ATTACHMENT STYLE AS A PREDICTOR OF POSITIVE EVENT-RELATED BRAIN POTENTIALS IN A SOCIAL-STIMULATION TASK

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Senior Paper in Completion of the Psychology Major
Haverford College
Final Draft: May 2009

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Abstract

Psychology has attempted over the past decades to consider the ways that humans construct their interpersonal relationships. One of the dominant methods of doing so is by investigating the attachment style of individuals. The current research considers the way that individual differences in attachment style might affect attentional allotment in social situations, as measured by electroencephalographic (EEG) methods and the Late Positive Potential wave (LPP). We hypothesized that highly attachment-anxious and highly attachment-avoidance subjects would demonstrate decreased LPP peaks in response to negative target images when those images were in a sequence of ambiguous images, due to a violation of expectancy. Using a computer-based image-presentation task, 40 subjects responded to both sequences of three images and images presented solo. The Experiences in Close Relationships and Adult Attachment Questionnaire were used to assess attachment style on the continua of Anxiety and Avoidance. Data were subjected to a repeated-measures ANOVA, with factors of image type (negative, positive, random, and neutral), context (in-sequence or solo), and site (Fz, Cz, and Pz). Analyses demonstrated no major distinction by attachment style, and no effect of expectancy violation. Rather, subjects seemed to respond to emotionality of images. Future research may attempt to differentiate further between expectancy and emotionality, and differentiate individuals based on attachment style.
Introduction

Overview

Current psychological thinking conceptualizes the functioning of individuals in the context of their relationships. We understand our separate cognitive processes to create a reality based in part on interpersonal context, where the concept of attachment is understood to form the basis of cognitive and affective regulation, which allows us to function in the world (Shore, 2003). Attachment style, the mode by which we approach relationships, shapes our ways of thinking about the world, and particularly influences our romantic relationships. Moreover, a number of theorists have suggested that early interactions between caregivers and infants may influence, in terms of attachment, the neural connections of the system, shaping the affective functioning of individuals and the way that each person pays attention to the world around them (e.g., Shore, 2003). The integration of nerve connections that takes place during childhood, that is to say, is partially driven by the formation of attachment bonds with caregivers (Beebe & Lachman, 2002). By focusing on how individuals distribute their attention, by investigating such a system of cognition and affect, we can look at attachment from a neurological point of view. Through this method, cognitive systems involved in attachment can be mapped to specific brain areas (Shore, 2003), and shown to work differently among different groups of people with different attachment styles.

And indeed, research has considered the ways that attachment style affects attentional processes. Past cognitive neuroscience research has focused on the way those with different attachment styles process basic emotion-inducing pictures (e.g., Zilber, Goldstein, & Mikulincer, 2007; Langeslag, Jansma, Franken, & Strien, 2007). Yet there has been almost no research investigating the ways in which attachment style influences the neural basis of complex social
processing, or the manifestation of attachment in attentional correlates. Thus, the current research aims to delve, through neurological means, into the differences in cognitive processing of social situations, into the way affect and attachment shape attention, explicitly in young adults. Specific brain regions are activated by exclusion (Eisenberger, Lieberman, & Williams, 2003) and failure (Cavanagh & Allen, 2007); the key to discovering how attachment activates the brain is to find tasks that can activate the processes involving attachment. Thus this study hypothesizes that the templates that shape how we see the world can come to light, in young adults, based on the situations to which they most closely attend. Furthermore, these processes, it is here argued, may demonstrate the effects of emotion regulation, based on distraction and distancing of individual subjects. Thus we postulate that attention and its neuropsychological correlates can help us understand a means by which attachment style shows its effects.

Attachment Style as a Predictor of Cognitive Models

In the 1970s, Bowlby hypothesized a model of attachment which became the field of attachment theory. His work, continued by Ainsworth and others (Ainsworth, Blehar, Waters, & Wall, 1978), suggested that infants form emotional attachments to their primary caregivers. These attachments shape their future experiences. Ainsworth et al.’s theory has since been established as a means by which one can understand adult romantic relationships (Hazan & Shaver, 1987), propelling attachment theory into greater applications than those that were originally imagined. Early attachment theory hinged on the actions of an infant when separate from its primary caregiver.

In this early theory, the original Strange Situation scenario developed by Ainsworth (Ainsworth et al. 1978), researchers placed infants with their mothers in a lab room and observed
the infants' interaction with their environments. A stranger entered the room, the mother left for a few minutes, and then returned; then the stranger left and the mother attempted to interest her child again in the toys. After this, the mother again left, leaving the child alone; the stranger the returned, and then the mother. This complex procedure was used to elicit attachment-related behaviors from the infants; based on their interactions with their environments, toys in the room, and the involved adults, researchers were able to classify specific behaviors of the infants as signifying a particular attachment style (Ainsworth et al., 1978). Secure infants, Ainsworth et al. suggested, had a more harmonious interaction with the mother, with a positive affect towards her, crying less and using their mothers as a base from which to explore strange environments. Conversely, anxious infants cried more often but had nonresponsive mothers, and manifested more separation anxiety; they were more distressed by the stranger and did not use the mother as a secure base, exploring less. Avoidant infants, finally, showed little desire to rejoin their mothers when they returned; Ainsworth et al. suggested that this might result from a desire to avoid the rebuttals of their mothers. These three categories formed an initial assessment of attachment, which has since been expanded considerably.

This research in infant attachment has been translated to adult behavior. When we speak of adult attachment, we focus on anxiety and avoidance in relation to our romantic partners. Hazan and Shaver (1987) were the first to view romantic love, and romantic relationships, as sub-categories of attachment; their study demonstrated that a questionnaire could allow adult subjects to be grouped into one of the three attachment styles: secure, avoidant, and anxious/ambivalent. They expected to find varying frequencies of these attachment styles in a representative sample of the population, and to find that securely attached individuals characterized love differently than those who were insecurely attached. They were also interested
in how avoidant and anxious styles affected individual behavior. The researchers used a newspaper survey that reworked infant attachment into terms that could apply to adults, asking respondents to look at their most important romantic relationship, and then to self-categorize as secure, anxious, or avoidant. The categorization was based on a description in which secure style began with “I find it relatively easy to get close to others,” anxious/ambivalent style began with “I find that others are reluctant to get as close as I would like,” and avoidant style began with “I am somewhat uncomfortable being close to others” (Hazan & Shaver, 1987). The researchers found that 56% of their respondents were secure, 25% avoidant, and 19% anxious—roughly what the researchers expected. Attachment styles, that is to say, vary across the population, but all are present in a significant amount.

To validate their results, Hazan and Shaver (1987) conducted a second study with undergraduates, and found results that validated their conclusions. In this second study, the researchers gave subjects in an undergraduate psychology course a questionnaire that asked questions about their most important love relationship, and also classified themselves much as the respondents to the newspaper survey had. They also answered questions about loneliness and interpersonal interactions, allowing the researchers to understand the way that attachment style might affect these aspects of life. Secure respondents characterized their love experiences differently from those who were insecure (anxious or avoidant). Whereas securely attached individuals had happy and positive experiences, avoidant subjects reported an increased fear of closeness, and anxious respondents described jealousy of others and a perceived lack of reciprocation from their romantic partners (Hazan & Shaver, 1987). There was a clear distinction in cognitive models as compared to attachment style. In the same sense, participants in each group characterized their cognitions relating to relationships differently; secure subjects
described themselves as generally liking others and easy to get to know, whereas anxious subjects had more self-doubts, and avoidant subjects found it rare to find other people whom they liked (Hazan & Shaver, 1987). In all, the researchers suggested that social interaction was based on specific mental models (e.g., Baldwin, 1992), which are revised when major changes occur—these models are how individuals understand their relationships, and how they understand the relationships of others. Hazan and Shaver used the language of cognitive psychology to describe attachment processes, suggesting that infants and hence adults create internal working models of their relationships with their caregivers or romantic partners.

Before we continue, it seems useful to gain a better understanding of how an internal working model (IWM) works. Baldwin (1992) explained the idea of internal working model as the internalization of personal relationship experience. He contrasted the relational schema and the self-schema—the one formed of a concept of the relationship between self and others, while the other represents a cognitive representation of the self alone. Baldwin hypothesized that individuals develop working models of their relationships that function to help them navigate the world, essentially scripts with expected (inter)action patterns. Individuals have more ease processing information that fits with their schemas, be they relational or self-based. Baldwin suggested that individuals process situations based on their expectations of each situation—a prototype—and react based on that expectation. This situation-processing working model, he said, is also applied to relationships; he discussed the incorporation of relationships into the working model, which is addressed in both cognitive psychology and the more psychodynamic object relations psychology. The IWM, then, can govern basic social interactions as well as romantic relationships.
Several years after Hazan and Shaver’s (1987) studies, Bartholomew and Horowitz (1991) suggested a more comprehensive manner of discussing attachment. Their model relies on Bowlby’s initial suggestion that attachment behavior was based on a working model of self, and a working model of others; the implication is that attachment is formed through the ways that one understands oneself and one’s partners. Bartholomew and Horowitz conceptualized four categories of attachment, using these two dimensions, one along a continuum of emotional dependence and the other along a continuum of avoidance. Thus on the dependence range, low dependence on others is characterized by positive feelings about self, while high dependence by negative feelings about the self; dependence is seen to relate to questions of self-confidence. On the avoidance range, low avoidance is characterized by positive feelings about others, while high avoidance by negative feelings about others. Securely attached individuals, by this model, are low on both continua, while “fearful” or anxious-avoidant individuals are high on both. Secure individuals, that is to say, have positive views of others and of themselves in relationships, while “fearful” individuals have negative views, viewing themselves as “unworthy” and “unlovable,” and others as “untrustworthy” and “rejecting.” Moreover, “preoccupied” or anxious individuals had negative views of themselves, but positive views of others. The converse was true for “dismissing” or avoidant individuals, who had positive views of themselves but negative views of others, in order to protect themselves from disappointment through independence (Bartholomew & Horowitz, 1991). (See Appendix A for a graphic representation.)

To investigate this model, Bartholomew and Horowitz (1991) interviewed undergraduates and their friends about friendship patterns, with the intention of learning about the attachment style, self-concept, and sociability of their subjects. Subjects were rated on how well they matched prototypic attachment styles based on the interviews—and the researchers
classified 47% as secure, 18% as avoidant, 14% as anxious, and 21% as anxious-avoidant (Bartholomew & Horowitz). This is to say, even in an undergraduate semi-random sample, subjects were arrayed across the four attachment styles similarly to those from Hazan and Shaver (1987). Nonetheless, Bartholomew and Horowitz did not find strict categories, but rather a mix of answers that allowed subjects to primarily fit within one category or another, suggesting that the dimensional model was more appropriate than a categorical one. The researchers found that self-concept was related to the continuum of dependence/anxiety—which is to say that having a strong self-concept was related to a decreased dependency on others, and moreover that the internal working model of self helped to shape attachment. Similarly, sociability was related to the avoidance continuum, and thereby the internal working model of perceptions of others. Moreover, the researchers found that problems with others in anxious-avoidant subjects resulted from passiveness and introversion, in avoidant subjects due to coldness with others, and in anxious subjects due to a controlling dependency on others. From a cognitive and neurological standpoint, these findings suggest differing reactions to social situations—and thereby different brain processes, as shall be discussed later.

Bartholomew and Horowitz (1991) thus suggested that, having formed attachment systems, individuals produce other behaviors that further the already-formed styles, evoking reactions from others that fit within their schemas. That is to say that subjects process situations as they expect each situation to affect themselves. Thus, upon viewing a situation in which a character is rejected by a romantic interest, anxious subjects might be reminded of self-insecurity, avoidant subjects reject the romantic interest in turn, and anxious-avoidant subjects feel negative about both self and other. Conversely, secure subjects might attribute the rejection to external forces. Individuals who identify with another will use their own schemas to process
the emotions and situation of the other. As internal models direct attention, we can expect to see a relationship between attachment processing and attention.

In an attempt to investigate the workings of the IWM as it relates to attachment thought processing and attention, Pietromonaco and Barrett (1997) construed the IWM as a model of attachment, suggesting that the IWM differed based on attachment style. In other words, they proposed that the differences between individuals based on attachment style found by Hazan and Shaver (1987) and Bartholomew and Horowitz (1991) were the result of differing IWMs. They focused on how the IWM of attachment was linked to social interactions. Pietromonaco and Barrett (1997) thus asked 70 subjects to keep daily diaries of their lives using a format called the Rochester Interaction Record, as well as assessing attachment style (using the same method as Bartholomew & Horowitz, 1991) and distress. Attachment groups, Pietromonaco and Barrett (1997) found, did not differ in the types of interactions in which they engaged, but rather in their perceptions of their interactions. In attachment-relevant (relational) contexts especially, the IWM led to clear differences between groups. For example, anxious individuals believed their daily interactions to be more intimate than avoidant individuals, and had lower self-esteem than secure individuals. Interestingly, in high-conflict situations, anxious individuals felt less unpleasant than other groups. In essence, Pietromonaco and Barrett’s findings suggest clear effects of IWM on interpersonal style, validating the more general findings of Bartholomew and Horowitz (1991).

The IWM, then, is the basis for the attachment style—it forms the basis for the way individuals construe their relationships (Mikulincer & Shaver, 2007). Although this idea remains important in attachment theory, methods of assessing attachment have changed over the years, even as they continue to demand re-thinking and re-consideration. Hazan and Shaver (1987) used a single-item inventory that asked respondents simply to categorize themselves based on how
closely they identified with a descriptive prototype of each style. Bartholomew and Horowitz (1991) used a long-form semi-structured interview. Fraley, Waller, and Brennan (2000) argued that complex dimensional models are useful only when coupled to detailed multi-item inventories, and therefore they revised an early model, the Experiences in Close Relationships Questionnaire (ECR) to create the Experiences in Close Relationships Questionnaire, Revised (ECR-R), which is used in the current study. Fraley et al. used factor analysis and item response theory to develop a more precise attachment scale, which they believe is best used primarily as a dimensional variable, but has been normed for use as a categorical one. The questionnaire, discussed in more detail below, asks a number of questions that allow subjects to be rated on both dimensions based on average score. By asking multiple questions, Fraley et al. suggest that their model gets at multiple facets of attachment that might be confounded by self-categorization, and may be teased out by variance of questions. By asking questions about attachment-relevant behavior, we can get a better understanding of attachment style for individuals.

Cognitive Neuroscience Models of Attachment

A relationship between attentional processes and attachment has been proposed (e.g., Buccheim et al., 2006), as situations that involve attachment processes draw the attention of an individual to the aspects important to that individual’s attachment style. Thus while securely-attached individuals may focus on positive ideas or situations, attachment-insecure subjects may focus on negative situations (e.g., Zilber et al., 2007). This differentiation in schemas allows the specific mental processing of attachment-relevant situations to be looked at from a neurological light, since different attentional processes (and therefore different regions of activation within the brain) are being accessed for individuals with different attachment styles. Moreover, based on
the suggestion that attention is incited by the activation of the internal working model or schema, we can look for a neurological foundation of that schema. By finding a neuroscience basis for this cognitive processing, we can demonstrate physical cerebral differences between people based on attachment and the processing it evokes—a useful step in advancing our understanding of what different attachment styles mean. Brain imaging serves a double purpose, here: it validates claims of attachment differences by showing differences not just in self-report but also in neural processing between individuals, and it allows us to understand where these processes take place.

In this vein of research, Buccheim et al. (2006) used a picture presentation sequence during fMRI scanning to activate attachment systems, asking subjects to create narratives of attachment-relevant scenarios. Although the researchers focused on ideas of “resolved” or “unresolved” attachment style, a concept related to pathology and identity formation, they found that as their task progressed, both groups had increased activation of a system, especially in the right inferior frontal cortex, which has been shown to be involved in emotion regulation, and which they called an attachment system. However, these suggestions of neural bases for attachment processes and these brief studies of the ways that attachment activates the brain are only the beginnings of the search for linking cognitive and neurological. Perhaps in part because (as Buccheim et al. suggest) attachment processes involve a number of disparate brain regions, activating the limbic system and attentional processes, few studies have investigated attachment-specific processes and found definitive results. The results of Buccheim et al. suggest a front-brain, top-down processing that is mediated by conscious control of emotion, since the activation was in the frontal cortex. These suggestions are unsubstantiated by further studies; Buccheim et al. used a very limited task based in ability to imagine scenarios, and focused away from every-
day processing. Nonetheless, the results imply that attachment processes can be demonstrably located in the brain; they demand further investigation and consideration.

To continue in this vein, some research has shown that specific brain areas are activated in response to social stimuli (e.g., Eisenberger, Lieberman, & Williams, 2003; Cavanagh & Allen, 2007), such as social separation—attachment-relevant situations. The study of social relationships has implicated regions typically associated with attention and cognitive control (Gillath, Bunge, Shaver, Wendelken, & Mikulincer, 2004), with emotion regulation (Eisenberger et al., 2003), and with love (Fisher, Aron, & Brown, 2005). For example, further fMRI research has delved into the ability of individuals to control cognitions about relationships (Gillath et al., 2004). Gillath et al. asked subjects in an fMRI machine to imagine relationship-based scenarios, or try not to think about the same scenarios, while their brains were scanned. They found that individuals with high attachment anxiety had higher activation in the orbital frontal cortex, an area associated with emotional regulation, as well as in the hippocampus. Perhaps more importantly, attachment-anxious individuals had high activity in the dorsal anterior cingulate cortex (Gillath et al., 2004), which is associated with social rejection (Eisenberger et al., 2003) and with attentional control. Avoidant individuals had similar results, but also showed decreases in activation in the lateral prefrontal cortex, which integrates emotion and cognition (Gillath et al., 2004). That is to say, avoidant individuals used similar—but slightly different—attachment thought processes than did anxious individuals. Differentiating between these two styles, beyond grouping them together as “insecure,” bears further study once the more general differences are clear. Moreover, Fisher et al. (2005) proposed an attraction mechanism based in their fMRI study of people in love, suggesting that the corticostriate system, the ventral tegmental area, and right caudate nucleus might be implicated in love processes and mate choice. These systems are
highly activated by dopaminergic reward pathways, and may relate to the attachment systems as well (Fisher et al., 2005).

However, while these studies make clear that specific regions are involved during the cognitions that involve attachment and similar processed, they leave many questions about how those regions are activated, in what patterns, and to what ends. Specifically, these studies encourage us to ask how attention is allocated differently by people with different attachment styles, and how this allocation changes the ways their brains function. Some of these questions are more difficult than others, but considerations of the way that the brain responds to attachment-relevant situations is possible, using a brain imaging technique with high temporal resolution: the electroencephalograph.

Event-Related Brain Potentials: The Late Positive Potential

The technique of measuring Event-Related Potentials (ERPs) permits investigators to study processes of attention and expectancy, allowing them to gain an understanding of these and other neuro-cognitive processes. ERPs are an electroencephalographic (EEG) technique through which electrodes are placed on the scalp and used to record electrical brain activity. By averaging a series of time-locked responses to stimuli, researchers can create a waveform with distinct peaks for analyses (Fabiani, Gratton, & Coles, 2000), and therefore quantify the attentional processes already discussed. There is a relationship between ERPs and expectancy violations and attentional processes; ERPs follow these processes (e.g., Duncan-Johnson & Donchin, 1977). EEG analysis has a very high temporal resolution, allowing it to be linked to specific events and used to consider the mental processes underscoring said events. To use data collected by EEG caps connected to computers, the difference from sites of interest and
reference sites is computed, allowing researchers to demonstrate increased activity within a region. It is important to note that ERPs measure the electrical activity of a general region, rather than a specific part of the brain. That is, for example, the Late Positive Potential, to be discussed further below, is believed to be the result of summed activity of a number of different brain areas (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). As a result of this, ERP peaks can demonstrate multiple functions (Fabiani et al.), although some ERPs can be traced to specific brain regions.

The Late Positive Potential (LPP), also called the P300 or P3b\(^1\), is a positive peak ERP found between 300 and 500 milliseconds after a stimulus presentation. It has been shown to be maximum at parietal midline locations on the scalp, and is elicited best by task-relevant oddball stimuli. That is to say, the LPP is elicited when subjects are given a task, and unexpected stimuli show up that are attended because of the task. For example, when Duncan-Johnson and Donchin (1977) had participants attend to oddball stimuli, they elicited LPPs for the rare stimuli presentation. However, the LPP is not directly connected to specific brain regions, but rather believed to emanate from a variety of simultaneous brain processes (Fabiani et al., 2000). The LPP waveform’s amplitude (height) and latency (width) can be affected by the stimulus type (Duncan-Johnson & Donchin, 1977).

Duncan-Johnson and Donchin employed an experimental design intended to measure response to oddball stimuli. They varied the frequency of low and high pitch tones, and varied whether subjects were to count tones or to ignore the low tones, while the EEG of participants was measured. Grand average ERP data was computed, and the LPP was seen only when subjects counted tones—that is to say, when they paid attention to them. The prominence of the

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\(^1\) These terms are used interchangeably, because they refer to the same general peak, but different terms are used in different studies. The term LPP is preferred, because the peak sometimes occurs later than 300 milliseconds after stimulus presentation. For simplicity, this study uses the term Late Positive Potential, or LPP, to refer to the peak.
LPP peak was heightened when the tone that was being counted was rare (Duncan-Johnson & Donchin, 1977). In essence, these results demonstrated the role played by expectancy in LPP formation: when subjects paid attention to stimuli, the amplitude of the LPP increased for rare stimuli. The important thing about the stimuli, explain Fabiani et al. (2000), is that they be possible to unambiguously categorize. This means that in image-based research hoping to elicit LPP waveforms, stimuli images presented to subjects must be clear, and the task that subjects perform must relate directly to the aspects of the images which are changing, which can allow for an examination of complex categories. This understanding informs the current study, as does a cognitive understanding of the LPP. For example, Donchin (1981) suggested that the LPP might relate to updating of the current working memory, but its true sources are of yet still unclear.

Although Duncan-Johnson and Donchin have shown that the sensory properties of a stimulus can create the LPP, further research has shown that the waveform can be demonstrated as a result of complex categorizations involving semantic meaning. It has been shown that clear LPPs can be evoked by sequential image presentation in sequence when subjects are asked to make judgments about images and not simply to count them (Cacioppo, Crites, Berntson, & Coles, 1993). Cacioppo et al. showed that attitudes towards stimuli—their likes and dislikes—could be differentiated by their LPP. The LPP, they showed, was a marker of emotional involvement and attitude, as well as simply expectancy. The researchers asked subjects to count how many positive images they were shown, after they had rated the images as positive or negative. A second block of trials had subjects count how many negative images they were shown. The researchers found that the LPP was elicited by categorization in an unexpected category—when an image they disliked followed a number of images they liked, for example
That is to say, the LPP reflects more than simply an automatic reaction to sensory stimuli, but actually is the result of a cognitive process activating the brain.

Perhaps this cognitive basis of the LPP is best illustrated by the fact that, beyond the violation of expectancy, the LPP has been shown to also be elicited by emotional images. Specifically, the waveform is demonstrated in response to emotional stimuli but not to neutral ones (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). Schupp et al. proposed that emotional stimuli elicit greater results because participants pay more attention to arousing stimuli; they used the term “attentional orienting” to describe the manner in which individuals direct attention towards of-interest stimuli (Schupp et al., 2006). That is, emotional images are eliciting an attentional process in some sense similar to that elicited by the oddball stimuli that provoke expectancy violations; the LPP seems to be related to this process of attention, rather than specifically the stimuli that causes it. It has also been demonstrated that following emotional pictures, the subsequent image has a reduced LPP regardless of its emotional valence (Flaisch, Stockburger, & Schupp, 2008). Flaisch et al. presented a stream of images, some positive, some unpleasant, and some neutral, to subjects while recording their EEG data, instructing participants to simply watch the images. They found that both pleasant and unpleasant images had an increased LPP compared to neutral images, and simultaneously resulted in a lowered LPP in the image that followed (Flaisch et al., 2008). Flaisch et al. argue that this results from a loss of accuracy in stimulus recognition—the images no longer evoke the same degree of emotion. That is to say, the attention is lessened by repetition, in a sort of microcosm of habituation, in much the same was as repeated “oddballs” will lessen the very status of the stimulus as oddball. This suggests, then, that emotional and expectancy effects are both resulting from cognitive attention.
Moving beyond Flaisch et al., Hajcak & Olvet (2008) have shown that the LPP increases due to emotional stimuli, and that it increases over a larger range for negative stimuli. The researchers presented subjects with pleasant, neutral, and unpleasant images, and asked them to simply view the images while their EEG was measured. The study found that the LPP in response to unpleasant images affected inferior regions as well as the more commonly-found superior regions of the scalp (Hajcak & Olvet, 2008). Moreover, they found that the LPP continued to vary by stimulus type, even after two seconds, and after the images were no longer visible. The researchers, more importantly, suggest that their results demonstrate a “negativity bias” in the attention paid toward emotional stimuli. That is, subjects were more likely to pay attention to negative stimuli.

Much as the LPP results from an attentional cognitive process, it can be controlled by an intentional cognitive processes. When participants were instructed to control their emotional responses to pleasant pictures—that is, to try not to feel their emotions to positive stimuli—they had lesser LPP peaks (Krompinger, Moser, & Simons, 2008). The researchers asked participants to either cognitively increase or decrease their emotional response to positive and neutral images, while continuous EEG data was recorded. The participants were given some strategies for decreasing affect, including distancing, and others for increasing affect, such as identification. In the enhanced condition, there were no LPP peak differences as compared to a baseline condition where the images were shown without control instructions. The fact that no difference in the LPP was present for the enhanced condition suggests that the subjects might have habituated to the stimuli (Krompinger et al.). More importantly, other results indicated a lessened LPP amplitude in the decreased condition, which imply that the LPP can indeed be controlled by attentional processes, and in fact clearly demonstrated emotional involvement. That is to say, the Late-
Positive Potential can be increased by cognitive processes that choose to pay attention to one stimulus but not to another.

In order to unpack individual differences in the attention subjects might pay to stimuli, we can turn to an exploration of differences as they relate to attachment. Studying the LPP has demonstrated that it is elicited by attention—whether that attention be the result of expectancy violation (e.g., Duncan-Johnson & Donchin, 1977) or the result of emotional image presentation (e.g., Flaisch et al., 2008). We have already posited a relationship between attention and attachment, suggesting that attachment style differences are associated with differences in emotional and attentional processing of situations based on internal working models. How, then, might these attachment style differences cause different neural attentional processing?

*An Expectation-Based Model for Measuring Attachment*

If the LPP is heightened in response to expectancy violation, LPP peaks can be elicited in an attachment study by presenting subjects with attachment scenarios that either confirm or deny their expectations, consistent with the theory of working models. For example, the LPP has been measured in response to love-related stimuli (Langeslag, Jansma, Franken, & Van Strien, 2007). As discussed earlier, if attention to images is increased by either emotionality or attention to targets, then the LPP becomes more pronounced. Langeslag et al. argue that when stimuli are both emotional and in the subjects’ attention, their augmentation should be mutual—and this pattern should be further increased by personally-relevant stimuli. Thus Langeslag et al. asked participants to view photographs of the faces of their friends, their lovers, and an unknown but beautiful person. Each face was shown multiple times while EEG was recorded. Participants also rated their relationships with their lovers, although attachment style was not addressed. The
Researchers found that the LPP peak was most pronounced following the face of the beloved, suggesting that more attention was paid to the lover (Langeslag et al., 2007). This idea is called “motivated attention,” and it implies that more attention was allocated to relationship-related stimuli, because cognitive systems are activated more strongly.

In a further study looking at the relationship between presented images and attachment, Dewitte and De Houwer (2008) investigated the way that facial expressions influence attention. They conceptualized attention as the reaction time for subjects to respond to a dot-probe task. Angry, happy, and neutral faces were shown on a screen, and then a dot-probe task in which subjects had to indicate the side of a screen on which a dot appeared. They argued that these facial expressions signaled attachment figure availability (happy) and unavailability (angry) during the task. Dewitte and De Houwer found that those individuals with high scores on both anxiety and avoidance dimensions of attachment had a decrease in attention for the threatening (angry) stimuli, which they postulated resulted from a defensive nature of their cognitive processes. They suggest that both dimensions together have a joint effect on directing attention to threat, leading highly anxious-avoidant subjects to avoid emotional cues in stimuli. Earlier research (Dewitte, Koster, De Houwer, & Buysse, 2007) had hinted at the interaction between anxiety and avoidance causing defensiveness from threats in a similar dot-probe study that employed threat words instead of face images, finding similar results that were underscored by the subsequent research. However, these results have not been replicated by imaging research (e.g., Zilber et al., 2007), suggesting that there may be some findings present in behavioral data but not shown by the processing methods we have available.

These studies imply that attachment style influences the attention individuals pay to stimuli in a statistically significant manner. Yet the direction to which the attentional processes
(and therefore the LPP) swing is still under investigation. In beginning to address this question, Zilber, Goldstein, and Mikulincer (2007) found that high attachment-anxiety participants had greater LPP amplitudes to negative pictures. The researchers had subjects complete the Experiences in Close Relationships Questionnaire to assess attachment categorically, and then to complete a task while EEG was recorded. The task asked subjects to view 60 pictures, divided evenly among pleasant, neutral, and unpleasant images, and after viewing each image to categorize it as pleasant, neutral, or unpleasant. They found that highly attachment-anxious participants committed more resources to the negative images, as reflected by greater LPP peaks following those images. However, while the researchers postulated that highly attachment-avoidant individuals would allocate fewer resources to processing emotional images, instead those individuals had enhanced LPPs to negative emotional pictures, similarly to the attachment-anxious group. Zilber et al. suggested that differences between insecure attachment styles would only be significant in higher-level processing not reflected in immediate ERP data, but it seems also possible that, to extrapolate from Dewitte and De Houwer (2008), it is only subjects who are both high-anxious and high-avoidant who demonstrate less activation. It seems as though these findings suggest an attentional bias towards negative images to contradict the attentional (and non-ERP-based) findings of Dewitte and De Houwer, who found an attentional bias away from threats. Moreover, the results of Zilber et al. support the suggestions of Dewitte and De Houwer, above, although Dewitte and De Houwer’s study was behavioral. It seems possible that the attention-based results of Zilber et al. are overshadowed by expectation biases, or “interpretation biases.”

Other studies have considered the responses of socially-anxious individuals to negative stimuli (Moser, Hajcak, Huppert, Foa, & Simons, 2008). Moser et al. studied “interpretation
bias” in an experiment that looked at both the LPP and the P600 (a similar syntactic-violation-based wave). They predicted that highly socially-anxious participants would not show the differences in reaction to positive and negative sentence endings that would be seen in low-anxious individuals. Although this study did not specifically consider attachment style, the measures of social anxiety used were similar to attachment measures, and the findings are similar to those one might expect from the findings of Dewitte and De Houwer (2008). Moser et al. conducted a language-based (rather than image-based) study that asked similar questions to those asked by Zilber et al. (2007), albeit with social anxiety instead of attachment. The researchers measured social anxiety using the Social Phobia Inventory and the Brief Fear of Negative Evaluations as a grouping variable, and had their subjects perform a computer task while EEG was recorded. The computerized grammar task asked subjects to decide if sentence-endings were grammatical or not; the terminal words of each sentence made the sentence either positive or negative. Moser and his colleagues found that low-anxious participants had more pronounced LPP amplitudes; they suggest that those participants saw negative endings to sentences as unexpected and inconsistent with their interpretations of the sentences. Socially anxious individuals, however, may have seen both endings as equally probably, as they had no difference in their LPP peaks between positive and negative sentence endings (Moser et al., 2008). Moser et al.’s findings suggest that the LPP is activated by expectation violation, thereby initiating attention-based processes. These results differed from those of Zilber et al., I suggest, because the violation of expectations gleaned from Moser et al.’s design was enough to cause highly-anxious subjects to deflect their attention, whereas the negative emotional images in Zilber et al. resulted in increased attention. I am interested, here, in investigating the differences between these two studies.
Rationale

Based on an understanding gleaned from the studies discussed above, I propose an investigation into the differences in attentional processes that result from emotional images shown in-sequence. I am interested in considering whether emotional images or images that violate expectations will be more able to elicit the LPP. Buccheim et al. (2006) and others attempted to use fMRI to find neurological bases of attachment, and began a path to an understanding of how these processes might function in the brain. Moreover, Gillath et al. (2004) showed that controlling attachment processes causes changes in brain function. However, both studies generated interest in the underpinnings of attachment—in what brain regions are activated by what processes. The question that results from these studies is this: How is attention to emotional stimuli, specifically social-emotional stimuli, allocated differently as a function of attachment style in individuals?

To answer this question, we turn to EEG technology, to provide time-specific tracking of brain electrical activity. From our understanding of the Late Positive Potential as elicited by emotional images (Schupp et al., 2006) and attenuated by emotional control (Krompinger et al., 2008), it was possible to consider how attachment might affect attention to images that portray social situations. Zilber et al. (2007) demonstrated an attentional bias such that negative images elicited greater LPPs from attachment-anxious and attachment-avoidant individuals. In highly anxious individuals, Moser et al. (2008) demonstrated an interpretation bias: low-anxious participants demonstrated pronounced P600 peaks to negative sentence endings, while high-anxious participants showed no difference in P600 amplitude between negative and positive sentence endings. From this we conclude that high anxiety causes some degree of expectation of
negativity, while leading to avoidance of recognition of negative images. Moser et al.’s study, combined with that of Zilber et al., leads the current study to consider the role of anxiety in shaping attention to negative images.

Thus I propose presenting individuals with ambiguous priming images, followed by target images that show positive, negative, and neutral attachment situations. In this design, I hypothesize that, when primed by ambiguous setting images, individuals with highly-anxious or highly-avoidant attachment styles will show smaller LPP amplitudes to negative target images than will securely attached individuals (low-anxious and low-avoidance), because they are more likely to expect negative social situations. This expectation bias, it is proposed, will affect the LPP more strongly than a negativity bias. To tease out this distinction, subjects will also view target images without priming images. Thus, when not primed with ambiguous setting images, these highly-anxious and highly-avoidant individuals will show a difference in their LPP amplitudes between positive and negative target images, with negative images eliciting greater amplitudes, as non-primed trials do away with expectation bias and reflect purely an attentional negativity bias, thus correlating with the results anticipated by Zilber et al. (2007). The activation of attentional processes will result in increased attention to these negative target images.

Through this study, I hope to demonstrate that attachment-systems are activated in measurable ways through the violation of expectancy of social cues. Greater understanding of the way these systems work will enable us to gain a clearer sense of how we form relationships.

Methods

Participants
Forty subjects were recruited from the student body at Haverford College. All subjects were undergraduates, between the ages of 18 and 22. Subjects were screened for standard exclusionary criteria that might affect EEG data. Those without normal or corrected-to-normal vision, with a history of neurological disorders, or those who regularly used drugs of any sort that affect the central nervous system were excluded. The sample included 24 female and 16 male subjects. Most subjects were right-handed \( (n = 33) \). Most subjects also identified as heterosexual \( (n = 36) \), although 2 identified as homosexual and 2 as bisexual. Most subjects identified as white \( (n = 28, 70\%) \), with the rest identifying as multiracial \( (n = 6, 15\%) \), Asian \( (n = 4, 10\%) \), African-American \( (n = 1, 2.5\%) \), or Hispanic \( (n = 1, 2.5\%) \). All but three of the subjects had been in romantic relationships at some point in their lives, and roughly half \( (n = 21) \) were currently in relationships at the time of the study.

Potential subjects completed a brief survey on the web, which asked them for answers to the exclusionary questions, to the questionnaire Experiences in Close Relationships, Revised (ECR-R, Fraley, Waller, & Brennan, 2000), and for the demographic data reported above. (Subjects responded first to the ECR-R so that researchers could insure a variety of attachment-style responses.) All students who entered their information into the screening questionnaire were entered into a lottery for $50. All subjects who participated in the task received $25 for their participation.

**Attachment Inventory**

Subjects who met the screening criteria were scheduled to come into the lab, located on the fifth floor of Sharpless Hall at Haverford College. After scheduling their appointment, they were emailed a link to a series of questionnaires that they filled out at least one day prior to their
appointment. The questionnaires were answered before the task in an attempt to minimize the effect of the task on the questionnaires. The questionnaires included the Adult Attachment Questionnaire (AAQ, Simpson, Rholes, & Phillips, 1996), the Brief Fear of Negative Evaluations Questionnaire (BFNE, Leary, 1983), and the State-Trait Anxiety Inventory (STAI, Spielberger, 1968). All of the questionnaires are included below in appendices C through G.

The ECR-R measures attachment style on two dimensions: anxiety and avoidance. It has 18 items measuring anxiety and 18 items measuring avoidance—for example, “I’m afraid that I will lose my partner’s love” measures anxiety, while “I prefer not to show a partner how I feel deep down” codes for avoidance (Fraley et al., 2000). Participants rated each question on a Likert scale of 1 to 7, and responses were averaged across items for each subscale. Fraley and colleagues have cautioned that secure attachment is coded less precisely with this scale, since there are limited questions for low-anxious and low–avoidant individuals. Both the anxiety scale ($M = 2.91, SD = 1.09$) and the avoidance scale ($M = 2.82, SD = 1.31$) had averages that were closer to secure than to insecure; the anxiety scale didn’t exceed 5 for any subjects’ data, and the avoidance scale only had two subjects who scored over 5. The range was 3.78 for the anxiety subscale, and 4.56 for the avoidance subscale.

The AAQ (Simpson et al., 1996) is a parallel to the ECR-R, and also measures attachment style; it was intended to ensure construct validity for the ECR-R, and to be a secondary mode of analysis. It includes 17 items divided into two scales of anxiety and avoidance, such as “I don’t like people getting too close to me.” Participants rate each question on a Likert scale of 1 to 7, which are then averaged across items for each subscale. The attachment-anxiety subscale ($M = 3.39, SD = .948$) and avoidance subscale ($M = 2.93, SD = $
1.01) also both tended to the lower end of the scale. The range was 4.39 for the anxiety subscale, and 3.75 for the avoidance subscale.

The ECR-R’s anxiety subscale correlated positively with the anxiety subscale of the AAQ (r (38) = .62, p < .01) and with its own avoidance subscale (r (38) = .59, p < .01). The ECR-R’s avoidance subscale also correlated with both the AAQ subscales. These correlations are presented in Table 1. Intercorrelations indicate that the ECR-R and AAQ both measure similar concepts. The subscales of the ECR-R were highly intercorrelated as well, suggesting that the two subscales may not be as different as suggested, and may measure similar constructs.

The BFNE measures social anxiety, and was intended, alongside the STAI, which measures state anxiety, to differentiate between anxious personality types and anxious attachment styles. The BFNE has been validated through factor analysis and significant correlations with social avoidance (Collins, Westra, Dozois, & Stewart, 2005). These measures allowed the use of state and trait anxiety as covariates in the analysis, since the two are closely related with attachment (Weems, Berman, Silverman, & Rodriguez, 2002). The BFNE (Leary, 1983) has 12 items and includes statements like “I am afraid that others will not approve of me,” while the STAI (Spielberger, 1968) measures state and trait anxiety with 40 statements such as “I feel upset” that are rated based on how true they are at the moment (for state anxiety) and in general (for trait anxiety). The STAI’s trait anxiety subscale correlated with every measure except for the anxiety subscale of the ECR-R, as demonstrated in Table 1.

Because attachment-anxiety is strongly associated with neuroticism (Noftle & Shaver, 2006), the current study used a measure of neuroticism to allow an examination of how neuroticism contributes to any significant attachment-related effects. Noftle & Shaver have stated that personality variables are associated with attachment style, but not accounted for by
attachment style; measuring both scales enables us to ensure that difference is due to attachment style. Thus we asked subjects to answer a ten-question inventory of neuroticism from the Big Five Questionnaire (Goldberg, 1999), which included questions such as “I change my mood a lot” that were rated on a 1-5 scale. Although the neuroticism scale correlated with the BFNE and STAI, it only correlated weakly with the AAQ’s avoidance subscale \( r (38) = .38, p < .05 \) and not at all with the other attachment subscales, as demonstrated in Table 1.

Following the questionnaires, a series of questions asked about subject’s relationship experience. These questions allowed us to ensure that subjects were reacting during the social stimulation task based on personal experience.

**Social Stimulation Task**

The social stimulation task was intended to replicate attachment-relevant situations. Subjects undertook the task between the hours of 10 AM and 10 PM during the winter of 2009. Subjects read directions that instructed them to pay attention to the person of their gender in each picture. For each target image, subjects rated the question “How happy is the person of my gender?” on a 1-9 scale using the number pad of a keyboard, so that they could make the ratings without looking down from the screen. This task helped subjects to identify with the pictures.

The images were drawn by Jacob Carroll ’09 and Rebecca Morgan ’10, following a script designed by the experimenters. They were simple black-and-white images (see Appendix B) with two primary characters in each. There were four categories of target images: positive social stimuli (e.g., a man and a woman holding hands), negative social stimuli (e.g., a man and a woman arguing), neutral unexpected stimuli (e.g., the sudden appearance of a penguin), and neutral social stimuli (a man and a woman without action). Although it might have been possible
to use photographs, simple line drawings allowed us to control the content more fully, and control size and color easily.

There were two types of trials based on context. In one type, in-sequence trials, the scenes were set with two ambiguous scene-setting images (e.g. a man and woman sitting at a restaurant, and then the two eating food), and then followed by a third “target” image in that setting, as described above (i.e., positive, negative, neutral-random, or neutral). In the second type of context, the control (“solo”) trials, subjects were presented solely with the target images, out of context. Images presented in-sequence were intended to elicit the expectancy violation, while those presented solo were intended to evoke emotion-based attentional processes.

Each trial began with a fixation cross (+) presented for 500 ms, followed by the images, each of which was presented for 1500 ms. The target images, in either context, were presented with a thick black border, to indicate that a response was necessary, and remained on-screen until a key-press was recorded. Between trials, a blank “wait” screen was presented for either 300 ms (in-sequence) or 500 ms (solo).

There were 26 sets of images, each with two ambiguous setting images and four target images, resulting in 104 target images in total. The in-sequence images were presented first, with the images drawn by Morgan presented first, followed by the images drawn by Carroll. Between each block of trials, subjects were reminded of the directions and told whether the images were in-sequence or solo. Each block of in-sequence images was repeated once, and then the images were shown solo. Because we re-used images three times, we hoped to allow for the expectancy violations by presenting the images in-sequence first, rather than removing the surprising by showing all of the target images solo, first. Within the blocks, the order of presentation was randomized. The task took subjects 20-30 minutes to complete.
Pilot Testing of Images

Because the images were used for the first time in this study, the experiment was preceded by pilot testing of the images. Students enrolled in the Introductory Psychology course received credit towards their experiment requirement for participation. Eleven participants in pilot testing performed the task described above without the solo portion. They answered questions about how surprising each image was, how well they understood the story, and how happy the characters were in each image. Target images that were deemed confusing for the study were removed.

Pilot Testing of EEG Task

Two subjects were run as pilot subjects for the EEG task. Following the analysis of their data, the decision was made to re-structure the task as described above, rather than having context decided randomly, in an attempt to increase the surprise of the sequential context by having the images first appear in this trial type, rather than solo.

EEG Data Collection

During the social stimulation task, the subjects’ EEG was continuously recorded. Electrodes were applied using an elastic cap (Quik-Caps) fitted with sintered Ag/AgCl electrodes. The cap’s positioning was ensured by measuring 10 cm from the nasion, for placement of the ground electrode, and by measuring from earlobe to earlobe to ensure that central sites were accurately placed. The software measured continuously from 3 scalp sites: Pz, Cz, and Fz, along the midline, as well as from four lateral sites (F3, F4, P3, and P4), referencing
to the average of the mastoids (A1 and A2), and collecting data from electrodes surrounding the eyes to catch eye movements (electro-oculogram). A NuAmps amplifier controlled by Neuroscan software was used to amplify the continuous data with a sampling rate of 1000 Hz and a bandpass of .1-70 Hz (-3 dB). Data was referenced on-line to the left mastoid and digitally re-referenced off-line to the average of both mastoids.

Artifacts in the waveform data were addressed offline by visual inspection, and any segments with large non-blink artifacts were manually rejected by the experimenters. Afterwards, blink artifacts were corrected for by Neuroscan’s built-in regression-based algorithm for ocular artifact reduction. Finally, remaining artifacts in the EEG data were rejected by excluding data which exceeds the $\pm 150 \mu v$ threshold. Epochs were baseline-corrected with the baseline defined by values in the interval of 100 ms prior to each image’s appearance. Averages were then created for each target image context, as discussed below, including a window from 100 ms before the image to 800 ms following the image’s appearance.

The Neuroscan program was used to quantify the waveform peak amplitude for each late positive potential. The software found the peak between 200 and 400 ms, and this number (the P300 or LPP) was used for analysis. A second peak between 500 and 700 ms after the target image (the P600) was also quantified.

**Data Analysis**

Data were subjected to analysis in a 2 (context: sequence or solo image) x 4 (target image type) x 3 (site location) design. Attachment style was considered as a continuous variable, allowing for a mixed ANOVA analysis with attachment as a covariate. Analysis was both
between-subjects (for attachment style) and within-subjects (for target image type, site, and context).

Results

EEG Data Analysis

Behavioral Data

The behavioral data gathered during the social stimulation task help to illustrate the sample’s responses. We first considered the responses acquired during the social stimulation task. Each time a target image was presented, the subjects pressed a number from 1 to 9, rating the character of their gender in the image from “not at all happy” to “very happy.” We excluded two subjects from these analyses, one of whom did not complete the task, and one of whom misunderstood the rating scale. A repeated-measures ANOVA was conducted, with factors of context and target image type. Context was significant \((F(1, 37) = 5.57, p < .05)\), with solo images \((M = 4.80, SE = .06)\) garnering higher ratings than images in-sequence \((M = 4.72, SE = .06)\). Target image type was also significant, \(F(3, 111) = 210.45, p < .01\). Pairwise post-hoc comparisons revealed that negative images received significantly lower ratings \((M = 2.05, SE = .18)\). Neutral \((M = 4.87, SE = .08)\) and random \((M = 4.92, SE = .09)\) images both received middling ratings that did not differ significantly from one another, but did differ significantly from the others. Positive images received the highest ratings \((M = 7.21, SE = .18)\). The interaction between target image type and context was not significant. These results confirm the intended emotionality of the target images.
Following this ANOVA, we considered whether the attachment variables predicted patterns of ratings using the AAQ and ECR-R, with anxiety and avoidance scales. The results of these ANOVAs were insignificant.

We then considered the reaction times, which were the times recorded from the onset of the target image to the button press of the rating. One subject’s data were excluded because she did not finish the task. Here, we again used a repeated-measures ANOVA to compare the context in which images were presented, the target image type, and the interaction between the two. The context $F(1, 38) = 38.58, p < .01$ effect showed that in-sequence images had a slower-reaction time ($M = 2493 \text{ ms}, SE = 160$) compared to solo images ($M = 1934 \text{ ms}, SE = 125$). There was also a target image type effect, $F(3, 114) = 32.50, p < .01$: For negative images ($M = 1956 \text{ ms}, SE = 130$), positive images ($M = 2077 \text{ ms}, SE = 123$), and neutral images ($M = 2182 \text{ ms}, SE = 143$), RT was considerably faster than for random images ($M = 2639 \text{ ms}, SE = 175$). A post-hoc test of Least Significant Difference showed that all RTs were significantly different from one another, except for positive and neutral images, which were responded to at similar speeds. The interaction between context and target image type was also significant, $F(3, 114) = 19.46, p < .01$. These means are reported in Table 2. To explicate this difference, we ran an ANOVA with a factor of target image type, first for in-sequence images ($F(3, 114) = 38.90, p < .01$) and then for solo images ($F(3, 114) = 13.43, p < .01$). For in-sequence images, there were no significant differences between positive and negative images, which were responded to most quickly. Neutral images elicited significantly slower RTs, and random images were slowest of all. For solo presentation, negative images were responded to most quickly. Neutral and positive images, while not significantly different in RT from one another, were significantly slower than negative images. Random images were still responded to most slowly.
Following this ANOVA, we again looked at whether the attachment variables caused covariance in the data, using both subscales of the AAQ and ECR-R. We did not find a significant effect for any of them when a covariate was added. Essentially, the response ratings and RT data confirmed the expectations, with positive images eliciting higher ratings, and negative images eliciting the lowest ratings. Random images had the slowest response times.

**LPP / P300 Analysis**

Figures 1-6 demonstrate the EEG data collected in-sequence and solo, and from the three sites Fz, Cz, and Pz. The sharp positive (downward) peak above 300 ms is the LPP, and the distinction by image type and by context is visible.

In order to investigate the interactions between EEG data, we used a repeated-measures ANOVA, of context by image type by site. We began by considering the peak amplitude of the Late Positive Potential, or P300. The basic effects of the LPP showed a significant effect of target image, $F(3, 117) = 31.32, p < .01$, where negative images ($M = 10.49 \mu V, SE = .6$) and positive images ($M = 11.24 \mu V, SE = .64$) had much higher amplitudes than random images ($M = 7.90 \mu V, SE = .55$) or neutral images ($M = 9.35 \mu V, SE = .626$). A post-hoc examination of least significant difference suggests that all four image types were significantly different from one another, with positive images eliciting the most positive peaks, followed by negative, neutral, and finally random images. There were no signs of the predicted expectation bias. The interaction between context and target image type was significant ($F(3, 117) = 9.60, p < .01$), with emotional images causing increased LPP peaks when in-sequence than when solo. The means of this interaction are demonstrated in Figure 7.
The location of the site on the EEG cap had a significant effect on the LPP ($F(2, 78) = 93.87, p < .01$), with more posterior sites demonstrating a greater LPP and a post-hoc test of LSD demonstrating significant differences between all three sites (Pz, $M = 13.31 \mu V$, Cz, $M = 9.87 \mu V$, Fz, $M = 6.05 \mu V$). Site location also interacted with image context, $F(2, 78) = 21.71, p < .01$; the means are presented in Table 3. Site location did not interact, however, with target image type, $F(6, 234) = 2.24, p > .05$. Lastly, all three elements interacted significantly, $F(6, 234) = 2.17, p < .05$. These means are listen in Table 4.

To investigate the interactions in the LPP ANOVA, we first ran an ANOVA with factors of target image type and site location for in-sequence trials. The simple main effects were significant for target image type, $F(3, 117) = 36.83, p < .01$, and a post-hoc LSD test confirmed that in-sequence, negative and positive target images did not differ from one another in peak amplitude, while neutral images were significantly less positive, and random images significantly less positive than neutral. The simple main effect of site was also significant, $F(2, 78) = 39.29, p < .01$, with all three sites significantly differing, and posterior sites more positive in amplitude. We also ran an ANOVA with factors of target image type and site location for solo trials. We saw somewhat different results, and the $F$ coefficients were smaller. The simple main effect for target image type was significant, $F(3, 117) = 7.95, p < .01$, with negative, positive, and neutral images not receiving significantly different peak amplitudes, and the random images receiving significantly less positive amplitudes than the others. The simple main effect was also significant, $F(2, 78) = 86.73, p < .01$, with posterior sites again receiving higher amplitudes. The interaction for target image type and site was not significant for either context, suggesting that the three-way interaction in the primary ANOVA is not meaningful.
A main goal of the study was to examine whether the differences in LPP amplitude could be explained by the variables collected via self-report questionnaire. As such, we used these variables as covariates. First, we considered the attachment questionnaires, the ECR-R and AAQ, which have sub-measures for anxiety and avoidance. The ANOVA statistics for these covariates were primarily not significant, with two exceptions.

The AAQ’s anxiety subscale significantly interacted with the electrode placement, $F(2, 76) = 5.01, p < .05$. In order to explore this effect, we divided that subscale into a categorical variable based on its median (3.39), with two levels of “low-anxiety” and “high-anxiety.” The interaction between the anxiety group and site remained significant ($F(2, 76) = 5.00, p < .05$). The means of this test are reported in Table 5. The means suggest that low-anxiety subjects had higher amplitude in posterior sites, and high-anxiety subjects had higher amplitude in anterior sites.

The ECR-R’s avoidance subscale neared significance in relation to the interaction between context and target image type, $F(3, 114) = 2.66, p = .054$. To further investigate this possible mediation between context and target image type, we considered the ECR-R sub-scale as a categorical variable, dividing subjects into “low-avoidance” and “high-avoidance,” with low-avoidance subjects scoring below a 2.82 (the median score) on the 7-point scale. When we considered ECR-R avoidance sub-scale as a between-subjects factor, the interaction became significant between all three of ECR-avoidance, context, and target image type, $F(3, 114) = 2.99, p < .05$. In-sequence, negative images elicited a more positive LPP from high-avoidance individuals and, to a significantly lesser extent, these same individuals also received higher amplitudes from positive and random images. For solo images, high-avoidance individuals received more positive LPP peak amplitudes for positive and random images. Following these
analyses, we conducted analyses with the other anxiety scales as continuous predictor covariates. None of these results were significant.

In essence, the LPP data demonstrated clear relationships between context and target image type, with in-sequence emotional images eliciting the most profound LPP peak amplitudes. These results differ from the hypothesized increased LPP for random images, which were not present. Random images, in fact, were significantly less positive than the other images across both contexts. It is worth considering whether these results continued to be demonstrated across the ERP waveform, and thus we turned to analyses of a peak slightly later in time, the P600.

**P600 Analysis**

We repeated the original repeated-measures ANOVA with factors of context, target image type, and site, using the data from the P600 time-frame. Again, there was a significant effect of target image type ($F(3, 117) = 21.95, p < .01$), with negative ($M = 11.97 \mu V, SE = .68$) and positive ($M = 11.68 \mu V, SE = .71$) images having higher amplitudes than random ($M = 9.61 \mu V, SE = .61$) or neutral ($M = 8.93 \mu V, SE = .62$) ones. A post-hoc test of LSD confirmed that positive and negative images were not significantly different from one another, but were significantly more positive in P600 amplitude than the random and neutral images which, in turn, were not significantly different from one another. There was also a significant effect of site ($F(2, 78) = 83.34, p < .01$), with the posterior site (Pz, $M = 13.47 \mu V, SE = .72$) and central site (Cz, $M = 11.60 \mu V, SE = .67$) having higher P600 amplitudes than the frontal site (Fz, $M = 6.57 \mu V, SE = .63$), although all were significantly different from one another. The interaction between
context and target image type was also significant, $F(3, 117) = 5.34, p < .01$, and the means for this interaction are reported in Table 6.

The context of the images was not significant in its affects on the amplitude of the P600, $F(1, 39) = 0, p > .05$, nor was the interaction of context and site, $F(2.78) = 1.88, p > .05$. The interaction of all three factors—context, target image type, and site—was just significant, $F(6, 234) = 2.44, p = .05$. The marginal means of this effect are reported in Table 7. However, within each context, the interaction between image type and site was not significant, suggesting that this three-way interaction is not meaningful.

To investigate the interactions in the P600 ANOVA, we first ran an ANOVA with a factor of target image type for in-sequence trials. There was a significant simple main effect of target image type, $F(3, 117) = 27.69, p < .01$. Positive images were not significantly different from negative in amplitude, and neutral and random images were not significantly different from one another. However, post-hoc tests of LSD confirmed that negative and positive images elicited significantly more positive LPP amplitudes than neutral or random images. We ran a second ANOVA for solo trials, and found a significant effect of target image type again, $F(3, 117) = 4.86, p < .05$. (Again, the $F$ value is significantly lower, although also significant.) Post-hoc tests of LSD confirmed that random images were significantly less positive than the other three image types, which did not differ from one another.

Again, we were interested to consider the ANOVA data in the light of the attachment variables we had measured, and therefore we ran the ANOVA again, separately, with each of these variables as covariates. None of these analyses was significant.
The P600 data analysis seems to follow the trend set forth of the LPP data, and doesn’t provide new information. It did not covary with the attachment variables, and seems primarily to back up the LPP data.

Discussion

The expectancy of attachment-related events did not influence the Late Positive Potential as expected, or even strongly at all, and thus it seems that the primary hypothesis must be rejected when it is viewed in the context of the results. The LPP instead seemed to be influenced primarily by the emotionality of the images used in the study (Schupp et al., 2006), and not by their relevance in terms of the subjects’ schemas. The data demonstrated main effects of context that caused in-sequence images to show significantly more positive peaks of the LPP, but these effects seemed to be due to the emotionality of the images. We had predicted that unexpected target images, when in-sequence, would cause highly positive LPP peaks, as a result of their violations of subject’s expectations of the sequence of images, along the lines of the results of Moser et al. (2008). However, these unexpected images did not produce the predicted responses, and we can speculate two bases for this.

First, it is possible that the expectancy processes violated in Duncan-Johnson & Donchin (1977—the oddball effect) were too basic to be accessed by a complex social stimulation task such as the one designed for this experiment. Duncan-Johnson and Donchin measured the LPP in response to the sounds of tones, but their oddball effect was clear and discrete. Moser et al. (2008) had suggested a similar effect in response to semantically confusing sentence endings, suggesting their effects were based on this same violation of expectancy. Moser et al. suggested that there were two possible peaks they could access: the LPP, and the N400, which is a
negative-directed wave resulting from strong semantic violations. The N400 results from violations of meaning—it is most well-studied in linguistic tasks (such as the “cloze probability” task), while the LPP seems to result from a more physical deviance (Coles & Rugg, 1995). In other words, the random images employed in the current study may have been too random, accessing a negative-leaning wave rather than the positive wave. Thus, further research in social images would need to include a condition in which images were physically random—different colors, or larger—rather than semantically different. As this study is the first to look at meaningful sequences of images in relation to the LPP, tinkering and shaping of the image set is necessary.

Secondly, it is possible that the emotional contexts of the images overpowered the expectancy violation responses. Zilber et al. (2007) demonstrated that emotional images elicited largely positive LPP peaks when compared to non-emotional images; perhaps this study more thoroughly accesses this paradigm, rather than the expectancy violation paradigm, because the images more successfully access emotional channels. The ratings of images suggest that subjects did indeed find emotional congruence within the image set, with positive images eliciting high ratings in terms of happiness and negative images eliciting low ratings, which suggests that the images were comprehensible on an emotional level. Perhaps this emotionality resulted in a more positive LPP waveform, over and above the less positive expectancy violation peak. It is also possible that both this and the other suggested explanation interacted together to form the present pattern of results.

Subjects in the pilot study rated the “random” target images as highly surprising, and subjects appeared to take considerably longer to rate these images on their happiness than positive or negative images; both behavioral results indicate that the images were accessing the
intended emotions. However, subjects did not show an increased LPP, which has been shown to result from “interpretation biases” (Moser et al., 2008)—thus implying that subjects were not suffering from such biases, or these biases were being shadowed by other factors. That is to say, the results of this study do indeed confirm the basic suggestions of past studies (e.g., Krompinger et al., 2008; Schupp et al., 2006) which indicate that emotional content of images will generate the Late Positive Potential. Krompinger et al. (2008) demonstrated that attention paid to emotional stimuli can be controlled, as was partially shown in the current study. The current task, however, was more complex than these studies, which focused on simple observation of single presented images.

However, the current study was unable to replicate the findings of Zilber et al. (2007), who suggested that an attentional bias was present in subjects with high attachment-anxiety and attachment-avoidant ratings. Zilber et al. had subjects categorize emotional images; they found more positive LPPs in response to negative images. Zilber et al. showed a relationship between attachment style and LPP response to these emotional images that was not present in the current study. That is not to say that one cannot replicate Zilber’s findings, but rather that attachment ratings did not actively affect the analyses in a manner that suggested meaning. Within subjects, attachment scores on the attachment measures did not meaningfully interact with the EEG analyses.

What we did find was that subjects’ EEG responses were influenced by the type of image—positive and negative images unilaterally demanded more positive LPP peaks, when compared to random or neutral target images. This was true both in-sequence and solo, and was more pronounced when in-sequence, demonstrating an image type by context interaction—yet this interaction was reversed for random and neutral images, for these images had less of an LPP
for in-sequence images, as demonstrated in Figure 1. These non-emotional images, it seems, were more comprehensible to subjects when presented on their own, and therefore resulted in increased LPP response, for their emotional valence could then be deduced.

These results as a whole suggest that the social stimulation images are not yet accessing the relationship schemas that would cause a modulation of subject response. There is a trend in the avoidance subscale of the ECR-R towards such a covariance, which suggests that population variations in attachment might result in results that more closely approximated Zilber et al.’s (2007), if confounding variables were removed. It seems possible that the current images require too complex a level of processing to result in the desired effects, and also possible that attachment is not being wholly accessed in these image schemes.

Attachment in this study was assumed to be accessed when subjects were asked to evaluate the emotions (happiness) of a character within a relationship scene. However, it is possible that subjects did not adequately identify with the character in the drawings, and therefore did not use their attachment schemas. It is also possible that the drawings were too detailed, and the characters difficult to identify with for some other reason. These images were very different from those used in most such studies (e.g., Zilber et al., 2007), which often draw their images from the well-validated International Affective Picture System. The images in this study were linked, however, in scenes, and were validated through the pilot study. However, for many of the analyses for which attachment was expected to play a role, the results did not even approach significance—suggesting that there may be a more complex variable than image set involved. Perhaps attachment as it is assessed by the ECR-R and AAQ measures an aspect of attachment that does not apply to imagined relationships, or perhaps it is not accessed by asking
subjects to rate happiness. Regardless, it seems clear that the task studied herein did not show an influence of attachment style.

Following from the analyses of Moser et al. (2008), in the current research we also evaluated the peak known as the P600, which is similar to the P300/LPP peak, and found similar results: the P600 also showed an interaction between context and image type that resulted in increased amplitude for the emotional (positive and negative) target images, especially when in-sequence. There was also a main effect by site, as in the LPP, wherein the P600 was more positive in posterior sites such as Pz. This effect also interacted with context and image type, becoming more pronounced for emotional images. This appears to suggest that the emotional images were accessing brain regions located centrally, rather than in the frontal lobe.

Reaction time analyses resulted as might be expected: images in-sequence took longer to respond to. Interestingly, neutral images took considerably longer to respond to than the other image types, suggesting that because of their ambiguous emotional content, subjects were unable to decide whether their characters were happy, and therefore took more time.

Looking at responses to the question of whether the character in each target image was happy, again we saw the expected pattern that was demonstrated in the pilot study: subjects rated the positive images as positive, the negative images as negative, and the random and neutral images as equivalent to each other, somewhere in-between. This indeed validates the emotionality of the images as intended, lowering the possibility of errors based on subjects processing the images incorrectly. Solo target images were rated as having very slightly happier characters than images in-sequence, suggesting that the context provided some cue of negativity for all subjects. It is important, of course, to recall that the images were always presented in-
sequence first, and therefore there was a confound of practice, as by the time they were presented alone, they had already been seen twice.

In reviewing the results of this study, it becomes clear that while the primary hypotheses were not supported, the hypotheses on which they were based were for the most part. That is to say, the social image sequences designed for the study did indeed elicit a response due to their emotional content, as demonstrated by Schupp et al. (2006), and others—social images can provide brain responses that correspond to their value. It would be interesting and enlightening to differentiate between mildly emotional social images (e.g., a man and a woman holding hands, a man and a woman looking displeased) and strongly emotional social images (e.g., a man and a woman being married, a man and a woman arguing animatedly). This might provide some insight as to whether the relationship between the LPP and emotional content covaries, and perhaps eventually provide some insight into the current study’s results. As discussed above, further studies may also wish to discuss the results with another type of random images—unexpected images that differ based on physical cues, rather than semantic ones. Perhaps this method would enable the study to demonstrate a concrete expectancy violation.

Moreover, it would seem interesting to attempt to differentiate further between attachment-anxiety as a scale and common models of anxiety—the STAI-Trait and BFNE both correlated strongly with both scales of both the ECR-R and the AAQ. This suggests that all of these scales are accessing a similar concept, and one that bears further differentiation. Although neither anxiety scale predicted the neural response to pictures any more clearly, it would be interesting to see how attachment, defined specifically in human (romantic) relationships, could pull apart from a more generalized anxiety, and a very specific anxiety of others. Are these separate processes and schemas in the brain? Or are they parallel functions that access similar
processes? This has been discussed theoretically (e.g., Mikulincer & Shaver, 2007), with suggestions that the two ideas are similar but distinct, but appears not to have yet been investigated neurologically.

While there were no apparent difficulties in sample-size, it would have perhaps been useful to use subjects who were more extreme on the attachment scales used; the subjects did not score highly on either scale, and while their ranges was not minimal, it tended towards the low (“secure”) end of the scale. In fact, the scales with larger ranges (the avoidance subscale of the ECR-R and the anxiety subscale AAQ) were the ones that had significant covariance with the EEG data, suggesting that a greater range in subject’s responses might be efficacious.

The current study failed to differentiate between groups based on their attachment styles, or to provide attachment style bases for EEG differences in subjects. However, attachment remains an interesting field of study, and it seems likely that further research will attempt to find further bases for attachment processes in the neural structures of the brain. If EEG is to be used, the Late Positive Potential remains a peak that may be influenced by higher-order attachment processing. Improvements of the current methods, as discussed above, might be fruitful, allowing future study to determine a relationship between attachment style and ERPs in this or a similar task of sequential image presentation. By so doing, we might gain a better understanding of how individual differences in attachment style shape the attention we pay to others.
References


Appendix A:

Figure 1. Graphic representation of the avoidance and dependence continua as suggested by Bartholomew and Horowitz (1991). Low-dependence and low-avoidance result in secure attachment, while higher ratings on the dependence dimension characterizes attachment-anxiety and higher ratings on the avoidance continuum characterizes avoidance. (Modified from Bartholomew & Horowitz, 1991.)
Appendix B:

Appendix C:
Experiences in Close Relationships Scale.

The statements below concern how you feel in emotionally intimate relationships. We are interested in how you generally experience relationships, not just in what is happening in a current relationship. Respond to each statement by indicating how much you agree or disagree with the statement. [items are rated on a 7-pt scale]

1. I'm afraid that I will lose my partner's love.
2. I often worry that my partner will not want to stay with me.
3. I often worry that my partner doesn't really love me.
4. I worry that romantic partners won't care about me as much as I care about them.
5. I often wish that my partner's feelings for me were as strong as my feelings for him or her.
6. I worry a lot about my relationships.
7. When my partner is out of sight, I worry that he or she might become interested in someone else.
8. When I show my feelings for romantic partners, I'm afraid they will not feel the same about me.
9. I rarely worry about my partner leaving me.
10. My romantic partner makes me doubt myself.
11. I do not often worry about being abandoned.
12. I find that my partner(s) don't want to get as close as I would like.
13. Sometimes romantic partners change their feelings about me for no apparent reason.
14. My desire to be very close sometimes scares people away.
15. I'm afraid that once a romantic partner gets to know me, he or she won't like who I really am.
16. It makes me mad that I don't get the affection and support I need from my partner.
17. I worry that I won't measure up to other people.
18. My partner only seems to notice me when I'm angry.
19. I prefer not to show a partner how I feel deep down.
20. I feel comfortable sharing my private thoughts and feelings with my partner.
21. I find it difficult to allow myself to depend on romantic partners.
22. I am very comfortable being close to romantic partners.
23. I don't feel comfortable opening up to romantic partners.
24. I prefer not to be too close to romantic partners.
25. I get uncomfortable when a romantic partner wants to be very close.
26. I find it relatively easy to get close to my partner.
27. It's not difficult for me to get close to my partner.
28. I usually discuss my problems and concerns with my partner.
29. It helps to turn to my romantic partner in times of need.
30. I tell my partner just about everything.
31. I talk things over with my partner.
32. I am nervous when partners get too close to me.
33. I feel comfortable depending on romantic partners.
34. I find it easy to depend on romantic partners.
35. It's easy for me to be affectionate with my partner.
36. My partner really understands me and my needs.
Appendix D:
The Adult Attachment Questionnaire:

Answer each item on a 7-point Likert-type scale, where 1 = strongly disagree and 7 = strongly agree.

1. I find it relatively easy to get close to others.
2. I'm not very comfortable having to depend on other people.
3. I'm comfortable having others depend on me.
4. I rarely worry about being abandoned by others.
5. I don't like people getting too close to me.
6. I'm somewhat uncomfortable being too close to others.
7. I find it difficult to trust others completely.
8. I'm nervous whenever anyone gets too close to me.
9. Others often want me to be more intimate than I feel comfortable being.
10. Others often are reluctant to get as close as I would like.
11. I often worry that my partner(s) don't really love me.
12. I rarely worry about my partner(s) leaving me.
13. I often want to merge completely with others, and this desire sometimes scares them away.
14. I'm confident others would never hurt me by suddenly ending our relationship.
15. I usually want more closeness and intimacy than others do.
16. The thought of being left by others rarely enters my mind.
17. I'm confident that my partner(s) love me just as much as I love them.
Appendix E:
Brief Fear of Negative Evaluation Inventory

[each item is rated on a 4-point scale]

1. I worry about what other people will think of me even when I know it doesn't make any difference.
2. I am unconcerned even if I know people are forming an unfavorable impression of me.
3. I am frequently afraid of other people noticing my shortcomings.
4. I rarely worry about what kind of impression I am making on someone.
5. I am afraid that others will not approve of me.
6. I am afraid other people will find fault with me.
7. Other people's opinions of me do not bother me.
8. When I am talking to someone, I worry about what they may be thinking about me.
9. I am usually worried about what kind of impression I make.
10. If I know someone is judging me, it has little effect on me.
11. Sometimes I think I am too concerned about what other people think of me.
12. I often worry that I will say or do the wrong things.
Appendix F:
State-Trait Anxiety Inventory

Part 1. Directions: Please read each statement and indicate how you feel right now, that is at this moment. There are no right or wrong answers.

[Each item is rated on a four-point scale]

1. I feel calm.
2. I feel secure.
3. I am tense.
4. I feel strained.
5. I feel at ease.
6. I feel upset.
7. I am presently worrying over possible misfortunes.
8. I feel satisfied.
9. I feel frightened.
10. I feel comfortable.
11. I feel self-confident.
12. I feel nervous.
13. I am jittery.
15. I am relaxed.
16. I feel content.
17. I am worried.
18. I feel confused.
19. I feel steady.
20. I feel pleasant.

Part 2. Directions: Please read each statement and indicate how you generally or typically feel.

1. I feel pleasant.
2. I feel nervous and restless.
3. I feel satisfied with myself.
4. I wish I could be as happy as others seem to be.
5. I feel like a failure.
6. I feel rested.
7. I am “calm, cool, and collected”.
8. I feel that difficulties are piling up so that I cannot overcome them.
9. I worry too much over something that doesn’t really matter.
10. I am happy.
11. I have disturbing thoughts.
12. I lack self-confidence.
13. I feel secure.
15. I feel inadequate.
16. I am content.
17. Some unimportant thought runs through my mind and bothers me.
18. I take disappointments so keenly that I can’t put them out of my mind.
19. I am a steady person.
20. I get in a state of tension or turmoil as I think over my recent concerns and interests.
Appendix G:
Experiences in Relationships

1. Are you currently involved in a romantic relationship?  (yes/no)
2. Have you even been involved in a romantic relationship? (yes/no)
3. What do you consider your primary sexual orientation?
   (heterosexual/homosexual/bisexual/other/prefer not to respond)
4. What is your gender?  (male/female)
5. What racial group do you most identify with? (white/African-American/Asian or Pacific
   Islander/ Hispanic or Latino/ multiracial/other)
Appendix H: Tables and Figures

Table 1  
Correlations between Anxiety Measures and Attachment Measures (N = 40)

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* p < .05; ** p < .01

Note. ECR-R: Experiences in Close Relationships Questionnaire, Revised. AAQ: Adult Attachment Questionnaire. BFNE: Brief Fear of Negative Evaluations Questionnaire. STAI: State-Trait Anxiety Inventory.
### Table 2
*How presentation in or out of context changes the main effect of target image type on RT*

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### Table 3
*How presentation in or out of context changes the effect of site on the LPP*

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Table 4
*The interaction between site, target image type, and context on the LPP.*

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Table 5

*How the effect of site on the LPP is influenced by the AAQ’s anxiety subscale.*

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Table 6

*How presentation in or out of context changes the main effect of target image type on the P600*

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Table 7
The interaction between main effect of site, target image type, and context on the P600.

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Figure Captions

*Figures 1-6.* These figures show the averaged EEG across subjects and trials. Figures 2-4 include data from in-sequence trials, and Figures 5-7 show data from solo trials. Within this context, each figure shows a different site location—Pz, Cz, and Fz—and includes four lines for image-type. The effects of target image type are most noticeable on images 2 and 5, which show Pz, and are more noticeable on the in-sequence images. Figure 2 shows that the target images that were negative and positive had significantly more positive LPP peaks than the neutral (no change) and random images.

*Figure 7.* The interaction between target image type and context. When in-sequence, negative and positive images have significantly greater LPP amplitudes than random and neutral (no change) images. When seen solo, these emotionally valent images invoke a less substantial LPP. The neutral and random images, conversely, evoke a more positive LPP peak when seen solo.
Figure 5

Solo Images
Cz electrode site

Figure 6

Solo Images
Pz electrode site
Figure 7

Context by Target Image Type Interaction

LPP value (μV)

sequence  solo

negative  positive  random  nochange