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Measuring Adult Attachment Representation in an fMRI Environment: Concepts and Assessment

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Abstract
Human attachment is defined as a biologically based behavioral system that influences motivational, cognitive, emotional, and memory processes with respect to intimate relationships (parents, life partner, own children). Recent neurobiological studies in this field have in common that they investigated social relationships by examining fMRI neuroimaging patterns while individuals viewed pictures of their beloved relationship partner versus friends, acquaintances, strangers, or mothers' responses to their young children. The researchers showed that the neural underpinnings of these unique intimate emotional states are linked to functionally specialized areas in the brain. Conceptualizing this work from a behavioral systems-attachment theory perspective, these studies did not directly address the subject's attachment representational system. Traditional attachment theory and research has been built on the analysis of attachment narratives, called 'attachment representation'. The Adult Attachment Projective developed by George and West in 2001 is a set of attachment-based schematic pictures. It is constructed to increasingly activate the participant's attachment system in the course of the task, that is, by the introduction of increasingly stressful attachment scenes concluding with pictures of individuals facing death and potential abuse alone. The attachment patterns are evaluated based on individuals' overall verbal response to the picture set. This paper proposes that the AAP is a fruitful measure to use in an fMRI environment to examine brain activation patterns in adults while they are speaking overtly about attachment stories in a standardized setting.

Attachment theory is an evolutionary-based theory of a specific type of intimate human social relationship conceived to have a major developmental influence from 'the cradle to the grave' [1]. According to attachment theory, the foundation of attachment relationship is a biologically based behavioral system that evolved in ways that influence and organize motivational, cognitive, emotional and memory processes. These processes are organized in early infancy with respect to significant caregiving figures and extend into adulthood with the addition of at-

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tachment to intimate adult partners. Attachment represents an organized set of behaviors (seeking proximity, vocalization, crying, following) directed toward a figure, who is wiser, stronger, and can provide protection, care and comfort [1]. This behavior is adaptive (both in an ultimate, evolutionary perspective and in a proximate, immediate care perspective) in that it keeps infants and children close to their primary caregivers. This early provision of care, thus, improves the chances of infant survival and parent reproductive fitness. It is important to emphasize here that the attachment behavior that serves the attachment relationship is thought to be organized and guided by a neurologically based mental or representational system [2–4]. Over the life course, this representation system continues to guide behavior and adds meaning to the individual's expectations and understanding of attachment-related experience and is an important contributor to the individual's development.

Two types of conditions are thought to activate the attachment behavioral system (i.e., create a condition where the individual desires proximity and often physical contact with a primary attachment figure, such as parent). One condition is experience of anxiety or stress-provoking internal conditions that, ultimately, could threaten an individual, especially a young child (illness, fatigue, hunger, pain). The other condition is experience related to dangerous appraisals of the environment, including interpretations of risk or threat such as separation from the attachment figure or the presence of a stranger. When activated, the child depends on the response of the attachment figure to comfort, soothe, and protect and, thus, produce feelings of safety or security that terminate the attachment arousal [2–4]. In adolescence and adulthood, mental representations of attachment figures can often replace the need for physical proximity to attachment figures that is required during childhood [5].

Over the course of more than three decades since Bowlby's seminal treatise, attachment theory and research have demonstrated empirically that qualitatively different experiences of receiving care from the attachment figure is related to the organization of the attachment relationship [e.g., 6–8]. There are four major patterns of attachment (also known as attachment status) defined in infant and child literature. These patterns have more recently been expanded to understand attachment behavior and representation in adults. In order to fully understand the adult patterns core to studying neurological correlates in adults, we must describe the nuances of attachment status in childhood.

Three of these patterns were originally identified by Ainsworth et al. [9]: secure, insecure-avoidant, and insecure-ambivalent-resistant. These patterns represent 'organized' patterns of attachment; each behavioral pattern demonstrates a clear strategy by which the infant seeks proximity to and/or contact with attachment figures when the attachment system is activated. Infants judged 'secure' demonstrate their preference for identified attachment figures and confidence that these attachment figures can soothe and care for them. Their confidence is based on consistent experience of attachment figures as available and sensitively responsive to their signals and bids for physical contact or proximity when they are distressed. When the experience of responsiveness and sensitivity has been compromised, infants develop insecure relationships with their attachment figures. Under these conditions, the infants cannot find comfort from attachment figures [6] and develop ways to first modulate their own distress prior to approach. These infants develop a coherent 'organized' set of secondary attachment strategies [7]. Sometimes infants experience caregivers as predictably rejecting with respect to attachment signals. These children, called 'insecure-avoidant', avoid eye contact and physical proximity during the initial minutes of reunion when the attachment figure is once again available after separation in the Strange Situation (a laboratory separation-reunion sequence). Sometimes infants experience caregivers as unpredictably responsive [8] and seek but cannot find comfort from attachment figures. These infants, called 'ambivalent', develop behavioral strategies that emphasize or heighten attachment cues, such as maintaining closer proximity or crying longer and more loudly than other infants. Because of the inconsistency of attachment figure responsiveness to even these heightened cues, these infants demonstrate that they are 'ambivalent' about their attachment figures.

These secondary behavioral strategies afford the infant the opportunity to regulate attachment distress so that they can subsequently approach attachment figures, or accept contact and interaction. These strategies work to a degree to alleviate distress but place strong reliance on the infant over the attachment figure to manage attachment distress. The essential feelings of security are, thus, compromised.

Since Ainsworth's original studies, researchers identified a fourth group of infants whose attachment strategies and responses to the attachment figure did not fit the organized patterns of the secure, avoidant, or ambivalent-resistant groups [10]. Contemporary theory understands their response to the attachment figure as representing a

diverse array of fear behaviors, including acting disoriented, seemingly undirected, or caught in an extreme approach/avoidance conflict. These infants are observed to be frightened and conflicted under the exact conditions in which organized infants are seeking some form of proximity or contact with the attachment figure. The fear is so strong that it dysregulates organized patterns of attachment behavior. The infant's behavior is conceived to be the product of the attachment figure's frightened or frightening behavior during caregiving-infant interaction [11], combined with hostile-intrusive caregiving in abusive or other threatening caregiving environments [12] that, ultimately, according to Solomon and George [13] results in a 'breakdown' in the infant's attachment system. The infant's subjective appraisal of attachment figures is that they will not and/or cannot provide protection and care and even secondary strategies fail to provide minimally successful attempts to maintain protective attachment relationships. As a result, the infant is left feeling helpless, frightened, and abandoned [12]. Once again, the essential feelings of attachment security have been compromised and the quality of attachment that 'disorganized' infants have with their caregivers is insecure. The experience of insecurity, however, is more extreme than organized insecurity and potentially more debilitating (i.e., a stronger risk factor to development) [12]. These infants are insecure because attachment behavior and the relationship itself fails to result in the care they need; they are hypervigilant and constantly on the edge of being dysregulated.

Attachment theory proposes that repeated experiences with the caregiver during infancy and childhood become encoded in implicit memory first as expectations and then as internal models of attachment [2, 3, 14, 15]. The quality of attachment in infancy (termed 'status') influences development across the life span. Research shows a significant relation between a mother's representations of her childhood attachment experiences and the observable attachment pattern of the one-year-old child [16–18]. Further, under typical childrearing conditions, organized attachment status shows significant stability in children from 1 to 10 years of age. The prognostic value of attachment experiences or deficits is high for the later social development, including self-image, self-esteem, social competence, and cognitive ability [19, 20]. Recent animal studies have found biochemical correlates of attachment-related experiences, with separation and loss unfavorably affecting primates [21–23]. As predicted by theory, studies have demonstrated an intergenerational 'transmission' of attachment to future generations by transmission of representational and behavioral patterns of sensitivity of the parent's own attachment experience and subsequent transformations of childhood experience through the parent's caregiving system [24, 25]. Intergenerational patterns are the strongest for secure mother-infant dyads, weaker for organized insecure dyads, and the least robust where attachment status in either mother or child is disorganized.

Bowlby [3] described attachment as a key mechanism related to maintaining biological homeostasis, including the modulation of physiological stress and mental health. Researchers have found physiological correlates of attachment and the affective components of relationships in nonhuman species and humans. Oxytocin, endogenous opioids and norephinephrine have been implicated in various kinds of relationships, including attachment behavior in animals [26, 27]. Kraemer [28] stated that the attachment system is not only an organizing feature of basic neurophysiological function but also the central organizing system in the brain of higher mammals. The mother-infant relationship in rat pups regulates the infant's neural system and its loss or dysfunction implies poor modulation and coordination of physiological function, affect, and behavior [29]. Moles et al. [30] reported a deficit in attachment behavior in mice lacking the μ-opioid receptor gene, providing perhaps a genetic link to understanding severe attachment problems, such as autism or reactive attachment disorder. Lim and Young [31] showed for the first time, that vasopressin neurotransmission occurs in the ventral pallidum during mating in male prairie voles, and that its V1a receptor subtype (V1aR) is necessary for bond formation. Insel and Young [32] asked the intriguing question, if animal studies of attachment relating based on neuropeptides are relevant to human love.

Research has not studied adult brain activation patterns as related to attachment; however, there are studies related more broadly to human social relationships. One fMRI study investigated intimate social relationships in adults. Individuals looked at pictures of their intimate partners vs. faces of unknown persons. This study found activation in the right insula for the 'partner' condition [33]. Another study examining intimate relationships (participants were exposed to pictures of beloved partners as opposed to close, nonromantic friends) found bilateral activation in the anterior cingulate (BA 24), medial insula (BA 14) as well as caudate and putamen [34]. The pattern of cortical activation was distinct from previous studies of face recognition, visual attention, sexual arousal or other emotional states, but resembled preliminary

Table 1. Main effect of picture presentation (n = 11, one-sample t test, p < 0.001 at the voxel, p < 0.05 at the cluster level, both uncorrected)

Region	Hemisphere	Putative BA	x	y	z	Z
Anterior cingulate	R	24	18	0	48	4.63
Superior frontal gyrus	L	6	–6	12	66	4.31
Middle frontal gyrus	L	6	–36	6	51	4.11
Precentral gyrus	R	6	54	–6	12	4.02
Precentral gyrus	L	6	–45	–9	36	4.19
Superior temporal gyrus	R	22	63	–12	0	3.78
Middle temporal gyrus	R	21	54	0	–18	3.92
Middle temporal gyrus	L	21	–57	3	–9	4.04
Occipital cortex	R	18	27	–93	3	5.17
Occipital cortex	L	18	–33	–93	6	4.63
Caudate nucleus	L		–15	6	21	4.26
Globus pallidus	L		–21	–12	–3	3.74
Cerebellar vermis	R		3	–63	–9	4.30
Cerebellar hemisphere	R		18	–50	–21	3.97
Cerebellar hemisphere	L		–18	–50	–18	3.89

x, y, z are coordinates of the MNI template in SPM 99, Z is the z-value of the most significant voxel in the region.

Table 2. Interaction effect for 'unresolved > resolved increasing activation of the attachment system' (resolved: n = 6, unresolved: n = 5, ANOVA, p < 0.001 at the voxel, p < 0.05 at the cluster level, both uncorrected)

Region	Hemisphere	Putative BA	x	y	z	Z
Inferior frontal	R	45	51	39	3	4.75
Superior temporal gyrus	L	22	–42	–33	–18	3.88
Caudate nucleus	L		–9	21	0	4.73
Amygdala-hippocampal region	L		–21	–15	–12	4.18
Amygdala	R		27	6	–24	4.00

x, y, z are coordinates of the MNI template in SPM 99, Z is the z-value of the most significant voxel in the region.

results from an fMRI study of new mothers listening to infant cries [35]. Strathearn and McClure [36] investigated maternal responses to infant facial cues using fMRI and explored the possible role of oxytocin in facilitating this interaction in a sample of 8 mothers. Comparisons of the mothers' responses to their own infants versus unknown infants, showed significantly increased bilateral brain responses in the ventral striatum, hippocampus, globus pallidus, thalamus, and fusiform face area. A positive, but nonsignificant trend was seen in serum oxytocin concentration during mother-infant interaction. The authors concluded that a unique pattern of neural activation was evident, with areas of activation including brain reward circuits, the limbic system and areas involved in memory consolidation.

In a study focusing on intimacy in the context of filial relationships, Bartels and Zeki [37] measured brain activity in mothers while they viewed pictures of their own and of acquainted children, their best friends, and acquainted adults as additional controls. The brain activation pattern observed was interpreted as analogous romantic love described in their earlier study [34] and was related to the distribution of attachment-mediating neurohormones described in other studies. Both types of attachment deactivated a common set of regions associated with negative emotions, social judgment and mentalizing, that is, the assessment of other people's intentions and emotions. The authors concluded that human attachment employs a push–pull mechanism that overcomes social distance by deactivating networks used for their critical social assessment and negative emotions, while it bonds individuals through the involvement of the reward circuitry. This view is consistent with views of human social emotion regulation [e.g. 38, 39].

Nitschke et al. [40] explored brain activation patterns when young mothers were shown pictures of their babies as well as pictures of unfamiliar infants and adult faces during acquisition of fMRI. Mothers exhibited bilateral activation of the orbitofrontal cortex while viewing pictures of their own versus unfamiliar infants. In the scanner, mothers rated their mood more positively for pictures of their own infants than for unfamiliar infants, adults, or at baseline. The orbitofrontal activation correlated positively with pleasant mood ratings. In contrast, the areas of visual cortex that also discriminated between own and unfamiliar infants were unrelated to mood ratings. These data implicate the orbitofrontal cortex in a mother's affective responses to her infant, an interpretation that is consistent with thinking about the role of the orbitofrontal cortex in emotional regulation [41]. Individual variations in orbitofrontal activation to infant stimuli may reflect an important dimension of maternal attachment.

What all these recent studies have in common is that they studied intimate social relationships, especially

mothers' responses to their young children, by examining fMRI neuroimaging patterns while individuals viewed pictures of their beloved relationship partner versus friends, acquaintances, or strangers. The researchers showed that the neural underpinnings of these unique intimate emotional states are linked to functionally specialized areas in the brain. Conceptualizing this work from a behavioral systems-attachment theory perspective, these studies demonstrate unique emotional states and brain activation patterns associated with important relationship behavioral systems – the caregiving behavior system and the sexual behavioral system (romantic partnerships) [15, 42, 43]. These studies did not directly address the attachment system; however, the results are especially interesting, especially the results of studies involving mothers. Mothering is organized by the caregiving system and attachment and caregiving are reciprocal and complementary behavioral systems [2, 3, 24, 42]. These studies then set the stage to pose hypotheses regarding the neurological correlates associated with the activation of attachment.

It is also important to note that these studies examined fMRI patterns in response to mothers viewing pictures of their social partners (infant, romantic partners). Pictures are good fMRI stimuli, however, there is no corresponding methodology in attachment adult research. Contemporary attachment theory and research has been built on the analysis of attachment narratives, called 'attachment representation'. As we mentioned earlier, Bowlby [2, 3] proposed that the inner working model of attachments with primary attachment figures is the mental foundation of the attachment relationship. Attachment researchers assess this representation in adults by using measures that focus on the linguistic and mental organization of speech.

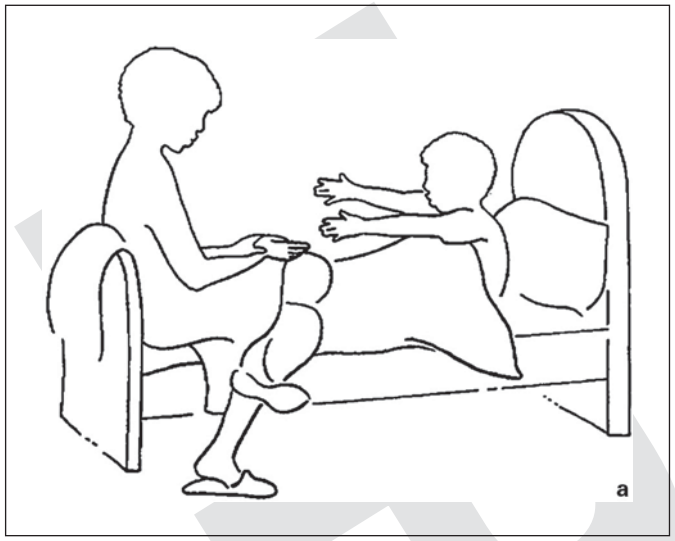
Until recently, the measurement of adult representations of attachment depended on the use of a lengthy clinical interview, the Adult Attachment Interview [44]. Recently, George et al. [45] developed and validated [46] a new measure to assess adult mental representations of attachment, the Adult Attachment Projective (AAP), which is based on the analysis of a set of projective attachment stimuli.

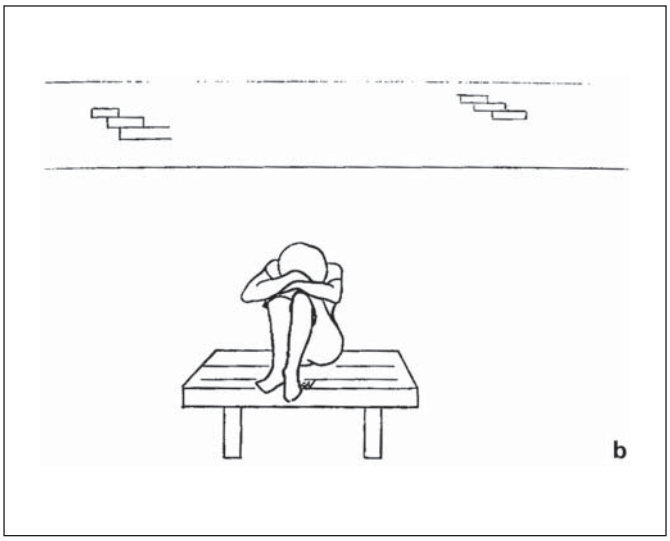
The AAP is comprised of a set of eight drawings, one neutral scene and seven attachment scenes. The AAP pictures are simple line drawings that depict events that, according to theory and research, activate the attachment system, for example illness, solitude, separation, and abuse. The drawings contain only sufficient details to identify an event; strong facial expressions and other potentially biasing details are absent. The seven attachment pictures include four scenes where individuals are portrayed as being alone (monadic) and three scenes where individuals are portrayed in dyadic relationships (fig. 1a–c): Child at Window – a child looks out a window; Departure – an adult man and woman stand facing each other with suitcases positioned nearby; Bench – a youth sits alone on a bench; Bed – a child and woman sit opposite each other on the child's bed; Ambulance – a woman and a child watch someone being put on an ambulance stretcher; Cemetery – a man stands by a gravesite head stone, and Child in Corner – a child stands askance in a corner.

The standard administration of the AAP under normal conditions takes approximately 25 min. An interviewer guides the individual through the picture set using a series of standardized prompts to help elicit story details regarding what is happening in the situation, what led up to the scene, what the characters are thinking or feeling, and what happens at the end. Interviewer interaction with the participant is minimal and prompts are used only as needed. The probes that are used are open ended and administrators are prohibited from suggesting information, ideas, or lead the participant toward particular stories or themes. Many individuals provide complete stories without prompting.

The AAP classification system designates the four adult attachment classification statuses that parallel infant/child classifications [14, 16]: secure, dismissing, preoccupied and unresolved. AAP classification is done from the transcribed verbatim narratives of the individual's response to the attachment picture stimuli, which are coded using a validated system that is described in a well-detailed manual [45, 46]. In essence, the picture stimuli activate the attachment system; individuals draw upon their mental representations of attachment to tell their stories. Accordingly, although not defined as autobiographical, the story lines constructed provide information concerning how different situations activate attachment, how internalized representations of attachment are organized, and how these guide individuals' beliefs about their worthiness to receive care and the availability and accessibility of attachment figures when needed [2, 45]. It is these beliefs, or the unconscious defensive transformation of their beliefs, that become evident during the story telling process.

When an individual's attachment representation is secure, stories include themes regarding attachment needs, protection, and caring and balanced interactions with attachment figures. When attachment figures are not obvi-





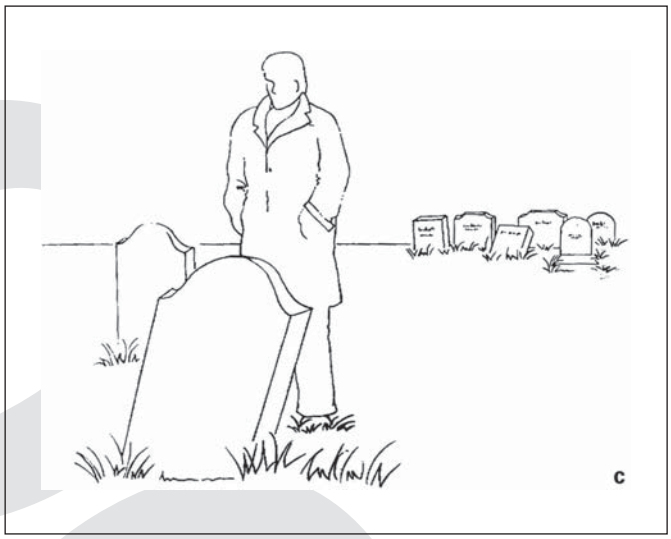


Fig. 1. a AAP picture 'Bed'. **b** AAP picture 'Bench'. **c** AAP picture 'Cemetery'.

ously available in drawing (e.g., 'alone' pictures), secure individuals demonstrate the use of internalized representations of attachment security to address attachment distress. Importantly, there is little evidence of defensive exclusion in the stories of secure individuals. By contrast, when an individual's attachment representation is insecure, attachment and the self are compromised (along the lines of the secondary strategies we described earlier). The personal and affectively charged elements in these stories are distorted through defensive processes as a way of modulating attachment distress from attention and memory [4, 14, 45].

Bowlby [4] described an extreme form of defensive exclusion that prevails when individuals have experienced attachment trauma (e.g., as associated with loss through death, abuse, threat of abandonment [12, 13, 45, 47–49]). He termed the representational product of this extreme form of exclusion the 'segregated system'. The processes of segregation acts to defensively separate or remove from consciousness the painful and potentially dysregulating affect and cognitions associated with the trauma. These separated segregated representational systems are brittle and prone to dysregulation and disorganization; this extreme form of defense is vulnerable to breaking down, the phenomenon we described earlier as the foundation of attachment disorganization in infants. The resulting state of representational dysregulation in adults has been termed 'unresolved' attachment.

Thus, the use of a standardized set of attachment-related pictures in the AAP combined with its linguistic analysis and established psychometric properties [45, 46, 50] makes this measure a promising assessment to use in a neuroimaging setting. The AAP uses picture stimuli, already shown to be powerful response-eliciting stimuli in previous fMRI research in social relationship [e.g. 33, 34, 37, 40]. The key responses to these stimuli are the narrative stories, narratives that are the gateway to individual differences in inner working models of attachment.

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