
10. If you’ve got a job to do, you should do it no matter who gets hurt. _____
11. It’s important to me that others like me. _____
12. It’s important to me to avoid doing things that others won’t like. _____
13. I find it hard to make a decision unless I know what other people think. _____
14. My relationships with others are generally superficial. _____
15. Sometimes I think I am no good at all. _____
16. I find it hard to trust other people. _____
17. I find it difficult to depend on others. _____
18. I find that others are reluctant to get as close as I would like. _____
19. I find it relatively easy to get close to other people. _____
20. I find it easy to trust others. 
21. I feel comfortable depending on other people. 
22. I worry that others won’t care about me as much as I care about them. 
23. I worry about people getting too close. 
24. I worry that I won’t measure up to other people. 
25. I have mixed feelings about being close to others. 
26. While I want to get close to others, I feel uneasy about it. 
27. I wonder why people would want to be involved with me. 
28. It’s important to me to have a close relationship. 
29. I worry a lot about my relationships. 
30. I wonder how I would cope without someone to love me. 
31. I feel confident about relating to others. 
32. I often feel left out or alone. 
33. I often worry that I do not really fit in with other people. 
34. Other people have their own problems so I don’t bother them with mine. 
35. When I talk over my problems with others, I generally feel ashamed or foolish. 
36. I am too busy with other activities to put much time into relationships. 
37. If something is bothering me, others are generally aware and concerned. 
38. I am confident that other people will like and respect me. 
39. I get frustrated when others are not available when I need them. 
40. Other people often disappoint me.
Appendix B: My Memories of Upbringing

Below are questions concerning your childhood. Please read through the following instructions carefully before answering the questionnaire.

Even if it is difficult to recall exactly how our parents behaved towards us when we were young, each of us does have certain memories of what principles they used in our upbringing. When filling out this questionnaire it is essential that you try to remember your parents’ behavior towards you as you experienced it. For each questions circle the alternative applicable to your own parents’ behavior toward you.

Be careful not to leave any questions unanswered. We are aware that certain questions are impossible to answer if you do not have any sisters or brothers or if you have been raised by one parent only. In this case leave these questions unanswered.

Read through each question carefully and consider which one of the possible answers applies to you. Answer separately for your mother and your father. In the questionnaire F is father and M is mother.

<table>
<thead>
<tr>
<th>Question</th>
<th>F</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It happened that my parents were sour or angry with me without letting me know the cause.</td>
<td>No, never</td>
<td>Yes, but seldom</td>
</tr>
<tr>
<td>2. My parents praised me.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. It happened that I wished my parents would worry less about what I was doing.</td>
<td></td>
<td></td>
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<tr>
<td>4. It happened that my parents gave me more corporal punishment than I deserved.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. When I came home I then had to account for what I had been doing to my parents.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I think that my parents tried to make my adolescence stimulating, interesting and instructive (e.g., by</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>---</td>
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<td>---</td>
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<tr>
<td>arranging activities or giving me good books.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. My parents criticized me and told me how lazy and useless I was in front of others.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>8. It happened that my parents forbade me to do things other children were allowed to do because they were afraid something would happen to me.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>9. My parents tried to spur me to become the best.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>10. My parents would look sad or in some other show that I had behaved badly so that I got real feelings of guilt.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>11. I think that my parents' anxiety that something might happen to me was exaggerated.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>12. If things went badly for me, I then felt that my parents tried to comfort and encourage me.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>13. I was treated as the “black sheep” or the “scapegoat” of the family.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>14. My parents showed with words and gestures that they liked me.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>15. I felt that my parents liked my brother(s) and/or sister(s) more than they</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>Liked me.</td>
<td>F</td>
<td>1</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>---</td>
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</tr>
<tr>
<td>16. My parents treated me in such a way that I felt ashamed.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>17. I was allowed to go where I liked without my parents caring too much.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>18. I felt that my parents interfered with everything I did.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>19. I felt that warmth and tenderness existed between me and my parents.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>20. My parents put limits on what I was and was not allowed to do, and they rigorously stuck to those limits.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>21. My parents would punish me hard, even for small offences.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>22. My parents wanted to decide how I should be dressed or how I should look.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>23. I felt that my parents were proud when I succeeded in something that I had undertaken.</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

In the questionnaire F is father and M is mother.
APPENDIX C: RESEARCH ETHICS BOARD APPROVAL

March 26, 2013

Dr. Martha Bailey
Master’s Student
Faculty of Law
Queen’s University
Kingston, Ontario  K7L 3N6

GREB Ref #: GPSYC-598-13; Romeo # 6007740
Title: “GPSYC-598-13 The Neurobiology of Adult Attachment”

Dear Dr. Bailey:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GPSYC-598-13 The Neurobiology of Adult Attachment" for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen’s ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this one year period (access this form at [https://eservices.queensu.ca/romeo_researcher/] and click Events - GREB Adverse Event Report). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To make an amendment, access the application at [https://eservices.queensu.ca/romeo_researcher/] and click Events - GREB Amendment to Approved Study Form. These changes will automatically be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or irvingg@queensu.ca for further review and clearance by the GREB or GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

John Freeman, Ph.D.
Professor and Acting Chair
General Research Ethics Board

cc: Dr. Mark Sabbagh, Faculty Supervisor
    Dr. Rod Lindsay, Chair, Unit REB
    Marie Tooley, Dept. Admin.
September 20, 2013

Dr. Martha Bailey  
Master's Student  
Department of Psychology  
Queen's University  
Kingston, ON K7L 3N6

Dear Dr. Bailey:

RE: Amendment for your study entitled: GPSYC-598-13 The Neurobiology of Adult Attachment; ROMEO# 607740

Thank you for submitting your amendment requesting the following changes:

1) To increase recruitment from 40 to 80 participants; and

2) To use the Psychology Subject Pool to recruit new participants.

By this letter you have ethics clearance for these changes.

Good luck with your research.

Sincerely,

Joan Stevenson, Ph.D.  
Chair  
General Research Ethics Board

c.: Dr. Mark Sabbagh, Faculty Supervisor
APPENDIX E: RESEARCH ETHICS BOARD APPROVAL FOR RENEWAL

March 19, 2014

Dr. Martha Bailey  
Master's Student  
Department of Psychology  
Queen's University  
Kingston, ON, K7L 3N6

GREB Ref#: 6807740  
Title: "GPSYC-598-13 The Neurobiology of Adult Attachment"

Dear Dr. Bailey:

The General Research Ethics Board (GREB) has reviewed and approved your request for renewal of ethics clearance for the above-named study. This renewal is valid for one year from March 16, 2014. Prior to the next renewal date you will be sent a reminder memo and the link to ROMEO to renew for another year.

You are reminded of your obligation to advise the GREB of any adverse event(s) that occur during this one year period. An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours. Report to GREB through either ROMEO Event Report or Adverse Event Report Form at [link]

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes in study procedures or implementation of new aspects into the study procedures. Your request for protocol changes will be forwarded to the appropriate GREB reviewers and/or the GREB Chair. Please report changes to GREB through either ROMEO Event Reports or the Ethics Change Form at [link]

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

[Signature]

Joan Stevenson, Ph.D.  
Chair  
General Research Ethics Board

c.: Dr. Mark Sabbagh, Faculty Supervisor  
  Dr. Stanka Filanova, Chair, Unit REB  
  Ms. Marie Tooley, Dept. Admin.