How Do I Love Thee? Adult Attachment and Reinforcement Sensitivity

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Declaration

I hereby certify that this thesis does not contain, without appropriate acknowledgement, any material previously submitted for a degree or diploma in any university. I also certify that this thesis does not contain, to the best of my knowledge, any material previously published or written by another person, except wherein reference is made.

Yixin Jiang

Abstract

The central aim of this thesis was to examine the nature of the relations between individual differences in adult attachment patterns and the sensitivity of motivational systems – the Behavioural Approach System (BAS), the Fight-Flight-Freeze System (FFFS), and the Behavioural Inhibition System (BIS) – as proposed by the revised reinforcement sensitivity theory (r-RST). As few studies have been conducted on the integration of these two domains (no studies have looked at links with all three motivational systems), further research may inform how the attachment behavioural system is related to general motivational mechanisms. Three studies were conducted to address this research question using self-report, behavioural, and neurophysiological methodologies.

The purpose of the first study was to collect preliminary data on the nature of the relations between adult attachment and reinforcement sensitivity at the psychometric level. A total of 225 first year psychology students completed the Experiences in Close Relationships-Revised scale (ECR-R) as an index of adult attachment. To assess reinforcement sensitivity, participants completed proxy measures including the Fear Survey Schedule (FSS) and the trait anxiety scale from the State-Trait Anxiety Inventory (STAI), along with the purpose-built measures of Carver and White's (1994) BAS scale (CW-BAS) and Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ), the latter of which is theoretically faithful to the revised theory. The results of the correlations, and, to a lesser extent, regressions, suggest differential links between attachment avoidance and BAS sensitivity, and between attachment anxiety and FFFS sensitivity, though both of these associations were modest. Hierarchical multiple regressions revealed that both attachment dimensions are significantly related to BIS sensitivity, which suggests that sensitivity to motivational ambivalence is a central feature of attachment insecurity.

Building upon the psychometric data obtained in Study 1, the purpose of the second study was to compare the prediction of individual differences in adult attachment and reinforcement sensitivity to behaviour in a virtual attachment-related separation scenario. In this study, 200 psychology undergraduates played a virtual social environment (VSE) game in which participants could direct a game character (the protagonist) to engage in solo activities, interact with his or her virtual spouse, and/or interact with other characters in the game. During the game, a critical scenario occurs where the virtual spouse had to leave the protagonist, and this was later followed by a reunion scene. Following the game, participants completed self-reported adult attachment and reinforcement sensitivity questionnaires. Multilevel and regression analyses revealed that attachment anxiety was associated with heightened distress overall and during separation, while attachment avoidance was related to more negative interactions overall and less emotional relief following reunion. In contrast, reinforcement sensitivity was generally unrelated to behavioural and affective responses to separation and reunion. These results suggest that adult attachment and reinforcement sensitivity do not share overlapping predictions to attachment behaviour, with the former having greater predictive power as situationally more relevant constructs.

Finally, the purpose of the third study was to examine the links between adult attachment and reinforcement sensitivity and neurobiological markers of approach and avoidance motivation. Individual differences in approach motivation have been linked to electroencephalogram (EEG)-derived neural markers including relative left frontal resting brain activity and relatively greater posterior delta and theta activity. Less consistently, avoidance tendencies have been associated with relative right frontal resting brain activity. In this study, 63 right-handed paid university community volunteers completed self-report measures of adult attachment and reinforcement sensitivity, as well as eight minutes of resting EEG. Aside from some associations between BAS and BIS sensitivities and relatively

greater parietal theta and delta activities, neither adult attachment nor reinforcement sensitivity exhibited strong and robust associations with the resting EEG indices of approach and avoidance motivation. This may reflect the construct heterogeneity of the attachment dimensions and reinforcement sensitivity, such that they do not neatly map onto neural correlates of approach and avoidance.

Together, the studies reported in this thesis suggest modest overlaps between individual differences in adult attachment and reinforcement sensitivities at the self-report level, but the two domains are largely independent in relation to attachment behaviour and neural correlates of approach-avoidance. It remains possible that adult attachment and reinforcement sensitivity are related in a more complex, hierarchical manner. Furthermore, BIS-mediated sensitivity to motivational ambivalence may serve an important role in attachment insecurity, and is an area for future research. The present thesis, nonetheless, contributes to the limited understanding of how the differential functioning of the attachment system is related to the sensitivities of the more general biologically-based motivational systems.

Acknowledgments

My great appreciation and respect goes first to my supervisor, Dr Niko Tiliopoulos, who has nurtured my intellectual growth and encouraged me to strive to be a better scientist. His passion for truth, wise guidance, kind support, and continual faith in my abilities have been vital in making this thesis possible.

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Dedication

To my attachment figures – my parents, my husband, and my God – whose love and support has not only enabled my achievements, but also enabled me to love.

“There is no fear in love. But perfect love drives out fear, because fear has to do with punishment. The one who fears is not made perfect in love...” (1 John 4:18)

Contents

List of Related Publications and Conference Presentations

During my doctoral degree, I have made substantial contributions to the following publications and conference presentations that either directly or indirectly arose out of the present thesis.

Publications

Jiang, Y., & Tiliopoulos, N. (2014). Individual differences in adult attachment and reinforcement sensitivity. *Personality and Individual Differences*, *68*, 205-210.

- **This paper is presented in Chapter 4.**

Jiang, Y., Schönbrodt, F., Fayn, K., & Tiliopoulos, N. (manuscript in preparation). Adult attachment and reinforcement sensitivity as predictors of behaviour in a virtual separation scenario.

- **This manuscript is presented in Chapter 5.**

Tiliopoulos, N., & Jiang, Y. (under revision). The empirical relevance of attachment theory to personality disorders. *Journal of Personality Disorders*. [A version is currently published in ACPARIAN: The Official Newsletter of the Australian Clinical Psychology Association, Issue 4, July 2012)

Conference Presentations

Jiang, Y., Smillie, L., & Tiliopoulos, N. (2014, November). *Adult attachment, reinforcement sensitivity and resting EEG neural correlates.* Paper presented at the 13th Australian Conference on Personality and Individual Differences, Newcastle, Australia.

Jiang, Y., Tiliopoulos, N., & Schönbrodt, F. D. (2014, July). *Individual differences in adult attachment and reinforcement sensitivity: Self-reported links and predictions to*

interpersonal behaviour. Paper presented at the International Association for Relationship Research Conference, Melbourne, Australia.

Jiang, Y., Tiliopoulos, N., Schönbrodt, F. D., de Rosnay, M., & Gatt, J. M. (2013, November). *Individual differences in adult attachment and reinforcement sensitivity as predictors of behaviour in a virtual social environment.* Paper presented at the 12th Australian Conference on Personality and Individual Differences, Brisbane, Australia.

Jiang, Y., Schönbrodt, F. D., Tiliopoulos, N., de Rosnay, M., & Gatt, J. M. (2013, November). *Attachment and motivational influences on behaviour in a virtual social environment.* Paper presented at the 13th Annual Conference of the Australian Psychological Society's Psychology of Relationships Interest Group, Sydney, Australia.

Jiang, Y., & Tiliopoulos, N. (2012, November). *Bridging behavioural systems: Individual differences in self-reported adult attachment and reinforcement sensitivity.* Paper presented at the 11th Australian Conference on Personality and Individual Differences, Melbourne, Australia.

Jiang, Y., & Tiliopoulos, N. (2012, November). *How do I love thee? Self-reported links between adult attachment and fear, anxiety and approach motivations.* Paper presented at the 12th Annual Conference of the Australian Psychological Society's Psychology of Relationships Interest Group, Adelaide, Australia.

Jiang, Y., Penney, E., & Tiliopoulos, N. (2011, August). *Adult attachment styles and emotion regulation in heterosexual and homosexual individuals.* Poster session presented at 5th International Attachment Conference, Oslo, Norway.

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Preamble

In the course of working on this doctoral thesis, I have experienced many joys (such as family relationships, friendships, rewarding research processes and outcomes, along with other positive events); the formation of a new romantic attachment; as well as illness, stress, sadness and disappointment. These experiences are not uncommon in the average person's life, and variably activate the motivational systems that mediate behaviour towards rewarding, threatening, and goal-conflict situations, along with the attachment behavioural system. The overarching purpose of this thesis was to examine the nature of the relations between these fundamental motivational systems that underpin such basic human experiences. Specifically, this thesis aimed to examine the links between two important types of motivational systems: the attachment system, which mediates behaviour in close relationships, and general motivational systems – as proposed by revised Reinforcement Sensitivity Theory (r-RST) – that mediate behaviour towards appetitive and aversive stimuli, and goal conflict. Each of these motivational systems is argued to be fundamental to survival.

The attachment system, as theorised by Bowlby (1969/1982, 1973, 1980), is an evolutionary-based behavioural system that prompts approach towards a close and trusted person (e.g., caregiver or romantic partner) for physical protection and/or emotional comfort when distressed. The importance of this system is most obvious in the early years of life, where the infant or child is reliant upon his or her caregiver for protection. However, attachment behaviour similarly occurs in adulthood whereby an individual seeks out an attachment figure (usually a romantic partner) for protection and comfort when ill, experiencing loss, or otherwise distressed. In this way, the attachment system is critically a universal and fundamental system for dyadic stress regulation. There are individual differences in the functioning of the attachment system, such that individuals experience varying degrees of attachment anxiety (worry about their attachment figure's availability) and

attachment avoidance (discomfort with intimacy) (Brennan, Clark, & Shaver, 1998). These individual differences have been related to diverse range of intrapersonal and interpersonal outcomes (Mikulincer & Shaver, 2007).

Given the importance of the attachment system for survival and stress regulation, it is of interest to investigate how individual differences in the functioning of this system might be related to the sensitivity of more general motivational systems. Gray and McNaughton's (2000) r-RST proposes three general, evolutionary-based, biobehavioural motivational systems that govern behaviour: the Fight-Flight-Freeze System (FFFS), which mediates avoidance behaviour away from threats; the Behavioural Approach System (BAS), which mediates approach towards rewards; and the Behavioural Inhibition System (BIS), which is responsible to resolving goal-conflict. There are individual differences in the sensitivity of the FFFS, BAS, and BIS, which has been related to a range of outcomes including psychopathology, personality, and health.

Very few studies have examined how the attachment system is related to evolutionary-based general motivational systems, let alone to reinforcement sensitivity. This thesis provides an integrative examination of adult attachment and reinforcement sensitivity, and, thereby, aims to provide a better understanding of how individual differences in the functioning of these basic motivational systems are related. The thesis structure is outlined below.

Thesis structure

This thesis is structured into 10 chapters. Chapter 1 provides an in-depth overview of attachment theory. The chapter outlines the origins and fundamental tenets of attachment theory; describes attachment system functioning in both childhood and adulthood; and

highlights important individual differences in attachment patterns, especially in the context of adult romantic relationships.

Chapter 2 provides an overview of the theory and research pertaining to reinforcement sensitivity, and in particular, the sensitivities of the BAS, and BIS. It describes the origins to the RST, briefly outlines Gray's (1982) original theory, and then, of greater relevance to the present thesis, expounds upon Gray and McNaughton's (2000) contemporary theoretical revision. The chapter also highlights issues relating to measurement and operationalisation, and considers various empirical applications of the theory.

Following the chapters describing attachment theory and reinforcement sensitivity, Chapter 3 highlights the important theoretical and empirical relations between the two theories. Possible links between individual difference in adult attachment and the sensitivity of each of the BAS, FFFS, and BIS are discussed in turn, and specific hypotheses are put forward.

Chapters 4 to 9 present the relevant background, methodology, results, and discussion for Studies 1, 2, and 3. Each of these studies were designed to provide insight into the nature of the relations between individual differences in adult attachment and reinforcement sensitivity, using different levels of analyses including self-report, behavioural, and neurophysiological data. Chapter 4 contains a published study focused on the psychometric relations between self-reported adult attachment and reinforcement sensitivity. Chapter 5 contains a submitted manuscript that examined the prediction of adult attachment and reinforcement sensitivity to behavioural and affective response to an attachment-related virtual separation scenario. Lastly, Chapters 6 to 9 details the background, methodology, results, and discussion of Study 3, which examined links between adult attachment, reinforcement sensitivity, and neural correlates of approach and avoidance motivation.

Finally, Chapter 10 provides an overall summary and discussion of the key findings obtained across the three studies. The chapter discusses the theoretical implications of the results with respect to the nature of the relations between individual differences in adult attachment and reinforcement sensitivity. The chapter also identifies some research limitations, applications, and future directions. It concludes with re-visiting the overarching thesis aim and summarising the contribution of the research programme to this aim.

Chapter 1: Attachment Theory

Introduction

From the inception of attachment theory, John Bowlby (1969/1982) regarded the "child's first human relationship as the foundation stone of his [*sic*] personality" (p. 177). Attachment behaviour, which involves seeking close and preferred other persons for support during situations of distress, is not simply an interpersonal phenomenon, but reflects a fundamental biobehavioural motivational system that is central to survival and emotion regulation. The development and functioning of this system, as influenced by early attachment experiences along with innate predispositions, has important consequences for socio-emotional development and personality formation more generally. This section will first overview classical attachment theory, and then describe adult attachment theory, measurement and research, specifically highlighting individual differences in intrapersonal and interpersonal functioning in relation to attachment patterns.

Classical Attachment Theory

Bowlby's attachment theory (1969/1982, 1973, 1980) has its origins in observations of the devastating effects of maternal deprivation in both human and non-human animals. In the 1940s, a number of clinicians observed that institutionalised infants would fail to thrive, both physically and psychologically, despite having their physical needs met (e.g., Bakwin & Bakwin, 1942; Spitz, 1945, 1947). These infants had received little affectionate caregiving (and in some cases, no human touch) as well as prolonged separation from their caregivers. Converging with these observations, Bowlby's (1944, 1951) initial studies of juvenile delinquents and homeless children after WWII also pointed to the adverse psychopathologic effects of early and prolonged maternal separation. Bowlby was furthermore influenced by research emerging from the fields of ethology and comparative psychology that similarly

showed the adverse effects of maternal deprivation in other mammalian species. In particular, Harry Harlow (1958) highlighted the need for "contact comfort", such that when an infant monkey is given a cloth-covered wire surrogate 'mother' to cling to, it survives better than one raised in a bare wire mesh cage or given only a wire-mesh surrogate 'mother', despite nutritional needs being met in all cases. All these observations of maternal deprivation pointed to a fundamental need for affection or love for an infant's healthy physical and emotional growth and development, which is critically served by the infant-mother (or caregiver)[1] bond – and upon this basic but important proposition, Bowlby built his theory of attachment.

Drawing upon evolutionary theory, as well as an ethological perspective, Bowlby (1969/1982) contended that behaviour needs to be studied in their environment of evolutionary adaptedness to shed light on the biological problems. Across early humans and non-human animals, Bowlby argued that the main evolutionary problem is protecting the growing infant from the dangers of predation. In the pioneering ethological work of Konrad Lorenz (1935) and Niko Tinbergen (1951), it is observed that infant non-human animals such as goslings and ducklings develop strong attachment bonds in the form of instinctive proximity-seeking of discriminated parental figures. A parallel observation was made in humans, whereby infants similarly exhibit proximity-seeking behaviour (e.g., crying, clinging, following) towards preferred caregivers (Bowlby, 1969/1982). This lead Bowlby to propose that attachment behaviour in humans likewise serves the important biological function of safety regulation, which includes physical protection from threats as well as emotion regulation when distressed. Attachment behaviour notably manifests in situations of

[1] Most early studies were conducted on and make reference to infants and their mothers. More recent studies and theoretical papers recognise that the primary caregiver may be a person other than the mother, such as the father, other family member or a non-family member. This thesis will use the general, encompassing term 'attachment figure' or 'caregiver.' However, in instances where reference is made to 'mother,' unless otherwise specified, it should be noted that other persons may similarly serve the role of an attachment figure.

alarm as infants instinctively seek out their older, stronger and more able caregivers for protection and comfort. Therefore, at its fundamental level, attachment behaviour is proposed to be an evolved, adaptive, and universal behaviour that serves to enhance the chances of survival.

Following the ethological approach, Bowlby (1969/1982) proposed that attachment behaviour involves multiple, hierarchically organised behavioural control systems. These systems refer to prototypic structures (that is, basic physiological structures) that produce normative, predictable patterns of behaviour, although individual variations can occur as a result of environmental influences. A number of behavioural systems are proposed to mediate attachment behaviour, and these are organised hierarchically from simple reflexive systems to more complex goal-corrected systems. Examples of the former include grasping, crying, and smiling reflexes in early infancy, which are not goal-corrected, while the latter refers to a diverse range of behaviours that are engaged in a non-random manner to achieve an end-goal. With regards to attachment behaviour, the predictable end-goal is proximity to the attachment figure to obtain stress alleviation, and the control systems regulate the proximity to the attachment figure in order to maintain this homeostatic condition. Therefore, attachment behaviour is theorised to be underpinned by multiple simple and complex behavioural systems that serve the common evolutionary-based end-goal of proximity to the attachment figure (Bowlby, 1969/1982).

Whilst having an evolutionary basis and mediated by behavioural systems, the more enduring phenomenon of attachment is defined by Bowlby (1969/1982) as the disposition of an individual, whether child or adult, to seek proximity to differentiated and preferred others (that is, attachment figures) in situations of distress. As such, it manifests as trait-like repetitive patterns of behaviour across situations and persons over time, although it is amendable to new attachment experiences. In infancy, attachment behaviour manifests as any

form of physical proximity seeking when experiencing distress. The newborn infant is equipped with instinctive responses such as crying, smiling, reaching out and other behaviours that serve to engage the attention of and maintain proximity to his or her attachment figure. Older infants may be able to physically approach the attachment figure in order to seek proximity and contact with him or her. Once proximity to or contact with the attachment figure is obtained, the attachment figure may be able to provide physical protection, emotional comfort and/or alleviation from stress, and thus achieve the end-goal of attachment behaviour. In older children and adults, attachment security can additionally be maintained via verbal agreements (such as an agreed upon union after temporary separation), remote communication, and evoking thoughts and memories of the attachment figure, in situations of distress such as illness, separation, and other adverse life events. Therefore, attachment behaviour is an enduring trait-like disposition, manifest as physical proximity-seeking in infants, and both emotional and physical proximity-seeking in older children and adults.

Importantly, the attachment figure is purported to serve the unique roles of a "safe haven" and a "secure base" (Bowlby, 1969/1982; Harlow, 1958). These two concepts were originally proposed by Harlow (1958), who observed that infant monkeys would rush to cling onto a cloth surrogate mother when presented with a fearful object or introduced to a strange environment. Thus, the mother or other attachment figure was theorised to serve as a haven of safety for the weaker infant in times of fear and danger. Furthermore, Harlow (1958) observed that the infant monkey would use the cloth mother as a "source of security" or "base of operations" from which it would go out and explore the environment and return intermittently. Bowlby (1969/1982, 1973) adopted the very same concepts in his theory, emphasising that the human infant flees not only from danger, but importantly also simultaneously approaches his or her attachment figure who serves as a safe haven, providing

alleviation from distress. Therefore, the attachment figure is a powerful emotion regulator, whereby their presence – and more specifically, their availability and responsiveness – brings about feelings of love, joy and "felt security" (a feeling that "all is well"), while their unavailability and unresponsiveness elicits greater distress and anxiety (Sroufe & Water, 1977). Furthermore, the human attachment figure likewise serves as a secure base for exploration in the absence of a threat, providing a safe environment and instilling confidence in the infant to explore his or her surroundings whilst having his or her attachment figure nearby (Bowlby, 1969/1982; Ainsworth, Blehar, Waters, & Wall, 1978). As important hallmarks of the attachment relationship, the degree to which the infant uses the attachment figure as a safe haven and secure base reveals the quality of their attachment bond.

Accordingly, Bowlby (1969/1982) stated that patterns of attachment can be distinguished on the basis of two critical elements: 1) the nature of the infant's response to separation from the attachment figure, and 2) the ability to use the attachment figure as a secure base for exploratory behaviour. Individual differences in attachment patterns were first documented by Mary Ainsworth (1967) from field observations of infants in Uganda, and then later more systematically observed by Ainsworth et al. (1978) in a structured home and laboratory Strange Situation Paradigm (SSP). The SSP involves a series of episodes including a period of play between the attachment figure (usually mother) and infant, a brief separation where the mother leaves her infant, the presence of a stranger, and, after the departure of the stranger, a reunion scene between the mother and the infant. Three patterns were observed by Ainsworth et al. (1978). The first pattern, labelled as 'secure', were active and interested in play (using mother as a secure base), upset by the separation, sought contact with their mother during reunion and were readily comforted. The second pattern, labelled as 'anxiously attached to mother and avoidant', showed little interest in their mother, lacked wariness about the stranger, displayed little anxiety over their mother's departure, and maintained physical

and emotional distance to their mothers during reunion. Finally, the third pattern, referred to as 'anxiously attached to mother and resistant,' were constantly wary and hypervigilant, showed ambivalent behaviour by oscillating between proximity seeking and resisting contact with their mother, and was angry and resistant when their mother returned and tried to get them to resume play.

Each of these three attachment patterns can be traced back to varied early caregiving experiences (Ainsworth et al., 1978; Bowlby, 1969/1982).[2] Ainsworth et al. (1978) emphasised the importance of maternal (or caregiver's) sensitivity, which includes the degree of availability, warmth and responsiveness. The secure infant is purported to have experienced consistently warm and responsive caregiving from his or her attachment figure. In contrast, the anxious and resistant infant has experienced inconsistent attachment figure availability and responsiveness, prompting the infant to engage in "protest" behaviour (heightened levels of proximity-seeking) to attract the attention of the attachment figure (Bowlby, 1969/1982). Finally, avoidant attachment may arise from consistently unresponsive and unavailable caregiving, which leads to what Bowlby called "detachment," relinquishing attempts of proximity-seeking and developing self-reliance.

Over time, these repeated caregiving experiences lead to the development of what Bowlby (1973, 1980) called Internal Working Models (IWMs). These are enduring and generalised cognitive representations that, much like cognitive scripts and social schemas,

[2] Attachment theory has been criticised for overemphasising nurture – especially in the form of parental caregiving – in the development of attachment patterns. This is what Harris (1998) termed as the "nurture assumption," arguing that research tends to focus on attachment experiences in the family, and ignore the influence of genes. However, in his theory, Bowlby (1969/1982, 1973) clearly defines the attachment system as biologically-based, involving innate dispositions that are shaped by relational experiences. There is also increasing research on genetic influences, with 36% to 45% of variance in attachment style attributed to genetic effects in some twin studies (e.g., Crawford et al., 2007; Donnellan, Burt, Levendosky, & Klump, 2008; Picardi, Fagnani, Nisticò, & Stazi, 2011). Therefore, nurture, together with nature, influences the development of attachment patterns, but this does not underplay the importance of early caregiving experiences.

guide future attachment behaviour, although they are also amendable to new attachment experiences. Bowlby (1973) proposed two independent though complementary IWMs. The first, model of others, concerns whether or not other people (attachment figures and potential attachment figures) are judged to be generally responsive to requests for support and protection. The second, model of self, refers to the degree to which the self is judged to be acceptable or unacceptable to attachment figures and worthy of love and support. These IWMs, whilst having their basis in specific childhood attachment experiences, are carried into adulthood, become integrated into the core of one's personality, and influence latter attachment experiences.

Attachment in Adulthood

While the focus of Bowlby's (1969/1982, 1973, 1980) trilogy is on infant-caregiver attachment, he regarded attachment behaviour as a lifelong phenomenon. Bowlby (1969/1982) proposed a "straightforward continuation" (p. 208) of the functioning of the attachment system in adulthood, whereby attachment behaviour is similarly elicited in situations of distress, such as sickness, separation, and times of danger, during which adults would seek proximity to close and trusted others for comfort and security. Therefore, attachment figures continue to serve the primary role of dyadic emotion regulation during distress, and to some degree, offer physical protection. As previously mentioned, although the function of the attachment system remains the same, attachment behaviour may take different forms in adulthood, such as verbal expressions of attachment needs and evoking cognitive representations of a comforting attachment figure. Furthermore, new attachment bonds are expected to form, with the primary attachment usually transferring from the caregiver to a romantic partner. Thus, in adulthood, critically, the romantic partner usually comes to serve

as the attachment figure to whom attachment behaviour is directed to obtain distress alleviation.

While Bowlby (1979) theorised that attachment behaviour exists across the lifespan from "cradle to the grave" (p. 129), it was Hazan and Shaver (1987) who first empirically examined whether similar attachment processes applied to adult romantic relationships. They created a newspaper "love quiz" that contained a number of questions about people's romantic relationships, as well as descriptions of Ainsworth et al.'s (1978) infant attachment styles appropriated for adult romantic relationships (see Table 1.1). Similar to infant attachment classification proportions, 56% of respondents endorsed the secure description, 25% avoidant and 19% anxious/ambivalent. Furthermore, these groups differed in their reported quality of romantic experiences, outlook towards relationship development, early attachment history, and internal working models of their love-worthiness and partner's availability. Secure respondents described their romantic relationships more positively (e.g., happy and friendly), reported warmer relationships with parents, and had more positive views of themselves and their partners. Avoidant individuals reported greater fear of intimacy, had a more sceptical attitude towards relationships, described more cold and rejecting childhood family relationships, and viewed themselves as self-sufficient. Anxious/ambivalent individuals reported greater experience of obsession and emotional extremes, found it easy to "fall in love", but were more insecure and experienced greater loneliness. These patterns of thought, feeling and behaviour were analogous to infant attachment styles. Therefore, the study provided initial support of attachment patterns as a trait, evidencing some degree of continuity in individual differences in attachment behaviour towards caregivers, and later on, towards romantic figures. Although fundamental similarities exist, Hazan and Shaver (1987) acknowledged that the romantic relationship is complicated by bi-directionality (where both partners use each other as attachments figures), and, additionally, involves caregiving and

Table 1.1

Hazan and Shaver's (1987) Adult Romantic Attachment Style Descriptors

Secure	I find it relatively easy to get close to others and am comfortable depending on them and having them depend on me. I don't often worry about being abandoned or about someone getting too close to me.
Avoidant	I am somewhat uncomfortable being close to others; I find it difficult to trust them completely, difficult to allow myself to depend on them. I am nervous when anyone gets too close, and often, love partners want me to be more intimate than I feel comfortable being.
Anxious/Ambivalent	I find that others are reluctant to get as close as I would like. I often worry that my partner doesn't really love me or won't want to stay with me. I want to merge completely with another person, and this desire sometimes scares people away.

sexual behaviour.

In an extension of Hazan and Shaver's (1987) tripartite typology, Bartholomew & Horowitz (1991) proposed four prototypic attachment patterns based upon the two types of IWMs postulated by Bowlby. As Bowlby's models of self and others can be dichotomised as positive or negative, Bartholomew and Horowitz speculated that together they should theoretically yield four attachment styles (see Figure 1.1). In this way, *secure* attachment entails a positive image of the self as worthy and loveable as well as viewing others as trustworthy and available. *Preoccupied* attachment involves a negative image of the self as

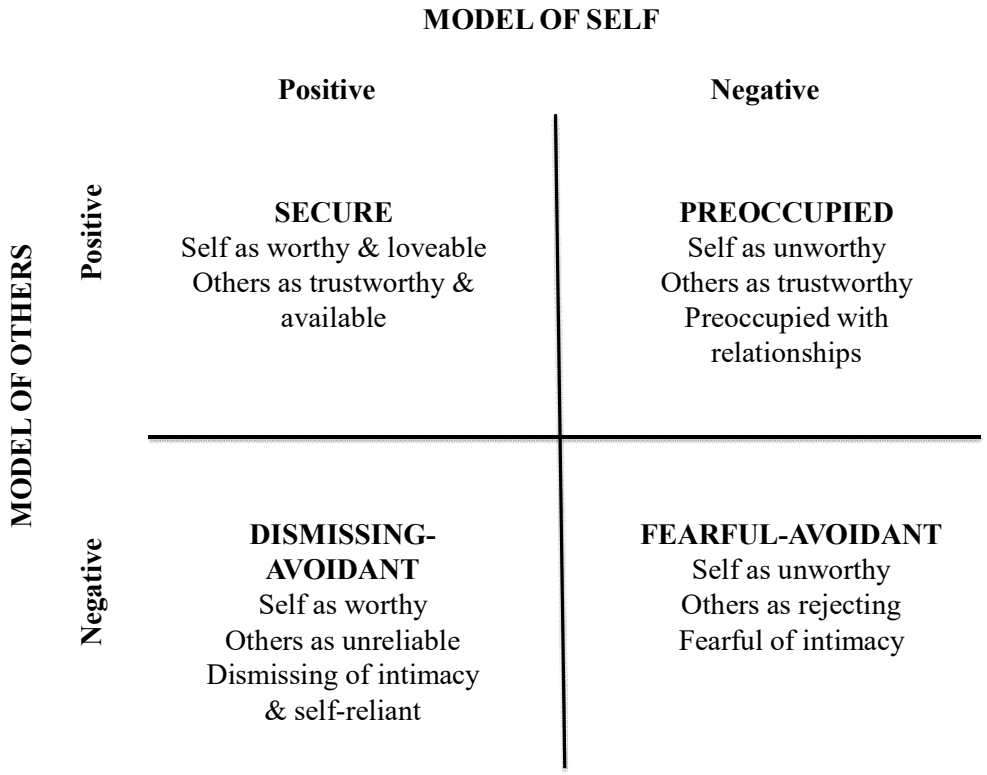

Figure 1.1 Bartholomew and Horowitz's (1991) typology. Adapted from Bartholomew and Horowitz (1991).

unworthy while viewing others as trustworthy and available, which leads to striving for the acceptance of valued others. *Dismissing-avoidant* attachment consists of a positive image of self as worthy, but simultaneously viewing others as unreliable and rejecting, promoting independence and self-reliable. Finally, a four pattern is proposed, namely, *fearful-avoidant* attachment, which involves a negative self-image along with negative expectations that others will be unavailable and rejecting. This combination of IWMs leads to interpersonal withdrawal in order to protect the fragile self from anticipated rejection by others. To an extent, this fourth category arguably corresponds to the 'disoriented, disorganised' infant attachment category identified by Crittenden (1988) and Main and Solomon (1990), where there is simultaneous display of both avoidant and anxious-ambivalent characteristics. In

further support of the fearful-avoidant style, Brennan, Shaver and Toby (1991) found that adult children of alcoholics tended to fall predominantly into this category, scoring highly on both avoidant and anxious-ambivalent scales on Hazan and Shaver's (1987) measure. Thus, Bartholomew and Horowitz's (1991) conceptualisation importantly distinguishes between two avoidant attachment styles – fearful vs. dismissing – and along with secure and anxious-ambivalent styles. The model forms the basis of the operationalisation of many typological measures of adult attachment.

Despite the historical conceptualisation of attachment patterns as 'types,' there has been emerging consensus over the twentieth century that two latent dimensions underlie attachment typologies (e.g., Brennan, Clark, & Shaver, 1998; Brennan et al., 1991; Fraley & Waller, 1998). Brennan et al. (1998) observed that Ainsworth et al. (1978)'s original discriminant analysis, from which she and her colleagues concluded that there are three infant attachment styles, actually revealed two functions: one capturing avoidant behaviour and the other capturing anxious behaviour. Similarly, with regards to Hazan and Shaver's (1987) tripartite model of adult attachment styles, Brennan et al. (1991) argued that the secure and avoidant types form the end-points of a single dimension, while the anxious-ambivalent type form the end-point of a second orthogonal dimension. Moreover, Brennan et al. (1991) showed that Bartholomew and Horowitz's (1991) quadrants can also be readily re-conceptualised, with the model of other (secure/fearful-avoidant distinction) and the model of self (preoccupied/dismissing-avoidant distinction) forming two independent dimensions. In these ways, both infant and adult attachment typologies can be re-conceptualised as regions in a two-dimensional space representing avoidant and anxious behaviour.

In an effort to statistically determine the existence and nature of an underlying dimensional structure, Brennan et al. (1998) administered 323 items that constituted 60 subscales representing attachment-related constructs obtained from existing adult attachment

measures. Factor analysis of scores on the 60 subscales produced two independent factors that corresponded similarly to the two dimensions recovered by Brennan et al. (1991). The first factor, Avoidance, refers to discomfort with closeness and dependence on others, while the second factor, Anxiety, refers to worry over the attachment figure's availability. From these items, Brennan et al. (1998) constructed two brief internally consistent scales representing attachment-related Avoidance and Anxiety, which is referred to as the Experiences in Close Relationships (ECR) questionnaire and is one of the most frequently used contemporary self-report measures of adult attachment. On the basis of their large-scale factor analysis, Brennan et al. (1998) argued that the two dimensions of Avoidance and Anxiety virtually underlie all self-report adult attachment measures. As shown in Figure 1.2, combinations of high and low scores on the bi-dimensions of attachment anxiety and avoidance correspond to the four attachment patterns described by Bartholomew and Horowitz (1991): secure (low anxiety, low avoidance), anxious (high anxiety, low avoidance), dismissing-avoidant (low anxiety, high avoidance), and fearful-avoidant (high anxiety, high avoidance).[3] Therefore, individual differences in attachment patterns may be better located on a two dimensional space characterised by varying degrees of attachment avoidance and attachment anxiety.

In a separate line of theoretical reasoning, Shaver and Mikulincer (2002; see also Mikulincer & Shaver, 2010) provided an integrative model of attachment system activation and functioning in adulthood. Their model consists of three stages of monitoring and appraisal. The first stage involves monitoring signs of threat, and in the presence of potential threat, this leads to the normative activation of the attachment system, which prompts

[3] Note that the term anxious attachment style [which is characterised by low levels of attachment avoidance and high levels of attachment anxiety, as per Brennan et al.'s (1998) model] is interchangeable with preoccupied attachment style [which is characterised by negative model of self and positive model of others, in accordance with Bartholomew and Horowitz's (1991) model].

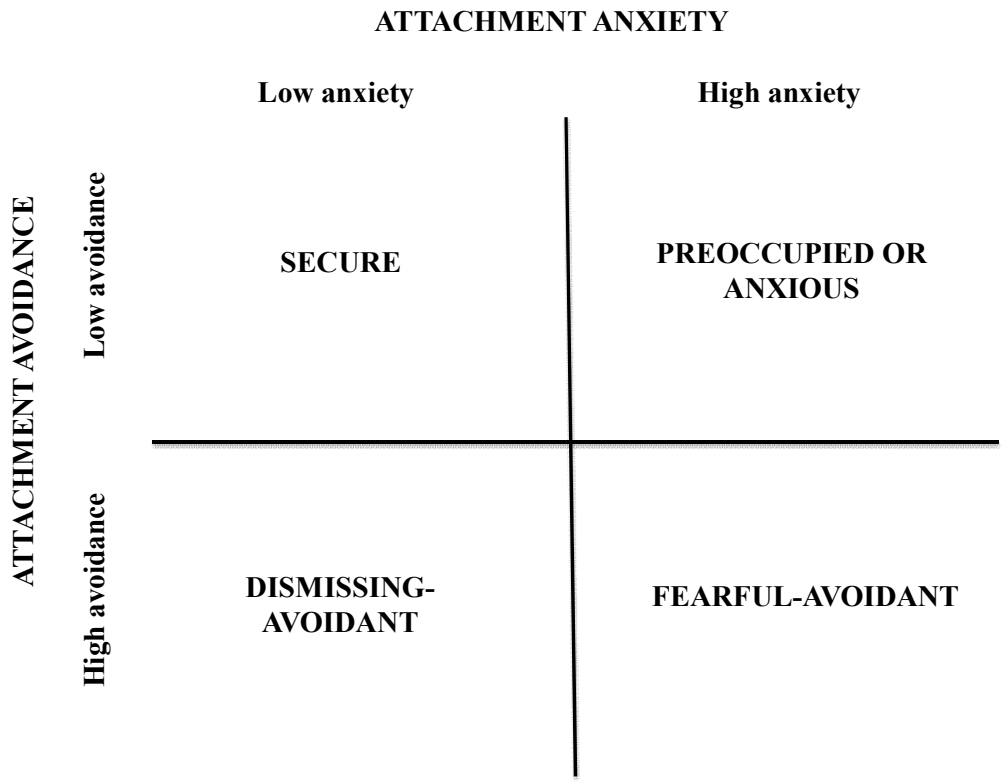

Figure 1.2. Brennan et al.'s (1998) re-conceptualisation of Bartholomew and Horowitz's (1991) typology as two independent dimensions of attachment avoidance and attachment anxiety.

proximity seeking (or evoking mental representations) of the attachment figure. The second stage involves appraising the availability and responsiveness of the attachment figure. If the attachment figure is appraised as being available and responsive, this results in the alleviation of distress. However, if the attachment figure is appraised as unavailable and/or unresponsive, this results in compounded distress and the adoption of what Cassidy and Kobak (1988) referred to as secondary defence strategies, which characterises attachment insecurity. The third stage entails appraising whether or not proximity-seeking remains a

viable option, and if it does, this leads to the secondary defence strategy of *hyperactivation*. Hyperactivation involves intensified efforts of support seeking, hypervigilance towards threat- and attachment-related cues, and heightened distress. Alternatively, when proximity-seeking is not possible or appears to be futile, *deactivation* strategies take place that manifests as the suppression of distressful threat- and attachment-related emotions and cognitions, as well as the absence of attachment behaviour. The defence strategies of hyperactivation and deactivation is theorised to characterise the attachment dimensions of anxiety and avoidance respectively (Shaver & Mikulincer, 2002).

Together, the literature on adult attachment typologies, dimensions, and functioning, provides a coherent picture of attachment behavioural patterns in adulthood. For the securely attached individual with low levels of attachment anxiety and avoidance, the attachment system only becomes activated during threatening situations. Proximity-seeking becomes a functional means of affect-regulation in order to manage with distress, and the secure person is readily comforted by the attachment figure, which also promotes optimistic expectations of their own ability to cope with distress. Secure individuals are, therefore, likely to appraise stressful events as less threatening, and have less defensive distortions of self-views and of others (Shaver & Mikulincer, 2002). In contrast, individuals with higher levels of attachment anxiety have a chronically hyperactive attachment system, even in the absence of threat. The anxious individual gives greater attention to cues of distress, ruminate on negative thoughts, engage in emotion-focused coping (which exacerbates distress), possess a negative self-view, and doubts about their own coping ability (Shaver & Mikulincer, 2002). Finally, higher levels of attachment avoidance involve the deactivation of the attachment system. Such individuals suppress negative cognitions and emotions, devalue intimacy, distance themselves from the attachment figure, are self-reliant, and possess an inflated self-view and confidence in their

own coping ability (Shaver & Mikulincer, 2002). A synthesis of these attachment behavioural patterns is presented in Table 1.2.

It is also important to note that the focus of the present thesis on romantic attachments using self-reported assessments of attachment-related anxiety and avoidance represents one stream of adult attachment research that is typically conducted by personality and social psychologists. A parallel and largely separate research stream conducted by clinical and developmental psychologists tends to assess attachment security in terms of the coherence of adults' representations of early caregiving experiences as revealed in qualitative interview and narrative methods. The most well-known method is the Berkeley Adult Attachment Interview (AAI), which probes adult interviewees' early relationships with parents, focusing particularly on mental representations (IWMs) and current states of mind, which are argued to affect both the content and manner of discourse (George, Kaplan, & Main, 1985). Secure persons are able to give an open, coherent, believable and balanced view of their early relationships with parents, relating both positive and negative experiences. Dismissing persons are uncomfortable and have difficulty recounting their childhood attachment relationships, deny the influence of those relationships on their current personality, may idealise events, and claim their parents are loving but describe rejecting behaviour. Preoccupied persons come across as anxious and/or angry when discussing their childhood relationships and appear to be still enmeshed in those experiences. Finally, persons who are unresolved with respect to losses, traumas or abuse show confusion and disorganisation when discussing trauma-related experiences, suffer from extreme attachment insecurities, and report loss and/or abuse. Therefore, the key feature of the AAI is that responses are not only assessed for content, but also for coherency (George et al., 1985; Hesse, 1999).

Although both research streams are rooted in Bowlby's classical attachment theory,

Table 1.2

Summary of Attachment Behavioural Patterns (Correspondence between Attachment Dimensions, Internal Working Models, and Secondary Defence Strategies)

Attachment dimension	Internal Working Model (IWM)	Secondary defence strategy
Attachment anxiety	Model of self	Hyperactivation
Attachment avoidance	Model of others	Deactivation

they diverge controversially in target relationship, methodology, and conceptualisation of attachment differences, and show empirical divergence. On the surface, one methodology (e.g., the ECR) is self-report and focuses on (mainly) romantic relationships, while the other methodology involves interviews and focuses on childhood caregiving experiences. Nevertheless, Roisman, Fraley and Belsky (2007b) found some degree of conceptual convergence in representing the latent structure of adult attachment between the two approaches. Bi-dimensionally, the AAI could be conceptualised in terms of the degree adults freely evaluate their early experiences or are defensive about them (i.e., avoidance), and attachment-related preoccupation (i.e., anxiety), which corresponds with self-reported attachment-related avoidance and anxiety (Roisman et al., 2007b). However, the two approaches evidence empirical divergence (Fortuna & Roisman, 2008; Roisman, 2009; Roisman et al., 2007a). Roisman et al.'s (2007a) large-scale meta-analytic review found that the correlation between AAI security and self-reported attachment dimensions was trivial to small (r = .09), while the measures also had divergent predictions to interpersonal functioning (Roisman et al., 2007a) and psychopathology (Fortuna & Roisman, 2008). These observations led Roisman (2009) to conclude that attachment security is not a single, monolithic construct, but reflects both confidence in self and others in close relationships, as well as the ability to form a coherent life narrative about childhood attachment experiences.

In accordance with the tradition of personality and social psychological research, as well as appropriate to this thesis' focus on adult romantic relationships, the current research programme uses self-report measures of adult romantic attachment.

Fraley and Shaver (2000) highlighted a number of critical issues that have been raised in the adult attachment literature in the tradition of personality and social psychological research. Firstly, researchers have debated the degree of continuity and stability of attachment bonds from infancy to adulthood, reporting varying degrees of stability (e.g., Baldwin & Fehr, 1995; Duck, 1994; Klohnen & Bera, 1998). In a meta-analysis of 27 longitudinal studies that examined attachment stability over different time spans in life (e.g., infancy, early childhood, adolescence, and adulthood), Fraley (2002) found that the continuity between early and later attachment security has a correlation of .39. This suggests that attachment security has a moderate degree of stability, but is also modifiable with new attachment experiences. However, contrary to some critics (e.g., Duck, 1994), this does not conflict with the proposed continuation of attachment behaviour into adulthood. As Hazan and Zeifman (1999) argued, the integrity of attachment theory does not depend on the degree of stability of attachment patterns. Rather, the more important proposition is that the attachment system continues to influence behaviour in adulthood, and specifically, in romantic relationships (Hazan & Zeifman, 1999).

The adult attachment literature has also been criticised as having a narrow focus on romantic relationships. As reviewed by Fraley and Shaver (2000), attachment researchers often assume that romantic relationships beyond a certain length (for example, six months) serve attachment-related functions. However, it should be recognised that not all romantic relationships are necessarily attachment relationships, such that some relationships may be only companionate and/or sexual in nature. Even for a romantic relationship that serves attachment-related functions, it is likely to also involve companionship, caregiving, and

sexual behaviour (Duck, 1994). The integration between the attachment system with other behavioural systems underlying caregiving, sexual and other behaviours has appropriately been given increasing research attention (Fraley & Shaver, 2000). Therefore, romantic relationships are multifaceted, and attachment theory is focally concerned with only one, albeit important, aspect of dyadic stress regulation.

Attachment relationships are also not limited to romantic partners, as some individuals may also view other figures such as friends, siblings, and teachers as targets for proximity-seeking and safe haven. Accordingly, some researchers have sought to assess *general* or *global* attachment, which refer to trait-like attachment patterns that manifest in a variety of close relationships (both romantic and non-romantic in nature) (e.g., Fraley, Heffernan, Vicary, & Brumbaugh, 2011; Overall, Fletcher, & Friesen, 2011). Fraley et al.'s (2011) Relationship Structures questionnaire adapted a selection of the ECR items to four attachment targets – mother, father, romantic partner, and best friend. While ratings of attachment behaviour show modest correlations across the different domains, they also converge to index global attachment. As a theoretical framework that converges with Fraley et al.'s (2011) measure, Overall et al. (2003) demonstrated a hierarchical model of multiple attachment representations in adulthood, whereby domain-specific attachment representations are nested under a higher-order overarching global working model. These studies suggest that adult attachment is characterised by both domain-specificity, as well global tendencies. The present research focuses on romantic attachments, which, while domain-specific, is one of the most (if not the most) important attachment relationship in adulthood.

In summary, the theoretical and empirical literature affirms the continuation of attachment system functioning in adulthood, as first proposed by Bowlby (1969/1982). Just as in infancy, adults also engage in proximity-seeking of close and trusted others for emotion regulation when distressed, although attachment behaviour is typically re-directed from

parents/caregivers to romantic partners. There are also stable individual differences in attachment behavioural patterns, which have been described using typologies in early research by Hazan and Shaver (1987) and Bartholomew and Horowitz (1991), and later re-conceptualised in terms of the bi-dimensions of attachment anxiety and attachment avoidance (Brennan et al., 1998). Together, these two attachment dimensions encapsulate differential models of self and others, appraisals of attachment figures' availability, degree of proximity-seeking, ability to utilise the attachment figure as a safe haven, and the use of secondary defence strategies such as hyperactivation and deactivation. In contemporary adult attachment research, the dimensions of anxiety and avoidance have also been empirically linked to differences in intrapersonal and interpersonal functioning, which will be reviewed in the next section.

Overview of Adult Attachment Research

An extensive number of studies have been conducted on adult attachment, with a search on PSYCInfo database in December 2015 returning 4101 results for the keyword "adult attachment" and 5477 results for the keyword "attachment theory." Attachment theory has been applied to almost all aspects of life, including, but not limited to, child development (e.g., Belsky & Fearon, 2002), schooling (e.g., Moss, Rousseau, Parent, St-Laurent, & Saintonge, 2008; Berman & Sperling, 1990), adolescent psychological health (e.g., Wilkinson, 2004; Wilkinson & Walford, 2001), work (e.g., Johnstone & Feeney, 2015), childbirth (e.g., Costa-Martins, Pereira, Martins, Moura-Ramos, Coelho, & Tavares, 2014), parenting (e.g., Jones, Cassidy, & Shaver, 2015), mental health (e.g., Mikulincer & Shaver, 2012), religiosity (e.g., Kirkpatrick, 1998), and physical health (McWilliams & Bailey, 2010). As a detailed and comprehensive perusal of the field of adult attachment research is

impossible, Table 1.3 provides an impressionistic summary of the broad relevance of individual differences in adult attachment.

As can be seen in Table 1.3, the attachment patterns have clear differential relations to intrapersonal and interpersonal functioning. Attachment security is generally associated with positive intrapersonal outcomes such as more positive self-appraisals, more positive emotions, lower distress levels, and generally better psychological well-being. In this way, individuals who are securely attached tend to be more emotionally resilient: the sense of security appears to act as a buffer against maladaptive coping during stressful events as well psychopathology. At the interpersonal level, secure individuals also tend to balance different needs (intimacy versus autonomy; personal versus partner); have more satisfied and longer-lasting relationships; experience higher levels of commitment and intimacy; and engage in better communication, conflict resolution and necessary adjustments to separation/loss. Therefore, attachment security is associated with a wide-range of positive intrapersonal and interpersonal outcomes.

Conversely, attachment anxiety is associated with negative intrapersonal outcomes and interpersonal difficulties, as also summarised in Table 1.3. Anxious individuals tend to report negative self-views, less adaptive cognitive styles, heightened distress, and more negative emotions, as well as exhibit a general vulnerability to psychopathology, especially disorders relating to emotion dysregulation. Relationships for anxious persons are also more volatile as their extreme insecurity lead to the adoption of maladaptive cognitions and behaviours. In close relationships, attachment anxiety is associated with greater focus on their own needs and desires (such as for intimacy), high rejection sensitivity, distress intensification, emotion-focused coping, lower relationship satisfaction, poor communication skills, lower levels of commitment, ineffective caregiving and maladaptive conflict management. Therefore, individuals with higher levels of attachment anxiety suffer from

Table 1.3

Impressionistic Summary of Adult Attachment Patterns and Individual Differences in Intrapersonal and Interpersonal Processes and Outcomes

	Attachment security	**Attachment insecurity**	
		Attachment anxiety	**Attachment avoidance**
Cognition	High global self-esteem, perceived self-efficacy & self-competence (see Mikulincer & Shaver, 2007, for a review)	Lower self-esteem, perceived self-efficacy & self-competence; hopeless cognitive style (e.g., Gamble & Roberts, 2005; Safford, Alloy, Crossfield, Morocco, & Wang, 2004; Sumer & Cozzarelli, 2004); external locus of control (Mickelson, Kessler, & Shaver, 1997)	Inconsistent associations with self-esteem (see Mikulincer & Shaver, 2007, for a review)
Affect	More positive emotions, especially in relationships (e.g., Shiota, Keltner, & John, 2006; Simpson, 1990; Torquati & Raffaelli, 2004); functional expressions of anger (Barrett & Holmes, 2001; Mikulincer, 1998); optimism	More frequent & exaggerated experience of negative emotions (Cassidy, 1994); less positive emotions (Shiota et al., 2006); dysfunctional, intense and prolonged experiences of anger (Mikulincer, 1998)	Less positive emotions (Shiota et al., 2006); hostility and aggression (Triosi & D'Argenio, 2004; Zimmermann, 2004); physiological arousal (Mikulincer, 1998)

Table 1.3 (continued)

	Attachment security	Attachment insecurity	
		Attachment anxiety	**Attachment avoidance**
Reaction to stressful events	Lower distress, higher psychological well-being; felt security as a buffer (Mikulincer & Shaver, 2007)	Higher levels of self-reported distress & negative affectivity (Maunder et al., 2006; Mikulincer & Shaver, 2007)	Greater physiological arousal to distress (Diamond et al., 2006); negative affectivity
Psychopathology	General psychological well-being; buffer to psychopathology (Mikulincer & Shaver, 2012)	General vulnerability factor to psychopathology including depression, anxiety, OCD, PTSD, suicidal tendencies & eating disorders; specific vulnerability to dependent, histrionic & borderline personality disorders (Mikulincer & Shaver, 2012)	General vulnerability factor to psychopathology; including depression, anxiety, OCD, PTSD, suicidal tendencies & eating disorders; specific vulnerability to schizoid & avoidant personality disorders (Mikulincer & Shaver, 2012)
Work	Engage in more exploration; higher job satisfaction (Hazan & Shaver, 1987)	Lower job-satisfaction; work-related distress; burn-out; job-performance concerns (Hardy & Barkham, 1994)	Lower job-satisfaction; work-related distress; more conflicts with co-workers (Hardy & Barkham, 1994)

Table 1.3 (continued)

	Attachment security	**Attachment insecurity**	
		Attachment anxiety	**Attachment avoidance**
Interpersonal goals and wishes	Balance between intimacy and autonomy (Mikulincer & Shaver, 2007)	Overemphasise need for protection & intimacy (Raz, 2002; Waldinger et al., 2003); high rejection sensitivity (Downey & Feldman, 1996)	Overemphasise need for autonomy & distance (Raz, 2002; Waldinger et al., 2003); prioritise nonrelational goals (Brennan & Bosson, 1998)
Reaction to separation/loss	Faster emotional recovery & better adjustment (e.g., Davis et al., 2003; Feeney & Noller, 1992, Feeney, 1998, Fraley & Shaver, 1998; Sbarra, 2006)	Emotion-focused coping (Birnhaum et al., 1997); distress intensification (e.g., Feeney, 1998; Sbarra, 2006)	Distancing strategies; quick emotional relief & low levels of distress for brief separations but maladaptive coping for major separations (Birnhaum et al., 1997)
Relationship satisfaction	Greater satisfaction (see Mikulincer & Shaver, 2007, for a review); effective communication (Fitzpatrick, Fey, Segrin, & Schiff, 1993); longer-lasting relationships; higher levels of commitment	Long-lasting, but unhappy relationships (Davila & Bradbury, 2001; Kirkpatrick & Davis, 1994); intrusive relational and communication style (Lavy, 2006); experience lower levels of	Report lower levels of actual & desired intimacy (Mikulincer & Erev, 1991); lower commitment levels & less invested (Pistole, Clark, & Tubbs, 1995); suppression of emotions (Feeney, 1999); less

Table 1.3 (continued)

	Attachment security	Attachment insecurity	
		Attachment anxiety	**Attachment avoidance**
Relationship satisfaction (cont.)	(Keelen, Dion, & Dion, 1994; Kirkpatrick & Davis, 1994); greater intimacy (see Mikulincer & Shaver, 2007, for a review); constructive strategies in managing conflict (Mikulincer & Shaver, 2007)	commitment (Mikulincer & Erev, 1991); greater distress (Guerrero, 1996); jealousy & suspicion (e.g., Collins & Read, 1990); difficulty in managing conflict (Mikulincer & Shaver, 2007)	frequent expressions of affection (Bombar & Littig, 1996); difficulty in managing conflict (Mikulincer & Shaver, 2007)
Sexual behaviour	Less likely to engage in causal, uncommitted sex; sexual enjoyment (Tracey, Shaver, Albino, & Cooper, 2003)	Deference to sexual partner (Davis et al., 2006)	Less interest and frequency in engaging in sexual behaviours (e.g., Brassard, Shaver, & Lussier, 2007); casual, uncommitted sex (e.g., Schmitt, 2005)
Caregiving	Effective caregiving; able to focus on others' needs; confident in own ability to provide a safe haven & secure base (Collins et al., 2006)	Ineffective caregiving; self-focused worries & concerns; intrusive& insensitive behaviour; lack self-confidence; motivated to satisfy own needs for closeness (Collins et al., 2006)	Ineffective caregiving; distant; unresponsive to suffering partners; disapproval of expressions of vulnerability (e.g., Rholes et al., 1999; Feeney & Collins, 2001; Collins et al., 2005)

Note. OCD = Obsessive Compulsive Disorder; PTSD = Post-Traumatic Stress Disorder.

both intrapersonal and interpersonal difficulties.

Finally, attachment avoidance is also associated with a range of negative intrapersonal and interpersonal outcomes, although the nature of those associations differs from those observed for attachment anxiety. As Table 1.3 reveals, attachment avoidance is less consistently associated with explicit reports of negative self-views and emotions, but some studies report greater negative affectivity and distress. More notably, attachment avoidance is associated with greater physiological arousal in reaction to stressful events, even in the absence of greater self-reported distress. As with attachment anxiety, attachment avoidance also presents as a general vulnerability factor to psychopathology. Within close relationships, avoidant individuals tend to prioritise autonomy and employ distancing strategies, which result in lower levels of intimacy, commitment, sexual interest, expressions of emotions, and ineffective caregiving. In these ways, attachment avoidance is associated with the deactivation of attachment needs and behaviour, although there are symptoms of underlying intrapersonal and interpersonal distress.

Although extensive research has been conducted on individual differences in adult attachment and a range of intrapersonal and interpersonal processes and outcomes, basic research relating attachment behaviour to the functioning of general motivational systems has been limited. This thesis will thus aim to examine the nature of the relations between adult attachment and the sensitivity of the general motivational systems governing appetitive and aversive behaviour. In turn, this may enable a better understanding of how attachment patterns are linked to fundamental motivational systems, in accordance with Bowlby's (1969/1982) original conceptualisation of the attachment system from a biological and motivational standpoint. In the next chapter, some background literature on the general motivational systems, as proposed by Reinforcement Sensitivity Theory (Gray, 1982; Gray & McNaughton, 2000), will be provided.

Chapter Summary

This chapter provided a comprehensive overview of both classical and adult attachment theory and research. Drawing upon evolutionary theory and ethological research, Bowlby (1969/1982, 1973, 1980) proposed a biobehavioural attachment system that prompts proximity-seeking of an attachment figure (such as caregivers and/or romantic partners) for physical protection and/or emotion regulation. Hazan and Shaver (1987) later extended and applied attachment system functioning to adult romantic relationships, which is the focus of the present thesis. According to the researchers, and converging with Bowlby's (1969/1982) perspective, adults also approach close and trusted others for practical and emotional support when distressed. As with infant attachment, there are stable individual differences in adult attachment patterns. These have been described in terms of the bi-dimensions of attachment anxiety, which refer to the degree of worry over the attachment figure's availability, and attachment avoidance, which refers to the degree of discomfort with intimacy (Brennan et al., 1998). Low levels on both dimensions correspond to a secure attachment. Individual differences in these attachment patterns have been associated with a range of interpersonal and intrapersonal outcomes. Although the attachment system is proposed to be a fundamental motivational system responsible for dyadic stress regulation, few studies have examined links with general motivational systems. One relevant motivational theory that may intersect with attachment theory is Gray and McNaughton's (2000) revised Reinforcement Sensitivity Theory (r-RST), which will be reviewed in the next chapter.

Chapter 2: Reinforcement Sensitivity Theory

Chapter Overview

This chapter will provide an overview of the Reinforcement Sensitivity Theory (RST; Gray, 1982; Gray and McNaughton, 2000). Firstly, some background on the development of the theory will be provided. Following this, Gray's original (1982) theory will be briefly described. Then, of greater relevance to the present thesis, Gray and McNaughton's (2000) revised version of the theory will be detailed, highlighting important departures from the original theory. The chapter will subsequently review some key empirical validation studies of the theory, along with highlighting issues relating to the measurement and operationalisation of the RST constructs. Finally, the chapter will provide a brief perusal of the application of the RST to a wide range of domains, although it is highlighted that few studies have considered the relevance of the RST to social relationships, which is an area that requires further research.

Background to the Development of RST

The reinforcement sensitivity theory is a neuropsychology theory of personality, motivation, emotion and learning. Although following on from Eysenck's (1967) biological perspective of personality, it draws uniquely and heavily upon basic animal learning research. In this way, RST was originally not intended to be a theory of personality, but a theory of learning and motivation. The theory's explanatory bedrock is reinforcement learning, postulating that basic motivation entails approach and avoidance of appetitive and aversive stimuli respectively (Gray, 1982). These responses to reinforcers are mediated by neurobiological systems, and individual differences in the sensitivity of these systems

contribute to personality variation (Corr, 2008). Therefore, RST emphasises a bottom-up approach from the level of neurobiological systems to explain personality.[4]

As Hans Eysenck's student, Jeffery Gray developed RST as initially a modification of Eysenck's theory of personality. Eysenck's (1967) theory was formulated to account for clusters of psychiatric disorders in terms of trait vulnerabilities mapped onto underlying neuro-circulatory. The first dimension that Eysenck (1967) proposed, *Introversion-Extraversion* (or simply, *Extraversion*, E), reflects the degree of conditionability, which is argued to be related to levels of general arousal and susceptibility to inhibitory processes. This dimension is further proposed to be underpinned by the activity of the ascending reticular activating system (ARAS), which is a structure in the brain stem that regulates the amount of information and stimulation that goes to the brain (see Figure 1; Eysenck, 1967). Eysenck theorised that, in the introverted individual, the ARAS allows more stimulation to the brain, and so they are highly conditionable and prone to disorders of over-socialisation such as phobias, obsessions and compulsions, anxiety, depression or other dysthymic symptoms. In contrast, the ARAS restricts stimulation to the brain in the extroverted individual, and so they are less conditionable and prone to disorders of under-socialisation such as delinquency, addictions and psychopathy. The second dimension, *Neuroticism* (N), is proposed to be associated with the arousability of the limbic circuit, which regulates emotional states and consists of the brain structures of the hippocampus, amygdala, septum, and hypothalamus (see Figure 2.1). Individuals who are more neurotic have greater activation levels in the limbic circuit, and experience greater intensity of emotional experience and reactions than more stable individuals. The third dimension, Psychoticism (P), refers to

[4] This contrasts with the lexical approach to personality that psychometrically analyses language used to describe personality to derive personality traits and dimensions (Allport & Odbert, 1936). This approach assumes that salient features of personality are embedded in language. Well-known theories of personality based on this approach include Cattell's (1965) 16 PF Trait Theory, Goldberg's (1993) Big Five Model, and Ashton and Lee's (2007) HEXACO model of personality.

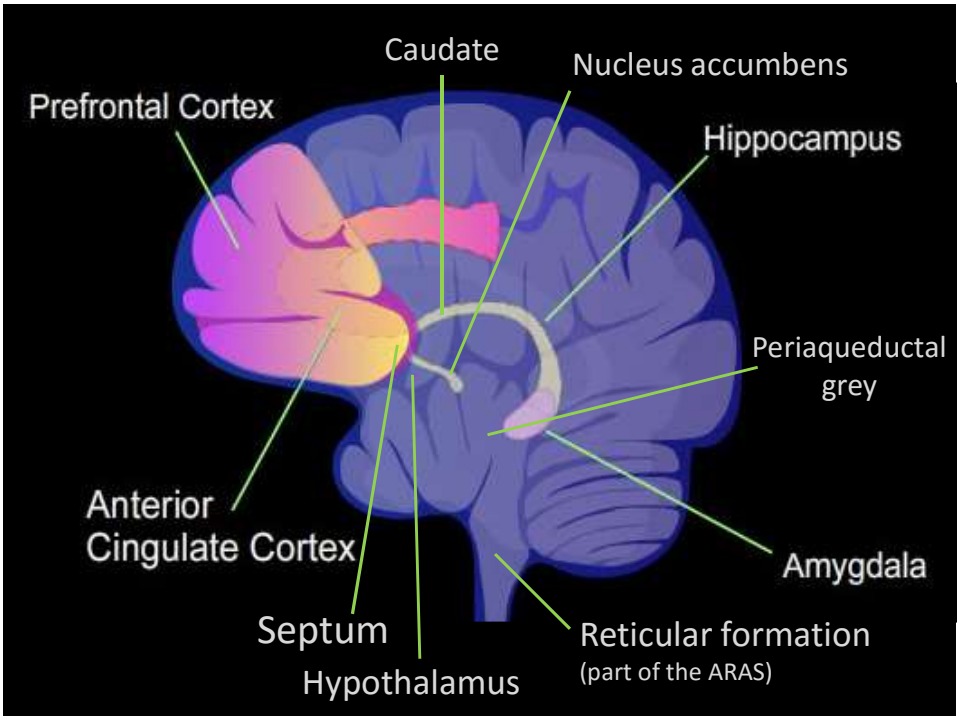

Figure 2.1. Brain regions highlighting areas of interest. Adapted and modified from NIMH Image Library (public domain). Retrieved February 11, 2016, from https://images.nimh.nih.gov/public_il/image_details.cfm?id=653.

tough-mindedness, interpersonal hostility, and vulnerability to psychosis. The neurobiological underpinnings are less well theorised, although it has been related to overactive dopaminergic function (responsible for exploratory behaviour) and underactive serotonergic function (responsible for inhibitory behaviour) (Eysenck, 1995).

In contrast to Eysenck's focus on conditionability and arousability, Gray (1970) alternatively proposed that sensitivity to reward and punishment as the neurobiological bases of personality. Specifically, while Eysenck (1963, 1967) found that introverts condition better than extraverts under some conditions and attributed this to greater conditionability, Gray (1970) noted that these conditioning experiments tended to be aversive in nature (e.g., eyeblink conditioning). Moreover, Gray (1970) cited data from Spence and Kimble's laboratory (e.g., Ominsky & Kimble, 1966; Spence, 1956) that showed that individuals with

high trait manifest anxiety – assumed to reflect a combination of high introversion and neuroticism – also condition more easily under relatively threatening conditions. Gray (1970) reasoned that if introversion simply reflects greater general arousability, then conditioning for high anxiety individuals should be independent of the degree of threat. Instead, according to Gray (1970), the data suggest an alternative explanation that introverts are more susceptible to fear – or sensitivity to punishment and nonreward – as opposed to being more conditionable. This is further substantiated by psychophysiological evidence that some drugs (e.g., barbituarates and alcohol) and frontal lesions that have extraverting effects on behaviour appear to also reduce sensitivity to punishment and frustrative nonreward, but has no impairment on simple reward learning (e.g., Albert & Bignami, 1968; Gray, 1969; Miller, 1959). Based on these observeations, Gray (1970) proposed that introverts form stronger conditioned reactions because they are more susceptible to fear, rather than generalised conditionability. Gray (1970) further proposed that neuroticism reflects the degree of sensitivity to both reward and punishment – that is sensitivity to all classes of reinforcement. Therefore, the dimension of anxiety – which consists of high levels of both introversion and neuroticism – critically "represents the steepest rate of increase in susceptibility to punishment" (Gray, 1970, p. 263). Moreover, Gray (1970; 1981) proposed that impulsivity – most closely aligned with extraversion – is associated with sensitivity to rewards.

To more precisely capture the alternative neurobiological bases, Gray (1972, 1981) proposed a psychometric re-alignment of Eysenck's Neuroticism and Extraversion dimensions. He proposed Trait Anxiety (Anx) and Impulsivity (Imp) as approximately 30° rotations of Eysenck's Neuroticism and Extraversion respectively: Anxiety corresponds with sensitivity to punishment, non-reward, and novelty; while Impulsivity corresponds with sensitivity to reward and non-punishment (Gray, 1981; Pickering, Corr, & Gray, 1999). In this way, Anxiety is suggested to be most closely related to Neuroticism, with a smaller

contribution of low Extraversion, which, in Eysenckian terms, is equated with neurotic introversion; while Impulsivity is suggested to be most closely related to Extraversion, with a smaller contribution of high Neuroticism, corresponding with neurotic extraversion (Gray, 1999; Pickering & Gray, 1999). These dimensions are argued to serve as more parsimonious trait representations corresponding with underlying neurobiological systems mediating response sensitivity to punishment and reward (Gray, 1970). In these ways, Gray (1970) proposed that sensitivity to reward and punishment reinforcement learning as the underlying principles of personality, and thereby termed the theory as reinforcement sensitivity.

Classical (1982) RST

Accordingly, based on evidence from animal research, Gray's classical (1987a, 1987b) RST proposed three separable albeit interacting neurobiological motivational systems that mediate responses to punishment and reward, which in turn gives rise to personality. The first system is referred to as the *Behavioural Inhibition System* (BIS), and is proposed to mediate responses to conditioned aversive stimuli (including extreme novelty, high intensity stimuli and innate fear stimuli). The sensitivity of the BIS is argued to map onto the trait dimension of Anxiety. The second system is referred to as the *Behavioural Approach System* (BAS), taking after Fowle's (1980) terminology, and proposed to be responsible for behaviour towards conditioned appetitive stimuli (i.e., susceptibility to reward and non-punishment). The sensitivity of this system is argued to correspond to the trait dimension of Impulsivity. Lastly, a third system, the *Fight-Flight System* (FFS), is proposed to mediate responses to unconditioned aversive stimuli including punishment or nonreward (for example, innately painful stimuli). It may sometimes manifest behaviourally as rage and panic, and the sensitivity of this system is suggested to relate to Eysenck's (1997) dimension of Psychoticism. The crux of the RST is that personality (in particular, the three dimensions

of Anxiety, Impulsivity and Psychoticism) reflects individual differences in the global functional variation of these three systems (Corr, 2008; Gray, 1987b).

Revised (2000) RST (r-RST)

Gray and McNaughton (2000) put forth a revised RST (r-RST), in the light of new neuropharmacological evidence. There were a number of substantial changes, in particular with regards to defining the FFFS and BIS, as well as removing the distinction between conditioned and unconditioned stimuli generally. As this thesis will focus on the r-RST, each of the three reconceptualised motivational systems will be described in greater detail in the following sections.

Fight-Flight-Freeze System (FFFS)

In the r-RST, the Fight/Flight System was relabelled as the *Fight-Flight-Freeze System* (FFFS) and is theorised to mediate behaviour towards all aversive stimuli, whether conditioned or unconditioned (Gray & McNaughton, 2000). It usually manifests behaviourally as pure avoidance in the form of fight, flight or freeze (the specific response depends on ecological conditions) and signals a sense of "get me out of this place" (Corr, 2008). Accordingly, this system involves negative feedback aimed to reduce the discrepancy between the immediate threat and the desired state of safety. It is accompanied by the emotion of fear, and a more sensitive FFFS is associated with higher levels of the trait fear-proneness. Clinically, an overly sensitive FFFS many manifest in disorders such as phobia and panic disorder.

Behavioural Approach System (BAS)

The BAS in the revised version is largely unchanged from its original

conceptualisation, although there are some minor modifications (Gray & McNaughton, 2000). Instead of mediating behaviour towards only conditioned appetitive stimuli, it is now responsible for behaviour towards all appetitive stimuli, both conditioned and unconditioned. It involves a positive feedback system that aims to reduce the temporo-spatial distance between the current appetitive goal state (e.g., hunger) and final biological reinforcer (e.g., food). It may be captured by the sense, "Let's go for it!" (Corr & Cooper, 2016). The system is still associated with the feeling of anticipatory pleasure, and the personality traits of optimism, reward-orientation and functional impulsiveness.[5] An overly sensitive BAS may underlie addictive behaviours, high-risk impulsive behaviours and mania.

The functioning of the BAS is argued to be a complex and multidimensional process (Carver & White, 1994; Corr, 2008). Reducing the temporo-spatial distance between the current appetitive goal state and the final biological reinforcer involves at least two separate but complementary components (Gray & McNaughton, 2000). Firstly, the incentive component characterises the early stages of approach and is accompanied by interest, drive, anticipatory pleasure and hope. It also often involves the restraint of behaviour, planning and sub-goal scaffolding – actions that are perhaps to some degree mediated by the BIS (Corr, 2008). This is because acting impulsively may sometimes be counter-productive to attaining the reinforcer, such as in situations involving longer-term goals. However, as the individual reaches the final biological reinforcer, the second consummatory component takes over and involves what Corr (2008) referred to as 'excitement attack.' This component is characterised by elements of impulsivity (that is, approach behaviour is no longer restrained) and affective pleasure/joy. Therefore, the BAS involves a hierarchical and multidimensional organisation

[5] Dickman (1990) makes a distinction between functional impulsivity, which refers to rapid responding to optimise one's circumstances, and dysfunctional impulsivity, which refers to rash behaviour without forethought. The relevance of this distinction for RST was highlighted by Smillie and Jackson (2006), who found that functional impulsivity, but not dysfunctional impulsivity, was positively associated with BAS sensitivity.

of behaviour, engaging various processes in order to approach and attain the appetitive stimuli.

Behavioural Inhibition System (BIS)

Re-conceptualisation of the BIS is the focal change made in the r-RST (Gray & McNaugton, 2000). The BIS, instead of being involved in conditioned aversive responses, is now critically responsible for the resolution of conflict between concurrently activated, equal and incompatible goals. Such situations may include approach-approach (for example, deciding between buying two desired items), avoidance-avoidance (for example, choosing between house chores or writing a paper), or approach-avoidance (for example, attending a job interview) conflicts. In the former two instances, Smillie, Pickering and Jackson (2006) noted that they may be reconceptualised as approach-avoidance conflicts, with the incompatible approach goals signifying both incentive and threat (frustrative non-reward) and the incompatible avoidance goals signifying both threat and non-punishment. Novelty is also a special case that elicits both approach and avoidance and prompts BIS activity. This thesis will focus on the role of BIS in resolving approach-avoidance conflicts, as is typically the case in r-RST research.

Gray and McNaughton (2000) proposed that the BIS involves the septo-hippocampal as a conflict detector. Once conflict is detected, the septo-hippocampal increases the valence of the negative stimulus (input from the FFFS) via recursive negative feedback loops until behaviour is resolved in favour of either approach or avoidance. The increasing negative valence produces the feeling of anxiety, a sense of "watch out for danger," as well as states of worry and rumination (Corr, 2008). When the BIS is activated, it leads to the inhibition of prepotent conflicting behaviours (both BAS and FFFS) to prevent either of the incompatible goals from gaining immediate control over behaviour. Following this, there is increased

hypervigilance and risk assessment, which involves scanning memory and the environment for information to assist with reaching a resolution. Finally, there is an increase in arousal level in preparation for split-second changes between approach to the appetitive goal and escape from potential danger that may suddenly emerge. Individuals with greater BIS sensitivity may have higher levels of trait anxiety, worry-proneness and anxious rumination. Moreover, an overly-sensitive BIS may underlie clinical disorders such as General Anxiety Disorder (GAD) and Obsessive Compulsive Disorder (OCD).

Neurophysiology of the FFFS, BIS, and BAS

In terms of the neurophysiological underpinnings of the FFFS and BIS, Gray and McNaughton (2000) proposed a hierarchical defence system that involves a network of nodes with distributed controls. At the lowest level, high-intensity freezing, explosive attack (e.g., panic), and undirected escape (flight) in response to proximal danger is mediated by the periaqueductal grey (PAG; see Figure 2.1). The PAG is an anatomic and functional interface between the forebrain and the lower brainstem, and is known to play a major role in integrated behavioural responses to pain (Benarroch, 2012). In response to distal danger, directed escape is mediated by the medial hypothalamus, which is a region of the brain associated with defence behaviour. Where there is potential danger to avoid, simple active avoidance is mediated by the amygdala, while more complex active avoidance is mediated by the anterior cingulate cortex, which plays a role in conflict monitoring (see Figure 2.1). Finally, risk assessment and behavioural inhibition in the context of potential danger to approach involves primarily the function of the septo-hippocampal, which has been shown to be either directly or indirectly affected by anxiolytic drugs. Additionally, BIS response is underpinned by the activity of the posterior cingulated as well as interactions between the septo-hippocampal and amygdala, given that FFFS-fear and BIS-anxiety are closely

interlinked and feedback upon each other. Therefore, as Gray and McNaughton (2000) described, progressively more central structures in the brain are responsible for progressively more complex aspects of defence.

The BAS similarly involves the activity of a number of hierarchically organised neural structures, given the multidimensionality of the system. Gray (Gray & McNaughton, 1996; Gray, Feldon, Rawlins, Hemsley, & Smith, 1991) originally proposed that the caudate and accumbens regions of the brain mediate the management of sub-goals, appetitive arousal, facilitation of reward processes, and flexible response sequences (see Figure 2.1). The caudate and accumbens map onto dopaminergic pathways – also referred to as the reward neural pathways of the brain that transmit the neurotransmitter dopamine from one brain region to another – and specifically, the nigrostriatal and mesolimbic projections pathways (see Figure 2.2). The central importance of the dopaminergic reward system in BAS functioning has been increasingly recognised (Pickering & Gray, 1999). Increased and decreased firing of dopaminergic cells in the midbrain has been related to the occurrence of unexpected reward and absence of expected reward respectively (Schultz, 1998; see also Pickering & Gray, 1999, 2001; Pickering & Smillie, 2008). Therefore, BAS is located, in part, within regions of ascending dopaminergic projections, although further research is needed.

Fear and Anxiety: Defensive Direction

In the r-RST, defensive behaviour is further categorised along two dimensions (Gray & McNaughton, 2000; McNaughton & Corr, 2004). The first categorical dimension, defensive direction, is based on the sharp ethological, behavioural and pharmacological distinction between FFFS-mediated fear and BIS-mediated anxiety. Critically, it is emphasised that FFFS-mediated fear occurs when moving *away* from a threat, while BIS-

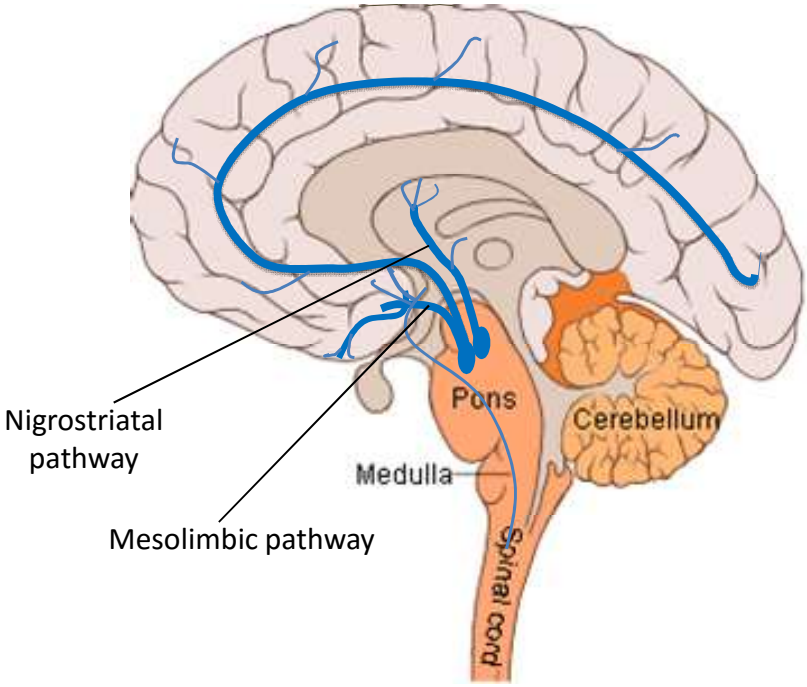

Figure 2. The dopaminergic projection pathways (including the nigrostriatal and mesolimbic pathways) of the brain. Adapted and modified from Brain human sagittal section.svg by Patrick J. Lynch from Wikimedia Commons, Retrieved February 18, 2016, from https://commons.wikimedia.org/wiki/File:Brain_bulbar_region.svg.

mediated anxiety occurs when moving *towards* a potential threat. The functional significance of the behaviour is highlighted, such that it is the defensive direction – whether leaving a dangerous situation (active avoidance) or entering it (cautious approach and risk assessment) – and not the type of stimuli (for example, immediacy versus potentiality of threat) that delineate between fear-FFFS and anxiety-BIS (Gray & McNaughton, 2000; McNaughton & Corr, 2004).

This distinction is based on the etho-experimental studies of Blanchard and Blanchard (1990), who demonstrated the unique adaptive utility of these behaviours in their natural environment using a Visible Burrow System (VBS). The VBS is a rat burrow system that involves a tunnel/chamber in which an animal can hide, and an open area where the animal

can explore, thereby permitting a range of defensive behaviours. The Blanchards observed that when a rat is in the presence of a cat (i.e., predator), this leads to clear-cut avoidance behaviour, in the attempt to remove itself from the threat if escape is possible (flight to the tunnel/chamber) or otherwise freeze or fight at close proximity to the threat. In contrast, when a rat encounters a potentially threatening situation (e.g., lingering cat odour), active avoidance may be unnecessary, useless or even counterproductive. Rather, a need to approach the situation prompts cautious exploratory behaviour and risk assessment. In the VBS, the rat is observed to cautiously approach the open area of the burrow system, whilst scanning for potential threat.

The Blanchards further demonstrated the double dissociative effects of panicolytic and anxiolytic drugs on fear-mediated and anxiety-mediated defensive behaviours (Blanchard & Blanchard, 1990; Blanchard, Griebel, & Henrie, 1997; see McNaughton & Corr, 2004, for a review). Various classical and novel anxiolytic drugs (e.g., benzodiazepine, buspirone, imipramine and clomipramine), although involving different neurobiological mechanisms for action and side-effects, have been shown to reduce symptoms of anxiety but not phobia or panic attacks (Gray & McNaughton, 2000). Therefore, it is argued that these drugs act on a single neural system. More specifically, anxiolytic drugs across the board appear to reduce the inhibitory action of BIS during a conflict situation, resulting in greater approach in an approach-avoidance conflict. The drugged animal appears to exhibit reductions in sensitivity to threats, inhibitory behaviour, hypervigilance, and arousal. The important point is that active avoidance and phobic behaviour are relatively insensitive to anxiolytic drugs. In contrast, FFFS-mediated fear reactions are instead relatively sensitive to panicolytic drugs, and not anxiolytic drugs. Panciolytic drugs reduce and panciogenic drugs enhance flight behaviour (affecting reaction frequency, speed and perceived distance to threat), freezing behaviour, and defensive attack during flight from oncoming predator (Blanchard et al.,

1997). However, these drugs have no effect on risk assessment during approach towards a potential threat. Therefore, the qualitative dimension of defensive direction is further substantiated by the unique relative effects of panciolytic and anxiolytic drugs on fear- and anxiety-mediated behaviours respectively.

Paralleling non-human animal studies, the dimension of defensive direction has also been demonstrated in humans. Blanchard, Hynd, Minke, Minemoto and Blanchard (2001) found that, when given 12 short threat scenarios, participants were more likely to endorse flight, freezing or attack in response to discrete and clearly dangerous stimuli, and choose risk assessment in response to ambiguous stimuli. Similarly, Perkins and Corr (2006) found that the extent to which flight and risk assessment behaviours were endorsed had respective negative and positive associations with the ambiguity of the threat stimuli. Furthermore, self-reported fear predicted orientation away from threat, while trait anxiety predicted orientation towards threat (Perkins, Cooper, Abdelall, Smillie, & Corr, 2010; Perkins & Corr, 2006). Although, contrary to expectations, self-reported BIS sensitivity also predicted orientation away from threat (Perkins & Corr, 2006). This may be due to the fact that the BIS scale used in their study did not reflect the revised conceptualisation. Nonetheless, it appears that human defensive behaviours also entail defensive direction, with FFFS-mediated fear response orienting away from threat, while BIS-mediated anxiety response orienting towards potential threat.

Fear and Anxiety: Defensive Distance

Defensive behaviour can be further categorised along a second continuous dimension of defensive distance (McNaughton & Corr, 2004). This dimension reflects a functional hierarchy that determines the appropriate behavioural response in relation to defensive distance, which is an internal cognitive construct capturing the intensity and closeness of the

perceived threat. The emphasis is on perceived threat intensity, and thus, defensive distance may vary between individuals for the same situation. Defensive distance could be equated with, greater than (for situations evaluated to be more dangerous), or smaller than (for 'braver' individuals) actual threat distance. Shorter perceived defensive distance (whether due to a more dangerous stimuli or highly defensive individual) elicits active avoidance. A very short defensive distance (perceived imminent threat) may elicit explosive attack or panic; immediate defensive distance may elicit freezing, flight and phobic avoidance; while at large defensive distance, normal non-defensive behaviour is observed. When approaching a potentially threatening situation, a small defensive distance elicits defensive quiescence; an intermediate defensive distance elicits risk assessment; while a large defensive distance allows for normal pre-threat behaviour. In this manner, defensive distance maps hierarchically onto different forms of defensive behaviour as a function of defensive direction (McNaughton & Corr, 2004), and this is summarised in Table 2.1.

It should be further elucidated that flight and avoidance behaviour are the dominant responses when escape is possible, while at short defensive distance, this gives way to fight and panic (Blanchard & Blanchard, 1990). When escape is not possible, freezing is more likely to occur so that the animal is less likely to be detected by the predator. Figure 2.3 depicts these defensive outcomes as a function of defensive distance and availability of an escape option. In humans, Perkins and Corr (2006) have found that defensive attack was strongly and negatively related to the escapability and distance of the threat, while flight was more likely in escapable and clearly dangerous situations.

In the case of anxiety-mediated approach of potential threat, Blanchard et al. (1997) showed that anxiolytic drugs alter internally perceived defensive distance, rather than specific defensive behaviours. As a consequence, anxiolytic drugs are observed to have a bidirectional effect on risk assessment relative to baseline behaviour. In a high threat scenario, anxiolytic

Table 2.1

Summary of Defensive Behaviours as a Function of Defensive Distance and Defensive Direction (Avoiding Threat versus Approaching Threat). Adapted from Corr & Perkins (2006)

Defensive distance	**Avoiding threat**	**Approaching threat**
Short (imminent threat)	Fight or panic	Freeze/defensive quiescence
Medium	Freezing, flight, or phobic avoidance	Risk assessment
Large	Normal non-defensive behaviour	Normal non-defensive behaviour

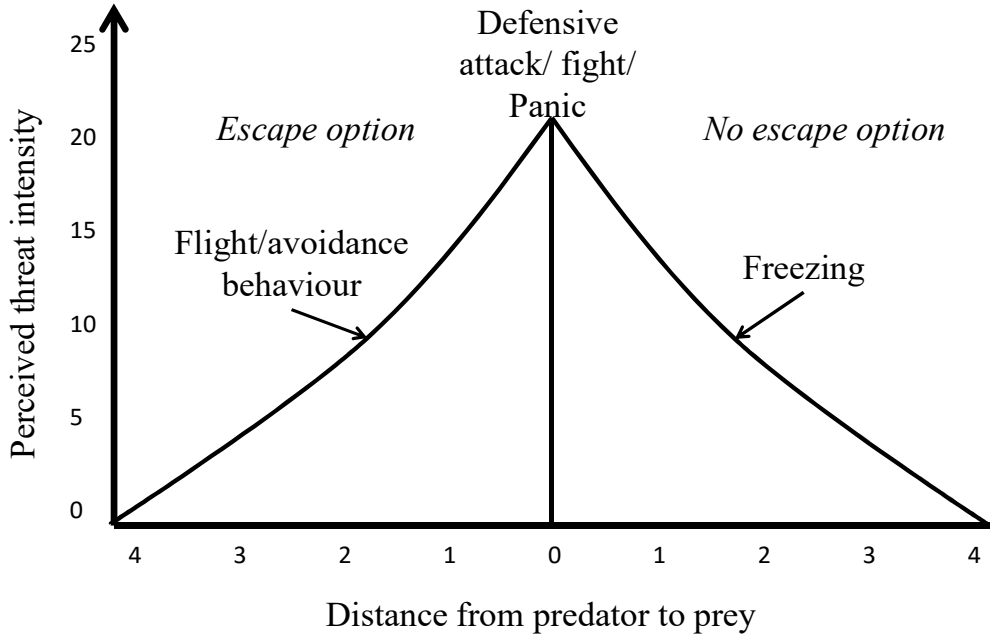

Figure 2.3. Variation in defensive behaviour as a function of defensive distance and escapability. Adapted from McNaughton and Corr (2004).

drugs increases risk assessment and approach behaviour, in the place of defensive quiescence; while in a medium threat scenario, anxiolytic drugs decreases risk assessment and promotes normal behaviour. In both of these cases, the change in form of defensive behaviour is due to the effect of the anxiolytic drugs in increasing perceived defensive distance.

In summary, Gray and McNaughton's (2000) r-RST introduces two important new concepts of defensive direction and defensive distance. Defensive direction critically distinguishes between FFFS-mediated avoidance of threat and BIS-mediated approach of a potentially threatening situation. Defensive distance determines the form of defensive behaviour that will be exhibited, ranging from fight, at close defensive distance to non-defensive behaviour at large defensive distances.

Measuring Reinforcement Sensitivity

Despite being a bottom-up biologically-based theory of personality, many studies use psychometric and/or behavioural measures to operationalise reinforcement sensitivity. Indeed, a search of the most current literature reveals that almost all studies use self-report instruments (e.g., Clark, Loxton, & Tobin, 2015; Corr & Krupic, 2014; Gaher, Hahn, Shishido, Simons, & Gaster, 2015), or correlate physiology/behaviour with self-report measures of reinforcement sensitivity (e.g., Aluja, Blanch, Blanco, & Balada, 2015). A diverse range of measures have been developed over the years, although most have been based on the classical RST. Nonetheless, measures have been adopted and developed to assess r-RST, which will be the focus of this section.

Self-report Measures

There are a number of purpose-built, theoretically-driven questionnaires designed to

assess reinforcement sensitivity. However, the majority of these measures are based on the classical RST, and, due to the shortage of instruments assessing the revised version of the theory, they are still commonly used in research. Purpose-built RST questionnaires usually assess self-reported behavioural responses to reward, punishment, and conflict, and thus possess good face validity. Long-standing measures include the Gray-Wilson personality questionnaire (GWPQ; Wilson, Barrett, & Gray, 1989; Wilson, Gray, & Barrett, 1990), General Reward and Punishment Expectancy Scales (GRAPES; Ball & Zuckerman, 1990), BIS/BAS scales (CW-BIS/BAS; Carver & White, 1994), and Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Ávila, Moltó, & Caseras, 2001) (see Torrubia et al., 2008, and Corr, 2016, for comparative reviews of these measures).

Of those listed above, the CW-BIS/BAS scales are the most widely used in the assessment of both classical and revised RST constructs. This instrument includes three BAS scales – *Reward Responsiveness* (the tendency to seek new incentives), *Drive* (persistence in pursuing incentives) and *Fun Seeking* (positive affective response to obtained incentives) – that capture the multidimensionality of the construct, as well as a single unidimensional BIS scale. While the CW-BAS scales may still be valid in assessing BAS as conceptualised in the r-RST, the CW-BIS scale is problematic in that it is based on the classical conceptualisation of BIS. As such, it is unclear whether the CW-BIS items assess FFFS or BIS as conceptualised in the r-RST. Rather, as Heym, Ferguson and Lawrence (2008) confirmed in their study, the two constructs are confounded within the scale. Heym et al. submitted the CW-BIS scale to confirmatory factor analyses and found that a two factor model separating BIS-anxiety (4 items) and FFFS-fear (2-3 items), instead of a single factor model that had poor fit. However, some other studies have recovered a two factor structure with two BIS-anxiety items and four FFFS-fear items (e.g., Johnson, Turner, & Iwata, 2003; Beck, Smits, Claes, Vandereycken, & Bijttebier, 2009; Poythress et al., 2008). It appears that the

restructuring of the CW-BIS scale demonstrates a number of psychometric issues including inconsistent factor structure across different cohorts, weak fit indices and internal consistencies (Dissabandara, Loxton, Dias, Daglish, & Stadlin, 2012). This has been attributed to the CW-BIS scale's limited range of items relevant to BIS and FFFS. Furthermore, Corr (2016) highlighted that the FFFS-fear subscale consists of the reverse-keyed items from the CW-BIS, which may suggest that the separation of these items may reflect a measurement artefact. Therefore, the CW-BIS (and similarly, other BIS measures developed prior to the revised theory) is not suitable for assessing the revised conceptualisation of FFFS and BIS.

Despite 16 years since the publication of r-RST, there have only been three published purpose-built measure and a few measures that are currently in development that reflect the updated conceptualisations (see Corr, 2016, for a review). The Jackson-5 (Jackson, 2009) consists of BAS, BIS, Fight, Flight and Freeze scales, with items self-generated by the author. However, some of the items lack face validity (e.g., BIS item: "I prefer to work on projects where I can prove my ability to others" and "Aim better than peers"). Such items may conceptually align better with BAS, and indeed Corr (2016) showed that BIS correlated most strongly with BAS (r = .27) and negligibly with FFFS Freezing (r = .05) and Flight (r = .03), which is theoretically inconsistent with the r-RST. Moreover, as highlighted by Corr (2016), there is only one BAS factor, which is contrary to multidimensional models of BAS (Carver & White, 1994; Corr, 2008). Some of the scales also possess low internal reliability (e.g., Cronbach's alpha of .62 and .61 for Flight and Freeze respectively; Harnett, Loxton, & Jackson, 2012).

Two other published purpose-built measures are the Reinforcement Sensitivity Questionnaire (RSQ; Smederevac, Mitrovic, Colobic, & Nikolasevic, 2014) and the revised Reinforcement Sensitivity Theory Questionnaire (rRST-Q; Reuter, Cooper, Smillie, Markett,

& Montag, 2015). Both of these measures also have only a unidimensional BAS measure, which is theoretically problematic (Corr, 2016). In his review, Corr (2016) noted that the RSQ also has weak differentiation between the BIS and FFFS scales, which does not provide a good measure of the revised RST distinction between the two constructs. Moreover, some items in the rRST-Q lack face validity (e.g., Fight item: "I am a rather quick-witted person"), which may contribute to the strong negative correlation observed between Fight and FFFS (Corr, 2016). Therefore, existing purpose-built measures of the revised RST such as the Jackson-5, RSQ, and rRST-Q suffer from psychometric and theoretical issues.

Two other r-RST measures are currently being developed and they are the Corr-Cooper Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ; Corr & Cooper, 2016), and the Heym-Reinforcement Sensitivity Theory Questionnaire (H-RSTQ; Heym, Skatova, Ferguson, & Lawrence, 2016). These are proposed to be theoretically more faithful to the r-RST, and show promise in a number of psychometric, behavioural and physiological validation studies. The RST-PQ assesses multidimensional BAS (Reward Interest, Goal-Drive Persistence, Reward Reactivity, and Impulsivity), multidimensional FFFS (FFFS, Panic and Defensive Fight) and BIS (one scale) (Corr & Cooper, 2016). The H-RSTQ similarly assesses multidimensional BAS (Drive and Reward Reactivity), multidimensional BIS (Anxiety and Appraisal), and multidimensional FFFS (Flight, Freeze, and Fight) (Heym et al., 2016). Both scales are strongly grounded in the revised RST. While the two scales are not yet widely used, they were included in Study 1 (RST-PQ) and Study 3 (H-RSTQ) of this thesis, and will be described in more detail in the relevant chapters.

Given the lack of thoroughly validated purpose-built self-report measures of r-RST, a number of existing personality trait scales have been used as proxy indices. As Gray's dimensions were originally proposed as a rotation of Eysenck's dimensions, some studies (e.g., Perkins & Corr, 2006; Pickering, Dfaz, & Gray, 1995; Corr, Pickering, & Gray, 1995)

have simply measured the latter to derive an estimation of former. The sensitivities of the BAS and BIS have been directly equated with E and N respectively, or alternatively, as combinations of E and N (and sometimes P) (Corr, 2001). However, Heubeck, Wilkinson, and Cologon (1998) found that Neuroticism and Extraversion were not predicted by Gray's (1970) combinations of BIS and BAS, leading the researchers to question the proposed correspondence between these dimensions. Furthermore, in the light of the r-RST, it is unclear how the sensitivity of the BIS and FFFS are related to Eysenck's tripartite model. For example, it has not been theorised how FFFS is related to the Eysenckian dimensions. Therefore, although some researchers have measured extraversion and neuroticism as proxy indices of reinforcement sensitivity, the relations between these constructs are not clear.

More conventionally, studies have measured fear-proneness and trait anxiety as proxy indices of the sensitivities of the FFFS and BIS respectively. Two commonly used measures are various versions of the Fear Survey Schedule (FSS; e.g., Geer, 1965; Wolpe & Lang, 1964, 1977) and the trait anxiety scale from the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983).[6] In accord with the r-RST, there is evidence for the psychometric distinction between FFFS-fear, as indexed by FSS, and BIS-anxiety, as indexed by the STAI. For example, Perkins, Kemp and Corr (2007) showed that while the STAI-trait anxiety and EPQ-N are highly correlated, FSS exhibits weak correlations to both of these constructs. Furthermore, lower scores on the FSS, especially on the tissue damage fear scale, is uniquely predictive of better military training performance. Cooper, Perkins and Corr (2007) similarly

[6] Various trait Impulsiveness scales such as Barratt's impulsivity scale (Patton, Stanford & Barratt, 1995) or the impulsiveness scale from Eysenck Personality Scales (EPS; Eysenck & Eysenck, 1991) have also been used to index the sensitivity of the BAS. However, as mentioned in the previous study, recent studies (e.g., Smillie, Dalgleish, & Jackson, 2007; Smillie, Cooper, Proitsi, Powell, & Pickering, 2010) have discriminated between the construct of reward reactivity, which closely aligns with approach motivation, and rash impulsivity, which is related to poor impulse control and more closely linked to Eysenck's P than BAS functioning. Therefore, impulsivity (especially rash impulsivity, which defines most impulsivity measures) is argued to be a misnomer in the RST literature (Smillie et al., 2006).

concluded that tissue damage fear is notably distinct from STAI and CW-BIS (which are highly intercorrelated) and more closely related to r-RST conceptualisation of FFFS. Finally, other BAS-related traits, such as novelty seeking, and BIS-related traits, such as Cloninger's (1986) harm avoidance, have also been used as measures to approximate the r-RST constructs. The exact correspondence between these trait measures and r-RST constructs is unclear. This issue also applies to proxy measures in general in that it is uncertain which particular 'surface' personality trait manifestations most closely map onto the underlying sensitivity of the r-RST biobehavioural systems, although fear-proneness and trait anxiety appear to best align with the theoretical predictions regarding FFFS and BIS respectively (Perkins et al., 2007).

There are a number of issues inherent to self-report measures of reinforcement sensitivity, whether purpose-built instruments or proxy indices. Firstly, there is no one go-to standard measure, but rather researchers have developed and utilised a diverse and heterogeneous range of measures. These measures differ in the way they were developed, how reinforcement sensitivity is conceptualised, and even the number of traits assessed (e.g., CW-BAS scales). Torrubia et al. (2008) argued that these factors in part have contributed to the difficulty in comparing data and lack of convergence in results. Aside from psychometric issues, the lack of convergence in results also suggests that the measures may not be assessing the same construct, although they may have substantial intercorrelations (Smillie, 2008a; Smillie, Pickering, & Jackson, 2006). Secondly, many studies still use the outdated RST operationalisations, especially the CW-BIS/BAS scales, and this is due to the lack of published and well-validated r-RST measures. As previously mentioned, the critical problem with measures based on classical RST is not taking into account the revised distinction between FFFS and BIS sensitivities, leading to difficulties in interpreting the data. Last but not least, there are methodological and conceptual difficulties in operationalising

reinforcement sensitivity with psychometric instruments (Matthews & Gilliard, 1999). Self-reported personality traits may be regarded as surface-level descriptive summaries of patterns of behaviour, but are arguably far removed from the biobehavioural variations proposed by r-RST (Smillie, 2008a). It is difficult to imagine that individuals are able to consciously introspect and report on the sensitivities of their neurobiologically-based motivational systems (Pickering & Corr, 2008; Smillie et al., 2006; Smillie, 2008a). Therefore, Smillie (2008a, 2008b) concluded that, for a bottom-up theory such as r-RST, psychometric paradigms are not ideal but rather more direct behavioural and physiological assessments need to be employed.

Behavioural Measures

Turning to behavioural measures of reinforcement sensitivity, the most straightforward assessments are learning tasks similar to those used in non-human animal research. For example, the sensitivity of the BAS can be assessed by performance (e.g., speed and accuracy) on learning tasks based on reward and non-punishment, while the sensitivity of the FFFS can be assessed by performance on learning tasks based on punishment and non-reward. Examples of such tasks include Discrimination tasks (Avila, 2001; Boddy, Carver, & Rowley, 1986; Nichols & Newman, 1986); the maze task (Pickering et al., 1995); the circle tracing task (Wallace & Newman, 1990); Card Arranging Reward Responsivity Objective Task (Kambouropoulos & Staiger, 2004) (see Leue & Beauducel, 2008, for a review). These tasks represent unambiguous non-conflict situations with clear-cut response-reinforcement associations (for example, rewarding correct responses and punishing wrong responses) that allow for the direct assessment of the functioning of the FFFS and BAS. In their review, Leue and Beauducel (2008) found modest but reliable effect sizes between self-reported trait measures and behavioural parameters designed to assess reinforcement sensitivity (for

example, mean true-score correlation (ρ) corrected for unreliability was .211 for impulsivity-related traits). Thus, while there is not a strong correspondence between self-report and behavioural measures, they nevertheless exhibit reliable convergence.

The assessment of BIS sensitivity is relatively more challenging, as, in accord with the r-RST, the BIS is proposed to underlie goal conflict resolution. Therefore, an experimental task or situation measuring BIS sensitivity needs to engender goal conflict. Possible tests of BIS sensitivity include passive avoidance tasks and extinction tasks, such as the Q-task (Kambouropoulos & Staiger, 2004; Newman et al., 1997), passive-avoidance conflict task (Newman et al., 1985); and the go/no-go discrimination task (Avila & Parcet, 2000). These tasks involve uncertain reinforcement whereby a previously punished response is no longer associated with punishment but with reward (passive avoidance learning) or a previously rewarded response is no longer rewarded (extinction learning). This is proposed to activate the BIS due to the need to resolve goal conflict with respect to the changed response-reinforcement associations. Higher BIS individuals are expected to demonstrate quicker behavioural adaptation, which may translate to more correct responses, quicker response time, fewer errors of omission and fewer errors of commission. In their meta-analysis, Leue and Beauducel (2008) found reliable effects between these behavioural parameters on conflict tasks and self-reported trait anxiety (ρ = .164), which were larger than for nonconflict tasks. However, the associations were modest, as were the case for between impulsivity-related traits and behaviour parameters. Nonetheless, Leue and Beauducel's (2008) meta-analysis showed that the behavioural assessment of BIS importantly requires a task that elicits motivational conflict.

Physiological Measures

A number of researchers have advocated for the use of physiological measures as a

more direct assessment of the sensitivity of the r-RST systems (e.g., Smillie, 2008b; de Pascalis, 2008). One such method is to assess autonomic activity using measures of heart rate, skin conductance, and startle reflex. Changes in heart rate have been proposed to be a direct index of somatic complying incentive and arousal, with increasing heart rate associated with response to rewards (e.g., see Fowles, 1980, for a review; Arnett & Newman, 2000) and higher levels of trait impulsivity (see Hare, 1978, for a review), although not all studies have found an association (e.g., Gomez & McLaren, 1997). Furthermore, changes in electrodermal activity as assessed by skin conductance can be used as an index of arousability and general cortical arousal, specifically during emotional reactions in anticipation of punishment (Fowles, 1980). For example, increases in skin conductance have been observed in reaction to punishment signals, indicative of greater FFFS sensitivity (Arnett & Newman, 2000). Additionally, increases in the magnitude of the eye-blink component of the startle reflex, as measured by electromyogram (EMG), have been found to be linked to fearful and aversive emotional states (Vrana, Spence, & Lang, 1988; Hamm et al., 1993). The greater startle reflex has also been related to response to unpleasant stimuli, especially for individuals with high levels of trait harm avoidance (Corr et al., 1995, 1997).

Another set of assessment tools are neuroimaging, such as functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), and the event-related potential (ERP) technique. fMRI is able to identify dynamic changes in the brain in response to events, and thus, arguably, provides a potential direct measure of reactivity to rewarding and punishing situations. For example, amygdala activation has been observed in response to emotionally conflicting stimuli and related to higher levels of neuroticism (Haas, Omura, Constable, & Canli, 2007). However, the high costs of fMRI can be prohibitive, and not conducive to individual differences studies that require large samples. Alternatively, a more cost-effective means is to use EEG to measure cortical electrical signals at the scalp, and the

related technique of ERP, which measures event-contingent electrical signal potentials. There is literature that suggests relative greater left frontal cortical activity, as indexed by less alpha waves measured by EEG, is associated with higher BAS sensitivity (e.g., Sutton & Davidson, 1997; a more thorough review is provided in Chapter 6). Additionally, a number of ERPs have been related to signals of reward and punishment (e.g., de Pascalis, Fiore, & Sparita, 1996; Peterson, Gable, & Harmon-Jones, 2008; Wacker, Chavanon, Leue, & Stemmler, 2008). While EEG allows for temporal precision in the data, it is limited by low spatial resolution and thus does not allow for pinpointing underlying brain regions.

A further avenue for assessing r-RST, and arguably perhaps the most direct method of manipulating reinforcement sensitivity, is the administration of psychopharmacologic drugs. Analogous to giving anxiolytic and panciolytic agents to rats, drugs that are known to influence specific neuroreceptors can be administered to humans to evaluate their differential effects on functioning as underpinned by individual differences in reinforcement sensitivity. For example, in addiction research, administering cocaine and amphetamine has been linked to incentive processing in humans (Knutson, Bjork, Fong, Hommer, Mattay, & Weinberger, 2004), as well as positive mood (White, Lott, & de Wit, 2006) and Extraversion (Depue, 2006; Depue & Collins, 1999). Other drugs such as selective dopamine agonists (e.g., lisuride) and dopamine antagonists (e.g., fluphenazine, sulpiride) can also be used to manipulate the reward system, with differential effects observed as a function of personality (e.g., Wacker, Chavanon, & Stemmler, 2006; Chavanon, Wacker, Leue, & Stemmler, 2007; Cools, Sheridan, Jacobs, & D'Esposito, 2007). The issue with psychopharmacologic manipulation is that many candidate drugs do not have sufficiently specific neurochemical effects to pinpoint pathways and mechanisms corresponding to reinforcement sensitivity.

Finally, recent technological advances have allowed for the identification of psychogenomic markers associated with reinforcement sensitivity. For example, the short

allele of 5-HTTLPR genotype has been linked to greater amygdala activity during perceptual processing of fearful and angry facial expressions (Hariri et al., 2002), as well as higher levels of trait neuroticism (Lesch et al., 1996) and harm avoidance (Cloninger, 1986). For approach processes, the most relevant genotypes are those pertaining to dopamine function. For example, the presence of the A1 allele of the Taq1A polymorphism of the DRD2 gene has been associated with greater reward sensitivity (Cohen, Young, Baek, Kessler, & Ranganath, 2005), while the 7-repeat allele of the DRD4 gene has been related to higher levels of trait extraversion (Canli, 2006). However, these effects often account for a very small proportion of variation in phenotypic behaviour. Genetic effects are often multiple and interactive, and to discover such effects requires the use of genome wide association tests that are costly and prone to type 1 error. Although knowledge in this area is still in its infancy, advancing technology and understanding of genetic mechanisms hold promise to discovering the biological bases of the r-RST systems.

In the present thesis, the EEG methodology was used in Study 3 to provide a neurophysiological index of r-RST. This method was selected as one of the more accessible, low-cost physiological measures, and one that has also demonstrated relatively straightforward links with reinforcement sensitivity. Some of the other methodologies such as fMRI, the administration of psychopharmacologic drugs, and genotyping are more resource intensive (especially for individual differences research requiring larger sample sizes) and so were not adopted in the studies reported in this thesis.

The Application of RST to Other Psychological Domains

Reinforcement sensitivity, as a general theory of motivation, has been increasingly applied as a framework to explain a diverse range of psychological phenomenon. As of December 2015, a PSYCInfo database search with the keyword “reinforcement sensitivity”

yielded 293 results. While a thorough review of the literature is impossible within the constraints of this thesis, Table 2.2 provides an impressionistic summary of a selection of studies between RST and various psychological constructs.

As can be seen from Table 2.2, RST has been applied to a diverse range of domains. Generally, BAS sensitivity has been related to positive affective, cognitive, occupational health, and relationship outcomes (e.g., Clark et al., 2015; Gomez & Gomez, 2002; Hundt et al., 2013; van der Linden et al., 2007). However, reduced BAS sensitivity has also been associated with depression, while greater BAS sensitivity has been linked to a range of externalising mental disorders such as conduct disorder, as well as risky behaviours and addictions (e.g., Bijttebier et al., 2009; O'Connor et al., 2009; Loxton, Nguyen, Casey, & Dawe, 2008). Conversely, BIS/FFFS sensitivity has been associated with more adverse outcomes across the board, ranging from poorer executive functioning (Jackson et al., 2014), more negative daily affect (Hundt et al., 2013), more internalising psychopathology such as anxiety (Bijttebier et al., 2009), poorer occupational health (e.g., van der Linden et al., 2008), and parenting and relational anxiety (e.g., Kiel & Maack, 2012; Ly & Gomez, 2014). The only exception is that BIS/FFFS sensitivity predicts safer driving behaviour (Harbeck & Glendon, 2013) and is unrelated to risky behaviours. Therefore, these studies demonstrate the differential links that BAS and BIS/FFFS sensitivities have to a range of psychological outcomes.

However, few studies have examined individual differences in reinforcement sensitivity in relation to behaviour within social contexts, and this thesis aims to address this gap in the literature. Reinforcement sensitivity has been recognised to be relevant to social interactions, which also entail appetitive-approach and aversive-avoidance processes (Knyazev, Wilson, & Slobodskaya, 2008). Of the extant research, there is evidence to suggest that an overactive BIS or BAS leads to social adjustment problems, such that an overactive

Table 2.2

Impressionistic Summary of Associations between the r-RST Motivational Systems and a Range of Psychological Outcomes

	BAS	**BIS (original or revised conceptualisation)**	**FFFS**
Personality	Extraversion, novelty-seeking (Corr, 2008)	Harm-avoidance, neuroticism, anxiety (Corr, 2008)	Fear-proneness (Corr, 2008)
Cognition	Processing of pleasant information (Gomez & Gomez, 2002)	Processing of unpleasant information (Gomez & Gomez, 2002)	Poorer executive functioning (Jackson, Loxton, Harnett, Ciarrochi, & Gullo, 2014)
Affect	More daily positive affect, less irritability/anger (Hundt, Brown, Kimbrel, Walsh, Nelson-Gray, & Kwapil, 2013); aggressive responses to anger scenarios (Cooper, Gomez, & Buck, 2008)	More daily negative affect & less daily positive affect (Hundt, Brown, Kimbrel, Walsh, Nelson-Gray, & Kwapil, 2013); emotion regulation difficulties (Tull, Gratz, Latzman, Kimbrel, & Lejuez, 2010); trait anger (Cooper, Gomez, & Buck, 2008)	
Psychopathology	Low BAS associated with depression; high BAS associated with externalising disorders such as	Internalising disorders such as anxiety, personality disorders (avoidant, dependent, & obsessive-	

Table 2.2 (continued)

Psychopathology	conduct disorders, substance abuse, antisocial behaviour (Knyazev et al., 2008; see Bijttebier, Beck, Claes, & Vandereycken, 2009, for a review)	compulsive, borderline and narcissistic) (see Bijttebier et al., 2009, for a review)	
Risky and/or addictive behaviours	Drinking & smoking; (O'Connor, Stewart, & Watt, 2009); problem gambling (Loxon et al., 2008); alcohol craving (Franken, 2002); substance use (Dawe & Loxton, 2004); risky driving behaviour (Harbeck & Glendon, 2013)	Safer driving behaviour (Harbeck & Glendon, 2013)	
Occupational health	Higher job satisfaction and involvement (van der Linden, Taris, Beckers, & Kindt, 2007); interest in studying & higher positive affect following positive feedback (Krupic & Corr, 2014)	Job stress and fatigue (van der Linden, Taris, Beckers, & Kindt, 2007); more negative effort and invested effort into university examination preparation (Krupic & Corr, 2014)	
Relationships	Inversely related to social interactional & evaluative anxiety (Ly & Gomez, 2014); reduced loneliness (Clark et al., 2015)	Overprotective parenting (Kiel & Maack, 2012); Social interactional & evaluative anxiety (Ly & Gomez, 2014)	Social interactional & evaluative anxiety (Ly & Gomez, 2014); loneliness (Clark et al., 2015)

BAS predisposes one to hyperactivity, conduct disorders and antisocial behaviour; while an overactive BIS predisposes one to emotional problems such as anxiety and depression (see Knyazev et al., 2008, for a review). In another study, Ly and Gomez (2014) found that both BIS-anxiety and social phobia had strong predictions to anxiety over interactional and evaluative (observation) concerns during social situations. There was also a modest positive prediction of FFFS-fear and a medium negative prediction of BAS to social observation and interaction anxiety (Ly & Gomez, 2014). Converging with these results, FFFS sensitivity has been linked to social anxiety and panic-like symptoms in situations of perceived inescapability (Kambouropoulos, Egan, O'Connor, & Staiger, 2014; Kimbel, 2008). Furthermore, Clark et al. (2015) found that higher levels of punishment sensitivity (FFFS) but not BIS-anxiety predicted higher levels of loneliness, while higher levels of reward sensitivity (BAS) was associated with reduced loneliness. Together, these studies suggest that greater BIS and/or FFFS sensitivities are associated with distress towards and avoidance of social situations respectively, while greater BAS sensitivity is associated with lower levels of social anxiety and avoidance. However, very few studies have looked at the intersection between attachment patterns and individual differences in reinforcement sensitivity, which will be the focus of the next chapter.

Notably, a major limitation of most of the extant reinforcement sensitivity research, including the studies listed in Table 2.2, is not taking into account the updated revision to the theory by Gray and McNaughton (2000). Many of the studies either explicitly assume Gray's (1982) classical RST and/or adopt measures such as Carver and White's (1992) BIS/BAS scales that reflect the outdated conceptualisation. In these studies, BIS and FFFS sensitivities are confounded, and conclusions are drawn regarding general aversive motivation, without making the fundamental distinction in defensive direction between BIS and FFFS (Heym et al., 2008). As such, in Table 2.2, the fourth column ('FFFS') lists very few studies that

pertain to links with FFFS-mediated pure avoidance, while most of the studies included in the third column ('BIS') represent generalised FFFS/BIS aversive motivation. Therefore, more research is required that takes into account the r-RST, especially as applied to the social domain.

Chapter Summary

In this chapter, a detailed overview of RST was provided. As a neuropsychological theory of personality, motivation, emotion and learning, the theory's explanatory bedrock is the postulation that basic motivation involves approach and avoidance of appetitive and aversive stimuli respectively, as underpinned by reinforcement learning. Based on basic animal research, the classical version of the theory (RST) proposes three biobehavioural motivational systems (Gray, 1982, 1987a, 1987b). In Gray and McNaughton's 2000 revision of the theory (r-RST), the same three systems are nominally retained although there are critical differences in their ascribed function. The first system, the FFFS, is responsible for mediating avoidance behaviour towards all aversive stimuli in the r-RST, as opposed to unconditioned aversive stimuli in the classical RST. The second system, the BAS, is largely unchanged and mediates approach towards all appetitive stimuli. Lastly, the BIS is proposed to be responsible for conflict resolution (e.g., when there is simultaneous, equal and incompatible activation of the FFFS and BAS resulting in approach-avoidance conflict) in the r-RST, as opposed conditioned aversive stimuli in the classical version of the theory. The FFFS, BAS and BIS are underpinned by hierarchically organised neural structures.

Given the inherent complexities and neurobiological focus of the r-RST, operationalising the FFFS, BAS and BIS has not been easy. Studies commonly use purpose-built and/or proxy self-report measures, although the majority are not appropriate for the assessment of the revised theory. Behavioural learning paradigms have also been utilised,

both in the assessment of unambiguous response-reward/punishment associations, as well as passive avoidance and extinction tasks that engender response conflict. Finally, physiological measures such as autonomic indices and neuroimaging (e.g., fMRI, EEG) potentially provide more direct assessments of the sensitivity of biologically-based motivational systems, although associations with FFFS, BAS and BIS may not be clear-cut.

Despite the measurement challenges, both RST and r-RST have been applied to a range of psychological phenomenon. As a general motivational framework, it is readily applied to explain approach-avoidance processes inherent to many psychological phenomena. However, very few studies have examined reinforcement sensitivity in interpersonal contexts, and in particular, in relation to attachment relationships, which will be considered in further detail in the next chapter.

Chapter 3: Adult Attachment and Reinforcement Sensitivity

Overview

This chapter will consider the nature of the relations between adult attachment and reinforcement sensitivity. Firstly, general theoretical overlaps between the two domains will be highlighted. Following this, the chapter will provide a review of specific theoretical relations, along with indirect and direct empirical links, between individual differences in adult attachment and each of the three r-RST motivational systems (that is, the BAS, FFFS, and BIS). Finally, this chapter will conclude with a summary of the overarching thesis aims, general hypotheses and overview of the three research studies designed to address the focal research question.

General Theoretical Overlaps

Bowlby's (1969/1982, 1973, 1980) attachment theory presents striking broad theoretical overlaps with Gray and McNaughton's (2000) r-RST. Although differing in explanatory scope, with r-RST providing a more general account of behaviour than attachment theory, they share theoretical frameworks (both are essentially theories of motivation and personality), have their origins in ethological and evolutionary research, and explain behaviour with references to biobehavioural systems and approach and avoidance dynamics. These overarching connections suggest that attachment behaviour and reinforcement sensitivity may be related in a more fundamental manner. In this section, I will elaborate upon the broader theoretical links between attachment and reinforcement sensitivity.

Firstly, attachment theory and reinforcement sensitivity theory are theories of motivation and personality. According to Bowlby (1969/1982), attachment theory is a theory

of motivation concerned with basic prototypic biobehavioural structures (focally, the attachment system) that are evolutionary-based and serve an adaptive purpose. While primarily a motivational theory, early attachment experiences are further purported to contribute to personality development, as Bowlby (1969/1982) stated that the "child's first human relationship [is] the foundation stone of his personality" (p. 177). Attachment experiences play a critical role in shaping cognitive representations of the self (and others), along with fostering emotion regulation ability, which, in turn, affects personality organisation (Bowlby, 1969/1982). Similarly, r-RST is first and foremost a motivational theory, emphasising the motivational function (as opposed to affective or personality processes) of the BAS, FFFS and BIS (Smillie et al., 2011). The behavioural outputs mediated by the BAS, FFFS and BIS are less important than motivational direction or goal (to avoid threats or approach rewards) that drives those behaviours. Secondarily, r-RST uniquely links the motivational systems to personality, whereby differences in the functioning of the underlying motivational systems are proposed to give rise to observed personality structure (Corr, 2008; Gray, 1970). Therefore, both attachment theory and r-RST are primarily theories of motivation, and secondarily theories of personality.

Secondly, both attachment theory and r-RST assumes evolutionary and ethological perspectives. Bowlby (1969/1982) explicitly drew upon the Darwinian view that behaviour is adaptive and ultimately serves to optimise survival, proposing that the attachment system is a safety regulating system that mobilises an individual towards the attachment figure in times of danger. Likewise, the r-RST motivational systems that govern responses to rewarding, threatening, and goal-conflict stimuli in the environment are explained in terms of historically functional/adaptive terms (Gray and McNaughton, 2000). Following an ethological approach, both theories also emphasise studying behaviour in its natural environment that allows for the functional significance of the behaviour to be observed (Blanchard & Blanchard, 1990;

Bowlby, 1969/1982; Gray & McNaughton, 2000). For example, Bowlby (1962/1982) argued that the study of attachment behaviour is optimal in naturalistic or quasi-naturalistic dyadic interactional settings, while Blanchard and Blanchard (1990) also recognised that the functional expression of defensive behaviour is ecologically-tied and context-dependent (such as on the potentiality of the threat, defensive distance, and availability of escape avenues). Finally, both theories expound upon the cross-species relevance of behaviour. Bowlby's (1969/1982) theory was inspired by observations of attachment behaviour in non-human animals such as Harlow's (1958) monkeys and Lorenz's (1935) goslings, suggesting that many animal species possess an attachment system. Similarly, basic defence responses such as avoidance, flight, and fight, are common across non-human animals and humans, with some of the first observations conducted in rats (Blanchard et al., 2001; Gray and McNaughton, 2000). Therefore, both attachment theory and r-RST assume evolutionary and ethological perspectives, whereby behaviour is conceptualised in adaptive-survival terms, needs to be studied in its naturalistic environment, and demonstrate cross-species relevance.

Thirdly, the concept of biobehavioural systems is central to both attachment theory and r-RST. According to Bowlby (1969/1982), attachment behaviour is underpinned by behavioural control systems, which function purposively, are goal-corrected, and are regulatory in nature. More specifically, attachment behaviour involves the set-goal of proximity to the attachment figure, which is achieved via a hierarchical coordination of behavioural systems (ranging from reflexive crying for the infant, to physical approach) that is implemented to regulate the distance to and direction (orientation of behaviour) towards the attachment figure. Conceptual parallels can be drawn with r-RST, which proposes three biobehavioural systems – the BAS, FFFS, and BIS – that are likewise purposive, goal-corrected, and regulatory in nature. Each of these biobehavioural systems involves the coordination of a range of behaviours to regulate the interspatial distance to a rewarding

and/or threatening stimulus. This likewise involves a hierarchical defence system ranging from simple reflexes to more complex behaviour. Therefore, the concept of biobehavioural systems is inherent to both attachment theory and r-RST, whereby behaviour is purposive and goal-corrected, regulated with respect to distance and direction, and involves the hierarchical coordination of behavioural systems.

Finally, both attachment theory and r-RST describe approach and avoidance dynamics. On one hand, Bowlby (1969/1982) referred to the avoidance of danger and approach towards an attachment figure as the "twin processes of survival" (p. 151). The attachment figure elicits approach when they are appraised positively as a source of comfort and refuge, while unfamiliar and threatening situations elicit withdrawal. Furthermore, where the attachment figure is unavailable, unresponsive, and/or rejecting, this may also elicit withdrawal, as in the case of individuals with higher levels of attachment avoidance. As such, attachment behaviour, in part, is linked to the appraisal of the attachment figure as either rewarding and/or punishing. On the other hand, r-RST explicitly defines each motivational system as mediating approach or avoidance behaviour in response to rewarding stimuli, punishing stimuli, or goal conflict. The theory, as its namesake, draws heavily upon reward and punishment learning, and survival behaviour is organised around this principle. Therefore, both attachment theory and r-RST describe individual differences in approach and avoidance behavioural patterns.

Whilst attachment theory and r-RST share broad theoretical frameworks and perspectives, there are some notable differences between the two theories. Firstly, attachment theory tends to emphasise relational experiences and early caregiving environment in the development of attachment bonds and individual differences in attachment patterns, whereas r-RST emphasises the neurobiological bases of the motivational systems. Attachment theory originated from direct observations of early infant-caregiver interactions, and, although

Bowlby (1969/1982, 1973, 1980) acknowledged the biological basis of the attachment system and the influence of the biological make-up of an individual that give rise to innate dispositions, greater consideration has traditionally been given to the history of relationship experiences, which constitute as environmental influences. In contrast, Gray (1982; Gray & McNaughton, 2000) strongly intended RST to be a bottom-up theory of personality, as he and his colleagues inferred neurobiologically-based motivational systems from ethopharmacological data to explain phenotypic trait variations in personality. Therefore, while both theories propose biological-based behavioural systems, r-RST research has provided theoretical and empirical emphasis on bottom-up biological processes. Given the different foci of the two theories, an integrative exploration may contribute to understanding how attachment patterns are related to more biologically-based motivational systems, especially since Bowlby (1969/1982) assumed that the attachment system is also fundamentally biologically based.

Secondly, attachment theory is a more circumscribed theory pertaining to close relationships, while RST describes domain-general motivations. Bowlby (1969/1982) theorised that the attachment system is one of several evolutionary-based behavioural systems (others include the exploratory, sexual, and caregiving systems) that regulate behaviour. The attachment system is specifically concerned with appraisals of threat and the availability and responsiveness of the attachment figure, and avoidance of threat and approach-avoidance behaviour with respect to the attachment figure. In contrast, Gray's (1982; Gray & McNaughton, 2000) RST specifies three fundamental motivational systems – the BAS, FFFS, and BIS – that govern behaviour towards all stimuli. The sensitivity of the BAS, FFFS, and BIS translates to generalised sensitivity to rewarding stimuli, threatening stimuli, and goal-conflict respectively. Therefore, the two theories differ in their domain-specificity such that attachment theory describes a mechanism of stress-regulation within the

context of attachment relationships, while r-RST proposes more general motivational systems that mediate sensitivity to all kinds of stimuli.

The different levels of domain-specificity at which attachment theory and r-RST explain behaviour have led some researchers to propose a hierarchical relation between the behavioural systems. Smillie et al. (2011) recognised that reinforcement sensitivity is concerned with approach and avoidance processes that are fundamental to many aspects of behaviour. Rather than theorise different motivational systems for each new behavioural context, basic motivational systems like r-RST may provide relevant distal, bottom-up neurobiological explanations. That is, the general relevance of approach and avoidance processes with regards to motivations such as eating, drinking, and sex, as well as attachment needs, implicate a role for the systems of r-RST. The domain-specific motivations cannot be completely reduced to reinforcement sensitivity, as they also involve context-specific behaviour, affect, and cognitions. Nonetheless, r-RST offers a general explanation of approach and avoidance motivations that are relevant to attachment system functioning.

In accord with Smillie et al.'s (2011) proposition that reinforcement sensitivity may offer a distal explanation to context-specific behaviour, Ure (2011) proposed a relation whereby the attachment system operates as a nested lower-order system of the higher-order r-RST motivational systems. That is, as Ure described, "the attachment system may operate as a sub-system of RST that is calibrated specifically to regulate appetitive and aversive processes in close relationships" (p. 31). Therefore, individual differences in reinforcement sensitivity that encompass general approach and avoidance tendencies have top-down influence on variations in approach and avoidance tendencies in attachment relationships. Whilst the attachment system entails context-specific manifestations of the higher-order global motivations, as previously noted, it also involves behavioural features specific to attachment relationships that are not explained by reinforcement sensitivity (such as

interpersonal regulation and internal working models). Nonetheless, given the proposed hierarchical relations, it is important to consider how the different motivational systems – higher-order reinforcement sensitivity and lower-order attachment system – function integratively to regulate behaviour.

In summary, this section has highlighted that attachment theory and r-RST broadly share theoretical frameworks. Both are essentially theories of motivation and personality, draw upon ethological and evolutionary research, and explain behaviour with reference to behavioural systems and approach and avoidance dynamics. The theories do, however, differ in explanatory scope, such that attachment theory pertains to stress regulation in the context of intimate relationships; while r-RST describe domain-general motivational systems that regulate responses to threatening stimuli, rewarding stimuli, and goal-conflict. Nevertheless, given the fundamental connections between attachment theory and r-RST, it is of interest to further explore the nature of these connections. The next section will review specific theoretical and empirical links between adult attachment and each of the three r-RST motivational systems (BAS, FFFS, and BIS) in turn.

Adult Attachment and BAS sensitivity

> *"...[those] who seemed most solidly attached to their mothers displayed little protest behaviour or separation anxiety, but rather showed the strength of their attachment to the mother through their readiness to use her as a secure base from which they could both explore the world and expand their horizons to include other attachments."*
>
> *(Ainsworth, 1963)*

Individual differences in adult attachment may be related to varying degrees of BAS sensitivity, which refers to the disposition to approach rewarding stimuli in the environment. At the domain-specific level, attachment insecurity, especially attachment avoidance, has been related to lower levels of appetitive-approach motivation in close relationships. At the domain-general level, Bowlby (1982/1969, 1988) proposed an intimate relation between attachment behaviour and exploratory-approach towards novel stimuli in the environment. Furthermore, there is some research relating adult attachment to BAS-related constructs such as social anhedonia and extraversion, as well as directly to BAS sensitivity. This section will provide a review of the theoretical and empirical connections between adult attachment and BAS sensitivity, examining both indirect links with social appetitive motivation, exploratory behaviour, social anhedonia and extraversion, as well as direct links with BAS sensitivity.

Attachment Avoidance and Social Appetitive Motivation

At the domain-specific level, a body of literature suggests that the specific dimension of attachment avoidance is inversely related to appetitive-approach motivation in close relationships. According to Simpson, Rholes and Nelligan (1992), attachment avoidance is characterised by "simple, unipolar avoidant behavior" (p. 444). Although the simplicity of the orientation is debatable, attachment avoidance is defined by negative appraisals of the attachment figure's availability, which translates into affective and behavioural manifestations of lower levels of appetitive motivation in the context of attachment relationships. The avoidant individual experiences a history of consistently unavailable and/or unresponsive attachment figures (Bowlby, 1982/1969). Consequently, the individual adopts a negative model of others as unreliable, does not seek out or approach the attachment figure for stress alleviation, and instead becomes self-reliant. Therefore, by definition,

attachment avoidance involves lower levels of appetitive-approach motivation, which may translate to reduced BAS sensitivity, in close relationships

Empirically, studies have shown that attachment avoidance is negatively associated with proximity-seeking and behavioural approach in social contexts. For example, studies have found that avoidant individuals tend to engage in lower levels of support-seeking under stress (Simpson et al., 1992), reduced proximity-seeking prior to separation (Fraley & Shaver, 1998), and less social interactions with relationship partners (Kafetsios & Nezlek, 2002; Pierce & Lydon, 2001; Pietromonaco & Barrett, 1997; Tidwell, Reis, & Shaver, 1996). Furthermore, it is positively related to distancing and contact avoidance behaviour in a situation of relationship threat (Meyer, Olivier, & Roth, 2005). Overall, the evidence consistently point to an inverse relation between attachment avoidance and behavioural approach in attachment relationships.

Moreover, attachment avoidance has been related to lower levels of perceived social reward in close relationships, indicative of reduced BAS sensitivity. For example, across two studies, Gere, MacDonald, Joel and Impett (2013) found that, whilst controlling for attachment anxiety, attachment avoidance was uniquely associated with lower self-reported perceptions of social reward such as opportunities for intimacy and connection toward current romantic partners. MacDonald, Locke, Spielmann and Joel (2013) similarly found that attachment avoidance was negatively linked to reward perception in romantic relationships. Furthermore, Spielmann, Maxwell, MacDonald and Baratta (2013) demonstrated across a series of studies that the devaluation of social reward only occurred in current and potential future relationships. That is, avoidant individuals appraised the potential for intimacy, romantic interest and connection as lower towards current romantic attachment figures and potential romantic interests, but not towards previous partners and romantically uninterested persons. Also, due to their devalued expectations, Spielmann et al. (2013) found that avoidant

individuals experienced less anticipated distress from reward loss in the form of relational disappointment and rejection. Therefore, the tendency to perceive lower social rewards appears to serve as a context-dependent defence mechanism that reduces the desire for romantic approach where the risk of frustrated reward may be higher (Spielmann et al., 2013).

Furthermore, there is evidence to suggest that the avoidant individual's appraisals of close relationships as less rewarding may be linked to physiological activity associated with reward motivation. Poore et al. (2012) found that unexpected social gains and losses moderated the same reward system neural activity as that for non-social gains and losses. This suggests that sensitivity to social reward may be mediated by a general reward motivational system such as the BAS. In an fMRI study, Vrticka, Andersoon, Grandjean, Sander and Vuilleumier (2008) were further able to link the activation of the general reward system to social reward as a function of attachment style. Specifically, they found reduced activation of the brain reward circulatory when viewing smiling faces for individuals with higher levels of attachment avoidance. They suggest that this may reflect a diminished capacity to experience pleasure from social contact, independent of fears of rejection. Furthermore, Yee and Shiota (2015) found that attachment avoidance was associated with reduced skin conductance responses, which is an autonomic "orienting response," when exposed to various positive stimuli such as lottery games, childhood characters, baby animals, cartoons and images of nature. Although in this instance, the stimuli are not social in nature, the study provides further evidence that attachment avoidance is associated with generally reduced sensitivity of the reward motivational system. Therefore, avoidant individuals appear to display not only a reduction in behavioural approach and less positive appraisals of social rewards, but also lower levels of neural and autonomic activity related to reward motivation.

Attachment and Exploratory Behaviour

In addition to the connection between attachment avoidance and reduced appetitive-approach in close relationships, attachment patterns are related to generalised tendencies to engage in exploratory-approach behaviour. Bowlby (1982/1969, 1988) originally proposed an intimate relation between the attachment system and exploratory behaviour. Exploratory behaviour refers to approach towards novel stimuli in the environment, and as such, it is by definition likely to be mediated by the BAS. One of the basic premises of attachment theory is that an available and responsive attachment figure serves as a secure base for the attached person (whether infant, child or adult) to venture out into and explore his or her external environment via play, work, learning, growth experiences, and accomplishing goals (Bowlby, 1982/1969, 1988). As the secure base, the attachment figure serves as a refuge for comfort and assistance when difficulties arise, and thereby instils confidence to engage in exploration. Conversely, the unavailability or absence of the attachment figure leads to reduced exploratory behaviour. This has been typically observed in infants, whereby the presence of the mother encourages exploratory behaviour (e.g., visual exploration, locomotion and play), while the absence of the mother inhibits exploratory behaviour and, instead, prompts proximity-seeking (Ainsworth & Bell, 1970). Therefore, the attachment bond plays an important role in regulating exploratory-approach behaviour, whereby a secure attachment enables a person to strike "a happy balance between exploration and attachment" (Bowlby, 1982/1969, p. 338).

In adults, this interactional dynamic between attachment and exploration has been evidenced in a number of studies. In support of the idea that the attachment figure functions as a secure base, attachment security is generally linked with higher levels of exploratory behaviour, while attachment insecurity is linked to reduced exploratory behaviour (Feeney & Van Vleet, 2010). For example, on one hand, secure individuals tend to engage more

positively with work (Hazan & Shaver, 1990), are more curious (Mikulincer, 1997), and pursue more leisure activities including those of a thrill and adventure seeking nature (Carnelley & Ruscher, 2000). On the other hand, insecure individuals possess a less positive attitude towards work (Hazan & Shaver, 1990), while, more specifically, avoidant individuals express less curiosity (Mikulincer, 1997) and anxious individuals report avoiding thrill and adventure-seeking leisure activities (Carnelley & Ruscher, 2000). Moreover, Green and Campbell (2000) found that both dimensions of attachment anxiety and attachment avoidance were negatively correlated with self-reported desire to explore physical, social, and intellectual environments. In a unique experimental manipulation, they additionally found that priming a sense of attachment security (by asking participants to memorise sentences containing security themes, for example, "Jean comforted her child") promoted the desire to explore, compared with insecurity priming (Green & Campbell, 2000). Therefore, this suggests that attachment security is directly related to increased approach-oriented exploration, while attachment insecurity inhibits exploration. The extant research, however, does not allow for a strong conclusion as to the nature of the relations between exploratory-approach behaviour and the specific attachment dimensions of anxiety and avoidance. Furthermore, it should be noted that exploratory behaviour, while embodying approach motivation, may not necessarily be directed towards appetitive stimuli, but could represent a general tendency to approach the external environment, which may also include neutral, novel, and aversive stimuli.

Adult Attachment and BAS-related Traits

Another domain of research that may inform upon the nature of the relations between adult attachment and BAS sensitivity are studies that have examined links between attachment orientations and BAS-related personality traits such social anhedonia and

extraversion. Unsurprisingly, the dimension of attachment avoidance has been positively related to social anhedonia, which is defined as the inability to experience positive feelings in interpersonal relationships (Berry, Wearden, Barrowclough, & Liversidge, 2006; Troisi, Alcini, Coviello, Nanni, & Siracusano, 2010). This is consistent with the previously reviewed research that attests to reduced social appetitive motivation for individuals with higher levels of attachment avoidance (e.g., Gere et al., 2013). Conversely, attachment avoidance shows inverse associations with extraversion, and in particular, with the facets of warmth, gregariousness and positive emotions (see Mikulincer & Shaver, 2010; Noftle & Shaver, 2006, for reviews). The lower levels of warmth and gregariousness may be attributed to the avoidant individual's defensive deactivation of intimacy needs and inhibition of emotional expression, while social anhedonia and lower levels of positive emotions may point to a diminished capacity to experience social reward (Troisi et al., 2010). The associations with these personality constructs are, however, small to moderate in size, with attachment avoidance providing unique explanatory power in the context of close relationships (see Mikulincer & Shaver, 2010; Noftle & Shaver, 2006, for reviews). Notably, the aforementioned traits and facets tend to be interpersonal in nature, rather than represent general BAS sensitivity.

In contrast to attachment avoidance, attachment anxiety does not display the same inverse associations with measures of approach-oriented behaviours and traits. Attachment anxiety has inconsistent links with extraversion, with about half the studies reporting no association while the other half of studies reporting a negative association (Mikulincer & Shaver, 2010; Noftle & Shaver, 2006). The relevant facets are also different, with lower levels of positive emotions and self-confidence/assertiveness, and this is not unexpected, since anxious individuals tend to exaggerate expressions of negative emotions and harbour self-doubts stemming from a negative model of self. Attachment anxiety is also not

significantly associated with social anhedonia (Berry et al., 2006; Troisi et al., 2010). Therefore, unlike attachment avoidance, attachment anxiety does not appear to have robust and consistent associations with BAS-related personality traits.

The reviewed associations between attachment patterns and social appetitive motivation, exploratory behaviour, and BAS-related traits are summarised in Table 3.1. As can be seen from the table, attachment avoidance is consistently related to lower levels of social and general appetitive motivation, which may indicate reduced BAS sensitivity. Conversely, the associations between attachment anxiety and social and general appetitive motivation are less clear, and do not provide strong indirect evidence of a link between attachment anxiety and BAS sensitivity. The next section will review direct evidence of links between adult attachment and BAS sensitivity.

Adult Attachment and BAS Sensitivity: Literature Review

Very few empirical studies have directly examined the nature of the relationship between adult attachment and reinforcement sensitivity. A review of studies that examined the direct link between attachment and BAS sensitivity was conducted. This search was performed using the PsycINFO, ScienceDirect and Web of Science databases in November 2015 for any articles with title or abstract keywords (1)"reinforcement sensitivity" or "BAS" or "Behavioral Approach System" and (2) "attachment," which initially yielded 113 references. The title and abstracts (and article, where the title and abstract were unclear) of these references was screened for the following inclusion criteria: (a) used an explicit measure of BAS sensitivity; (b) measured either adult or infant attachment; and (c) reported direct links between attachment and BAS sensitivity. Following this screening process, there were only three relevant papers. By examining the reference lists and publications of prominent researchers in the area, an additional two papers were found, resulting in a final

Table 3.1

Summary of Indirect Links between Attachment Dimensions and BAS Sensitivity

	Attachment anxiety	**Attachment avoidance**
Reduced social appetitive motivation (including proximity-seeking)	unclear	✓
Lower perceived social reward	unclear	✓
Reduced reward-related neural activity	unclear	✓
Inhibited exploratory-approach behaviour in general	✓	✓
Social anhedonia	×	✓
Lower levels of extraversion	unclear	✓

Note. ✓ = evidence of positive links; × = no reported links.

total of five papers. A summary of these studies is presented in Table 3.2.

Although there were very few relevant studies, across all studies, attachment avoidance was consistently and inversely related to BAS sensitivity, with correlations ranging from -.18 to -.38, $p < .05$. Only one of these studies [5] did not report a significant correlation, although the direction of the association was negative and similar in magnitude to those found in the other studies. This study also recruited a much smaller sample compared to the other studies, which may have reduced the statistical power to find a significant correlation. While most of the studies calculated an overall score on the BAS scales to index general BAS sensitivity, one study [4] did find that attachment avoidance was specifically linked to lower levels of BAS Reward Reactivity. Furthermore, Meyer et al. (2005) found that BAS sensitivity was related to confront-approach behaviour, especially in high threat situations, whereas attachment avoidance was related to distance-avoidance responses more

Table 3.2

Summary of Findings of Links between Adult Attachment and BAS and BIS Sensitivities

	Reference	Year	Sample	Attachment measure	Correlations with CW-BAS		Correlations with CW-BIS	
					Attachment anxiety	Attachment avoidance	Attachment anxiety	Attachment avoidance
1	Meyer, Olivier, & Roth	2005	202 female psychology undergraduates	ECR	.03	-.18**	.48**	.12
2	Mikulincer & Shaver, Study 1	2007	324 American students	ECR	.04	-.29**	.37**	-.07
3	Mikulincer & Shaver, Study 2	2007	125 Israeli students	ECR	.07	-.38**	.40**	-.10
4	Carnelley & Story	2008	105 online sample (92 F)	ECR	.04	-.24*	.39***	-.19
5	Hervas & Vazquez[a]	2013	59 undergraduates (41 F)	ECR	.08	-.20	.43**	-.06
6	Gallitto	2015	326 psychology undergraduates (243 F)	ECR	.04	-.23**	.43***	.01

Note. *$p < .05$; **$p < .01$; ***$p < .001$. [a]Used a state version of Carver and White's (1994) BIS/BAS scales. CW-BAS = Carver and White's (1994) BAS scales; CW-BIS = Carver and White's (1994) BIS scale.

generally across varying threat levels. These divergent predictions provide support for the inverse relations between the two constructs. It should be noted that all the studies reported in Table 3.2 utilised Carver and White's (1994) BAS scales, which were based on the original RST. Nonetheless, as the conceptualisation of BAS in the r-RST remains similar to original theory, the results still validly inform upon the nature of the relations between attachment avoidance and BAS.

Across all five research papers [Studies 1 to 6] that have directly examined the nature of the relationship between adult attachment and reinforcement sensitivity, no significant links were found between attachment anxiety and BAS, with near-zero correlations. This suggests that attachment anxiety is unrelated to reward sensitivity, either in general or social contexts. This could be due to the conceptualisation of the dimension as representing worry about the attachment figures' availability, fear of rejection, and having a negative model of oneself as unworthy of love, which constitute aversive rather than appetitive motivations. Therefore, no association between attachment anxiety and BAS sensitivity was expected.

Research Question and Hypotheses

The present thesis will examine whether individual differences in adult attachment are related to BAS sensitivity, which underpins a general tendency to approach rewarding stimuli. The reviewed literature suggests that attachment insecurity is related to inhibited exploratory behaviour, while, more specifically, attachment avoidance is related to reduced social and general appetitive-approach motivation. However, there were very few studies that directly examined adult attachment and BAS sensitivity, and all relied solely upon Carver and White's (1994) BAS scales, which were based on the original conceptualisation of RST. Although the

construct of BAS in the revised theory remains largely similar, it is useful to also include purpose-built measures of BAS sensitivity based on the r-RST. Therefore, across three studies, the present research programme will examine the nature of the relations between adult attachment and BAS sensitivity using different self-report measures of the latter, as well as at different levels of analysis (that is, self-report, behavioural, and neurophysiological). The hypotheses were as follows:

It was hypothesised that attachment avoidance would be inversely related to BAS sensitivity. No significant association was expected between attachment anxiety and BAS sensitivity.

Adult Attachment and FFFS Sensitivity

> *The first [proposition] is that when an individual is confident that an attachment figure will be available to him whenever he desires it, that person will be much less prone to either intense or chronic fear than will an individual who for any reason has no such confidence.*
>
> (Bowlby, 1973, p. 235)

FFFS sensitivity refers to the tendency to avoid aversive and threatening stimuli, manifest as fear-proneness (Gray and McNaughton, 2000). Bowlby (1969/1982, 1971) originally proposed an intimate connection between attachment behaviour and the fear response. This has been further substantiated by empirical data linking attachment orientations to a range of aversive dispositional and situational responses including fear-proneness, phobic reactions, threat

appraisals, and stress-related physiological processes. Finally, there is a small body of literature that have explicitly theorised and empirically assessed the nature of the relations between adult attachment and FFFS sensitivity. This section will provide a review of these disparate but related areas of research in order to determine the theoretical and empirical connections between attachment behaviour and FFFS sensitivity.

Theoretical Background

Bowlby (1969/1982, 1973) speculated on an important and intimate connection between attachment behaviour and the fear response, with two major sections of the second volume of his trilogy devoted to the ethology of and individual differences in susceptibility to fear. Both behavioural systems are proposed to have overlapping developmental trajectories, such that between six months and the second year of life, attachment behaviour and fear responses are simultaneously strengthened. Infants at that age show increasingly differentiated preference for their primary attachment figure as well as stronger protest behaviour and intensified proximity-seeking in response to (the threat of) separation. At the same time, these infants display a stronger fear response to strangers and novel situations, including towards previously familiar non-primary attachment figures such as friends and relatives. Therefore, in early infancy, the attachment bond and a healthy fear response to novel persons and situations are simultaneously strengthened.

Furthermore, from an ethological perspective, both attachment behaviour and the fear response serve complementary and critical roles in promoting survival (Bowlby, 1973). Fear elicits attachment behaviour, and the latter regulates the former. In accord with r-RST, Bowlby (1973) stated that fear leads to the predictable outcomes of immobility (freezing), increased

distance from threat (flight), or attack (fight). However, he additionally proposed that fear prompts behavioural approach to safety in the form of increased proximity-seeking towards an attachment figure. Indeed, Bowlby (1973) regarded attachment behaviour as a component of the fear response. The role of proximity seeking in the regulation of fear is highlighted whereby both infants and adults seek out companionship and physical contact when distressed. Being alone, especially in a threatening situation, increases one's vulnerability to danger and leads to compounded fear, while the presence of familiar and trusted attachment figures signals safety, provides protection and alleviates distress. Therefore, avoidance of threat and approach to an attachment figure functions in partnership and serve the same purpose of safety regulation.

While attachment behaviour is proposed to regulate the fear response with the end-goal of stress alleviation, a consistently unresponsive or unavailable attachment figure may lead to maladaptive, dysregulated and intensified fear response (Bowlby, 1973). For example, Harlow (1958) observed that infant monkeys in the absence of a surrogate mother showed extreme fear to all novelty and crippling displays of freezing, as well an enduring fear response, being unable to be pacified by other objects such as a cloth diaper. Similarly, an infant who experiences prolonged separation from the attachment figure displays dysregulated and heightened fear responses (Bowlby, 1973). Attachment insecurity in infancy, especially anxious-ambivalent attachment styles, has been related to greater fear of strangers (Stevenson-Hinde & Shouldice, 1990) and general fearfulness to novel and aversive stimuli (Kochanska et al., 1998). In these cases, the infant has difficulty co-regulating their fear response with their unresponsive attachment figure, and this, in itself, is a source of distress. Therefore, attachment behaviour coupled with the availability of the attachment figure as a secure base plays a vital role in helping the infant learn to respond appropriately to and regulate their fear response. In

accordance with Bowlby's (1973) theory, attachment security is expected to be linked to the development of a more functional FFFS, while attachment insecurity results in dysregulated and intensified fear responses.

Attachment Behaviour and FFFS Sensitivity: Indirect Evidence

A considerable number of studies have shown that individual differences in attachment orientation is related to self-reported experiences, expressions, and appraisals of fear, as well as cognitive, behavioural and physiological responses to threatening stimuli. To the degree that these responses are mediated by the FFFS, the research reviewed in this section may provide indirect evidence of the nature of the relations between adult attachment and FFFS sensitivity.

Firstly, at the phenomenological level, individual differences in the frequency of fear experiences and expressions have been reported as a function of attachment orientation. On one hand, fearful-avoidant and preoccupied attachment styles have been associated with more frequent experiences and expressions of fear (Consedine & Fiori, 2009; Consedine, Fiori, & Magai, 2012). Furthermore, both of these attachment styles exhibited greater right frontal activation of the brain, associated with aversive motivation, while watching fearful film clips, and for preoccupied individuals, higher levels of self-reported arousals on such occasions (Rognoni et al., 2008). On the other hand, dismissing attachment style has been associated with reports of less frequent experiences and expressions of fear (Consedine & Fiori, 2009; Consedine et al., 2012). Regardless of the frequency of fear experience and expression, all forms of attachment insecurity have been related to greater withdrawal when frightened, whilst attachment security has been inversely related to withdrawal and inhibition when frightened (Consedine et al., 2012). Together, these studies suggest that insecure attachment styles that involve higher

levels of attachment anxiety (i.e., preoccupied and fearful-avoidant) are related to more frequent self-reported experiences and expressions of fear, while secure and dismissing-avoidant styles show the reverse pattern.

Moreover, attachment insecurity has been related to self-reported appraisals of ambiguous and aversive situations as more threatening. In one study, undergraduate students were presented with 12 ambiguous social scenarios such as greeting and being ignored by a fellow student (Barrett and Holmes, 2001). Current attachment orientation accounted for 44% of variance in threat interpretation, with students who were insecurely attached to their parents and/or romantic partners being more likely to interpret the ambiguous scenarios as more threatening, compared with securely attached individuals. This study did not find differences in threat appraisal as a function of different insecure attachment styles. In another study, Mikulincer and Florian (1995) found that both ambivalent and avoidant Israeli army men undergoing a four-month combat training appraised the training in more threatening terms, compared to individuals who were securely attached. Ambivalent and avoidant men did cope in divergent ways, such that the first group tended to use emotion-coping strategies while the second group tended to use distancing strategies. Therefore, while both groups appraised the situation as more threatening, ambivalent individuals tended to focus and ruminate upon their fear reaction, while avoidant individuals tended to disengage from their fear response. In this way, anxious/ambivalent individuals may appraise ambiguous and aversive situations as more threatening and emotionally respond with intensified fears.

In addition to self-reported fear experiences and threat appraisals, attachment orientations have been differentially linked to behavioural responses to threat. Ein-Dor, Mikulincer and Shaver (2011a) found that during an experimental lab-threat situation where a room was

gradually filling with smoke, attachment anxiety predicted quicker detection of threat, while both attachment anxiety and attachment avoidance predicted quicker flight reaction after the detection of threat. This remained true after controlling for the personality dimensions of extraversion and neuroticism. Corresponding with these findings, the authors proposed a social defence theory, whereby attachment anxiety is associated with sentinel behaviour (threat detection), while attachment avoidance is related to rapid fight-or-flight behaviour. In another experimental situation, converging with the hypothesised sentinel behaviour, Ein-Dor and Tal (2012) found that anxiously attached individuals were more efficient at alerting others to the potential threat of a computer virus, while less anxious individuals were more likely to allow themselves to be delayed in relaying the warning message. The two studies suggest that attachment anxiety is related to quicker detection of, as well as defensive behavioural response to, threat. To some degree, attachment avoidance is also associated with rapid defensive response to threat.

A number of studies have shown that attachment patterns are differentially associated with the cognitive processing of aversive stimuli. Overall, attachment insecurity (including both attachment anxiety and attachment avoidance) has been associated with slower responses to emotion words in a Stroop task (Warren, 2010) and attachment-related threat words in a dot-probe task (Dewitte, Koster, De Houwer, & Buysse, 2007). Both of these studies suggest that attachment insecurity is associated with attentional avoidance of or interference by emotion stimuli, and in particular, by attachment-related threat stimuli. Moreover, the dimension of attachment anxiety has also been specifically associated with slower cognitive processing of aversive stimuli. For example, Dewitte et al.'s (2007) study found that attachment anxiety marginally predicted slower responses to and attentional avoidance of general threat words. Similarly, Silva, Soares and Esteves (2012) found that attachment anxiety was associated with

reduced accuracy of target image detection when there were negative emotional distracters in the series of images. This suggests that attachment anxiety is associated with attentional bias to aversive emotional images, which in turn, interferes with the cognitive task at hand. Finally, disorganised/fearful-avoidant individuals have also been found to respond more slowly to negative attachment-related emotion stimuli, including fear words, while dismissing-avoidant individuals tend to display greater attentional control and faster cognitive processing of aversive stimuli (Atkinson et al., 2009; Jain & Labourvie-Vief, 2010). Together, these studies suggest that attachment insecurity, especially attachment anxiety, is associated with attentional avoidance of aversive attachment-related and general emotional stimuli.

A number of studies have also observed the modulation of threat-related neutral activity by attachment orientation. For example, Warren (2010) found that the insecurely attached individual's slower response to unpleasant emotion words in a Stroop task was accompanied by brain activation in the lateral and medial orbitofrontal cortex and right hemisphere, which is implicated in the inhibitory regulation of emotions. Furthermore, both attachment anxiety and attachment avoidance have been found to be positively correlated with amygdala activation to threatening faces, an area of the brain that is directly associated with the processing of threats and the emotion of fear (Norman, Lawrence, Illes, Benattayallah, & Karl, 2015). Conversely, trait attachment security and increased state attachment security have been linked with reduced threat-related activity in the amygdala (Buchheim et al., 2006; Lemche et al., 2005; Norman et al., 2015; Vrticka et al., 2008, 2012) and other associated brain regions such as the hypothalamus, prefrontal cortex and anterior cingulated in response to physical and social pain (Conner et al., 2011; Karrenmans et al., 2011). This attenuation of threat-related neural response in the hypothalamus and prefrontal cortex was specifically observed for anxious children and

adolescents when undergoing fMRI scanning in the presence of their caregivers (Conner et al., 2012). Therefore, these findings demonstrate that attachment insecurity is associated with threat-related neural activity in response to various aversive stimuli, and this activation is reduced by trait and state attachment security, which serves as a safety cue.

At the more enduring trait level, research suggests that attachment insecurity is related to a generally more fearful disposition towards various situations. A number of studies have found that general attachment insecurity, as well as attachment anxiety specifically, has been linked to greater fear of personal death (Berant & Pizem, 2015; Besser, 2008; Cooper, Shaver, & Collins, 1998; Lubetzky & Gilat, 2002; Mikulincer, Florian, & Tolmacz, 1990). In particular, Mikulincer et al. (1990) found that ambivalent attachment was related to overt fear of personal death, while both ambivalent and avoidant styles were related to subconscious fear of personal death. Furthermore, individuals with greater attachment anxiety tend to appraise physical pain as more threatening (pain catastrophising), as well as report greater pain-related fear (Martínez, Miró, Sánchez, Mundo, & Martínez, 2012; McWilliams & Asmundson, 2007; Meredith, Strong, & Feeney, 2005). In contrast, comfort with closeness, which is associated with attachment security, was linked with more adaptive appraisals of pain as a challenge (Meredith et al., 2005). Finally, in a divergent domain, two studies have found that incarcerated adolescents who are insecurely attached to their parents report being more fearful of criminal victimisation (such as being attacked or robbed) (May, Vartanian, & Virgo, 2002; Wallace & May, 2005). Together, these studies attest to links between attachment insecurity, especially attachment anxiety, and a more fearful disposition, while attachment security is related to lower levels of fearfulness.

Attachment insecurity has also been related to specific phobias, which are clinical conditions that involve extreme fear and avoidance responses to specific stimuli that are

appraised as threatening. For example, attachment insecurity has been associated with hypochondriasis (somatic and illness fears; Jordan, Williams, & Smith, 2015), aerophobia (fear of flying; Veronese, Romaioli, & Castigioni, 2012), agoraphobia (fear of open spaces) and panic disorder (Brown & Harris, 1993; Faravelli, Webb, Ambronetti, Fonnesu, & Sesarego, 1985), and arachnophobia (spider phobia; Mikulincer & Shaver, 2007). The attachment patterns related to these phobias once again tend to fall on the attachment anxiety dimension, with both hypochondriasis and arachnophobia associated with attachment anxiety (Jordan et al., 2015; Mikulincer & Shaver, 2007) and aerophobia associated with a fearful-avoidant attachment style (Veronese et al., 2012). Veronese et al. further reported aerophobic individuals described themselves as "'anxious', 'weak' and 'frightened' by a world perceived as dangerous and anxiety-provoking" (p. 308). In this sense, the perceived risk of flying (or associated with other phobic stimuli) accentuates the feeling of lack of protection and safety from an attachment figure, and so exacerbates a fear response. This connection between attachment security and phobic fear response was experimentally demonstrated by Mikulincer and Shaver (2007), whereby the visualisation of a rejecting attachment figure led to stronger aversion responses to spider pictures among phobic individuals. Conversely, increasing state attachment security by asking phobic participants to visualise their security-enhancing attachment figures lead to less aversion to the spider pictures. Therefore, attachment insecurity is directly related to phobic reactions such that the lack of a secure base increases clinical manifestations of fear, whilst attachment security provides a protective effect.

A summary of the reviewed indirect evidence for the nature of the relations between attachment patterns and FFFS sensitivity is provided in Table 3.3. As can be seen from the table, attachment anxiety is consistently associated with a range of behavioural, cognitive, and

Table 3.3

Summary of Indirect Links between Attachment Dimensions and FFFS Sensitivity

	Attachment anxiety	**Attachment avoidance**
More frequent experiences or expressions of fear	✓	–
Heightened threat appraisal	✓	unclear
Quicker threat detection	✓	×
Quicker defensive reaction (e.g., flight)	✓	✓
Attentional avoidance/interference by threat stimuli	✓	unclear
Heightened threat-related neural activity	✓	✓
Fearful dispositions	✓	unclear
Specific phobias	✓	unclear

Note. ✓ = evidence of positive links; – = evidence of negative links;

× = no reported links.

affective aversive responses to threat that may be associated with greater FFFS sensitivity. However, the pattern of associations is less clear for attachment avoidance: higher levels of attachment avoidance appear to be related to less frequent experiences and expressions of fear, and simultaneously, quicker defensive reactions and heightened threat-related neural activity in the presence of an aversive stimuli; associations with threat appraisal, cognitive processing of threatening stimuli, fearful dispositions, and specific phobic reactions are less clear. Therefore,

the research suggests that attachment avoidance is not linked to consistent and explicit aversive responses. The next sections will consider theorised and evidenced direct links between attachment patterns and FFFS sensitivity.

Adult Attachment and FFFS Sensitivity: Theoretical Models and Literature Review

Very few studies have focally considered the nature of the relations between adult attachment and FFFS sensitivity from either a theoretical and/or empirical standpoint. However, there are two existing theories that have explicitly addressed potential links between adult attachment and FFFS sensitivity. This section will review each of these theories against the broader relevant literature (as reviewed in the preceding sections), along with the extant empirical research supporting these theories.

One theory, proposed by MacDonald and Kingsbury (2006), suggests that the dimension of attachment anxiety is uniquely linked to FFFS sensitivity. According to these researchers, attachment anxiety represents sensitivity to threats of rejection and unavailability in attachment relationships, which corresponds with fearfulness. This is in accord with research that suggests that attachment anxiety is related to aversive relational goals and motives, such as avoiding rejection (Gable, 2006). MacDonald and Leary (2005) extends this connection by suggesting that perceived rejection and unavailability of the attachment figure triggers feelings of pain that activate the FFFS, in the same way as a physical injury or assault. In contrast, attachment avoidance is argued to correspond with perceptions of reward such as intimacy in close relationships, and thereby may be linked to BAS sensitivity (MacDonald & Kingsbury, 2006). In support of their theory, MacDonald and Kingsbury (2006) found that attachment anxiety, but not attachment avoidance, was significantly linked to self-report physical pain affect. It should be

noted that the study did not directly measure FFFS sensitivity, but used self-reported pain affect as a proxy index of the construct. Additionally, the correlational nature of the study makes it unclear whether physical pain experiences lead to greater activation of attachment concerns for the anxious individual, or the anxious individual has a truly more sensitive FFFS. Nonetheless, MacDonald and his colleagues provided some evidence to suggest an association between attachment anxiety and FFFS sensitivity.

Alternatively, Ure (2011) in her dissertation theorised that both attachment dimensions may be related to FFFS sensitivity, although the nature of the relations is different. She proposed that attachment anxiety is related to a hyperfunctioning FFFS, involving heightened threat sensitivity and poor discriminatory ability between threat and non-threat cues. This is evidenced by the anxious individual's hypervigilant orientation, exaggerated fear responses, and tendency to appraise both aversive and ambiguous stimuli as threatening (e.g., Barrett and Holmes, 2001). According to Ure (2011), such behavioural patterns may reflect the chronic activation of the defence system, leading to excessive FFFS outputs. With regards to attachment avoidance, Ure (2011) proposed that this dimension is related to a hypersensitive FFFS that results in an increased sensitivity to, and detection of, threatening stimuli. It is argued that individuals with higher levels of attachment avoidance have negative appraisals of the attachment figure, find relationships threatening, and engage in effortful avoidance strategies. This last behavioural output shares the same functional goal of the FFFS, which is the avoidance of aversive situations. Across three studies, Ure (2011) found partial support for her theory. In one study, both attachment dimensions were significantly correlated with self-reported FFFS-Fight response. Furthermore, in a dot-probe task, FFFS-Fight was related to bias away from threatening words for highly avoidant individuals, indicative of a hypersensitive FFFS; and

related to bias away from both threatening and rewarding words for anxious individuals, indicative of a hyperfunctioning FFFS. However, in Ure's (2011) second and third studies, only attachment anxiety (and not attachment avoidance) was related to fight/flight/freeze behavioural choice responses to relationship and substance-use threat vignettes. It should be noted that Ure's (2011) second and third studies did not include a direct measure of FFFS sensitivity. In sum, Ure (2011) theorised that both attachment dimensions are linked to the FFFS, although attachment anxiety and attachment avoidance correspond differentially to a hyperfunctioning and hypersensitive FFFS respectively.

Both MacDonald and Kingsbury's (1996) and Ure's (2011) theories proposed that attachment anxiety is linked to greater FFFS sensitivity, and this is supported by a sizeable empirical literature. As reviewed in the preceding sections, attachment anxiety is associated with more frequent experiences and expressions of fear (e.g., Consedine et al., 2012; Rognoni, 2008), the tendency to appraise situations as more threatening (e.g., Barrett & Holms, 2001), more rapid detection and response to threat (Ein-Dor & Tal, 2012; Mikulincer & Shaver, 2011), attentional avoidance of aversive stimuli (e.g., Atkinson et al., 2009; Dewitte et al., 2007), and trait fear-proneness and phobic reactions (e.g., Berant & Pizem, 2015; Martínez et al. 2012; Meredith et al., 2005; Mikulincer et al., 1990). Together, the research base provides consistent and strong evidence that attachment anxiety is associated greater aversive motivation and fear responses, which points to a more sensitive FFFS.

While MacDonald and Kingsbury (1996) theorised that only attachment anxiety is related to FFFS sensitivity, Ure (2011) argued that attachment avoidance is also related to FFFS sensitivity. However, the empirical evidence in support of this second supposition is less strong. Indeed, Ure (2011) found only indirect support for this link such that attachment avoidance

moderated the relationship between endorsing FFFS-Fight behaviour and attentional bias away from threatening stimuli, with no direct associations between attachment avoidance and FFFS responses were found. Furthermore, although both attachment dimensions have been associated with threat-related neural activity in response to aversive stimuli (Norman et al., 2015) and quick defensive reactions to threat (Mikulincer & Shaver, 2011), attachment avoidance has generally been related to an inhibited defensive behaviour, as opposed to the heightened fear responses observed for attachment anxiety. For example, as reviewed in the preceding sections, attachment avoidance has been linked to reports of less frequent experiences and expressions of fear (e.g., Consedine et al., 2012), tendency to inhibit fear responses (Mikulincer & Florian, 1995), attentional avoidance of aversive stimuli (Warren, 2010), and, at the same time, greater attentional control and unaffected processing of aversive stimuli (e.g., Atkinson et al., 2009; Jain & Labourvie-Vief, 2010). Therefore, attachment avoidance does not appear to be obviously related to manifest FFFS sensitivity, contrary to Ure's (2011) thesis.

Further evidence directly pertaining to the nature of the relations between adult attachment and FFFS sensitivity is needed. A literature search was conducted on PsycINFO, ScienceDirect and Web of Science databases in November 2015 for any articles with title or abstract keywords (1)"reinforcement sensitivity" or "FFFS" or "fight flight freeze System" or "fight-flight-freeze system" and (2) "attachment" This initially yielded 4 results. Subsequently, the title and abstracts (and article, where the title and abstract were unclear) of these references was screened for the following inclusion criteria: (a) use of an explicit measure of FFFS sensitivity operationalised in accordance with the r-RST; (b) measured either adult or infant attachment; and (c) report directed links between attachment and FFFS sensitivity. Following this criteria, no relevant papers were found. Some studies did report associations between adult

attachment and Carver and White's (1992) BIS measure, which contains items that assess both FFFS and BIS sensitivity (Heym et al., 2008). As shown in Table 3.2, consistent positive correlations were found between the measure and attachment anxiety, but no significant links were found with attachment avoidance. However, Carver and White's (1992) BIS measure does not provide a focal and valid assessment of FFFS sensitivity as conceptualised in the r-RST. Therefore, at most, the studies using this measure provide an indication of associations between the attachment dimensions (in particular, attachment anxiety) and general aversive motivation, which will be discussed further in the next section. To date, there appears to be no published peer-reviewed papers that have directly examined attachment patterns and FFFS sensitivity.

Research Question and Hypotheses

The present thesis aims to examine the nature of the relations between individual differences in adult attachment and FFFS sensitivity. Attachment theory, as well as a body of empirical research, suggests an intimate relation between attachment behaviour and fear responses, especially between attachment insecurity in the form of attachment anxiety and defensive reactions to threats (see Table 3.3). Aside from research by MacDonald and Kingsbury (2006) and Ure (2011), no studies have directly examined links between adult attachment and FFFS sensitivity as conceptualised by Gray and McNaughton's (2000) r-RST. In the present research programme, the nature of the relations between adult attachment and FFFS sensitivity will be examined at the self-report, behavioural, and neurophysiological levels. The hypotheses were as follows:

It was hypothesised that attachment anxiety would be positively related to FFFS sensitivity. No significant association was expected between attachment avoidance and FFFS sensitivity.

Adult Attachment and BIS Sensitivity

"In the schema proposed, a period of separation, and also threats of separation and other forms of rejection, are seen as arousing, in a child or adult, both anxious and angry behaviour. Each is direct towards the attachment figure: anxious attachment is to retain maximum accessibility to the attachment figure; anger is both a reproach at what has happened and a deterrent against its happening again. Thus, love, anxiety, and anger, and sometimes hatred, come to be aroused by one and the same person. As a result painful conflicts are inevitable." (Bowlby, 1973, p. 253)

The third and last motivational system put forward in Gray and McNaughton's (2000) r-RST is the BIS, which is responsible for resolving motivational ambivalence. Although Bowlby (1982/1969, 1973) elaborated upon the intimate connections between attachment behaviour and the fear response and exploratory-approach behaviour, he gave limited attention to how the attachment patterns, especially insecure attachments, might be linked to sensitivity to motivational conflict. Nonetheless, Bowlby (1982/1969) acknowledged the possibility of incompatible behavioural systems, whereby there is a conflict between simultaneously activated and incompatible behavioural tendencies (such as the desire to flee danger and approach a situation). This conflict may result in behavioural inhibition and compromise, which parallels the output of the BIS. Furthermore, according to Bowlby (1982/1969), a specific manifestation of incompatible behavioural tendencies is observed with insecure attachments (especially attachment anxiety), which involves relational conflict between the desire to seek proximity to, and fear of rejection from, the attachment figure. This section will begin by considering the research on the links between adult attachment and relational ambivalence, and in turn, how this

is related to general ambivalence as manifest in personality traits such as neuroticism and trait anxiety, and finally, BIS sensitivity.

Adult Attachment and Relational Ambivalence

Relationships have long been recognised as the source of both pleasure and pain (e.g., Berscheid & Reis, 1998). Accordingly, motivational dynamics within social relationships have been recognised to involve both appetitive goals toward relational rewards such as desire for closeness and social support and aversive goals away from relational threats such as conflict and rejection (Nikitin & Freund, 2012; Locke, 2008; Gable & Gosnell, 2013; Gable, 2000, 2006; Gable & Berkman, 2008; Gable & Impett, 2012). Individual differences in adult attachment are related to experiencing different degrees of appetitive and aversive relational goals and motives, and consequently, varying levels of relational ambivalence.

On one hand, securely attached individuals possess positive Internal Working Models (IWMs) – that is cognitive representations – and view other people as generally supportive and available, and see themselves as loveable and acceptable (Bartholomew & Harowitz, 1999). Therefore, they have been shown to have predominantly positive, non-ambivalent cognitions and emotions, and approach motivations toward their attachment figures (MacDonald et al., 2012; Nikitin & Freund, 2010). Furthermore, McClure et al. (2012) have shown that priming attachment security reduces ambivalent behaviour and leads to more prosocial behaviour. Therefore, attachment security plays an important role in resolving motivational conflict and promoting an appetitive orientation in close relationships.

On the other hand, insecure individuals are disposed to experiencing relational ambivalence in close relationships, especially toward their attachment figures. Attachment

insecurity, whether in the form of attachment anxiety and/or attachment avoidance, stems from appraisals of uncertainty regarding the attachment figure's availability and responsiveness. At the same time, attachment needs, as manifest in proximity-seeking and need for comfort, is undeniably fundamental and universal to all persons. This is most apparent for infants who are dependent on their caregivers, whereby attachment behaviour constitutes as a survival motivational system. However, adults too require support (emotional, practical, or otherwise) during times of distress. As such, insecure persons may experience a conflict between fear of rejection and desire for proximity, which may manifest as ambivalent motivations and confused behaviours, rather than a complete aversion to attachment relationships (Reis & Patrick, 1996). Indeed, a few studies have shown that attachment insecurity is associated with ambivalent attitudes toward parents in both children (Maio, Fincham, & Lycett, 2000) and young adults (Levy, Blatt, & Shaver, 1998), as well as ambivalent sexual attitudes in adults (Davis, Shaver & Vernon, 2004). Therefore, attachment insecurity is linked to strong contradictory motivations in close relationships.

There is evidence to suggest that relational ambivalence is most obviously manifest for individuals with higher levels of attachment anxiety. Such individuals tend to positively appraise their attachment figures but regard themselves as unworthy of love, resulting in an internal struggle that manifests in conflicting behaviour. For example, at one extreme, anxious individuals have been found to remain sexually attracted to and emotionally involved with former partners (Davis, Shaver, & Vernon, 2003), including those who have been abusive (Henderson, Bartholomew, & Dutton, 1997). In laboratory contexts, attachment anxiety has also been linked to motivational ambivalence in the form of inconsistent, slower decisions between cooperative and non-cooperative behaviours in social dilemma games (McClure, Bartz, &

Lydon, 2012). Furthermore, in a record of daily interpersonal interactions, Locke (2008) found that attachment anxiety was associated with stronger and less consistent approach and avoidance goals (such as simultaneous assertion and submission), resulting in stronger motivational conflict. More systematically, in a series of five studies, Mikulincer et al. (2010) found that attachment anxiety was related to holding both explicit and implicit ambivalent attitudes and approach-avoidance motivations in romantic relationships. Together, these studies suggest that relational ambivalence is a key feature of attachment anxiety.

With regards to attachment avoidance, relational ambivalence is less obviously manifest in behaviour, but appears to characterise subconscious processes. For example, in Locke's (2008) diary study, individuals with higher levels of attachment avoidance did not display motivational conflict in terms of their expressed relational goals. Similarly, Nikitin and Freund (2012) found that neither fearful-avoidant nor dismissing attachment styles, both of which involve high levels of attachment avoidance, were associated with self-reported motivational ambivalence. Rather, at the self-report level, attachment avoidance appears to be associated with weaker social approach goals and stronger social avoidance goals (Locke, 2008; Nikitin & Freund, 2012). However, while Mikulincer et al. (2010) did not find associations with explicit attitudinal and behavioural ambivalence, attachment avoidance was related to implicit motivational ambivalence in the context of a relational threat. Specifically, they found that attachment avoidance was related to pulling a lever faster in response to closeness words (stronger approach response) and pushing a lever faster in response to distance words (stronger avoidance response), when thinking about relationship dissolution. This disconnect between explicit and implicit motives may reflect the process whereby more automatic, subconscious

fears are suppressed and replaced by the avoidant individual's strong "defensive facade" (Mikulincer, Shaver, Bar-On, & Ein-Dor, 2010, p. 466).

The possibility that different mechanisms may underpin motivational ambivalence associated with attachment anxiety and attachment avoidance has been supported by a study conducted by MacDonald, Locke, Spielmann and Joel (2012). MacDonald et al. found that high levels of both attachment anxiety and avoidance predicted increased relational ambivalence within individuals who perceived greater reward than threat, but for different reasons. Attachment anxiety was associated with amplified social threat perception, while attachment avoidance was associated with reduced reward perception. In both of these cases, this resulted in increased similarity in threat and reward perception, which promotes ambivalence. However, when threat perception was higher than reward perception, ambivalence was resolved in the direction of aversive motivation. Therefore, whilst attachment insecurity is generally characterised by relational ambivalence, attachment anxiety and attachment avoidance is differentially associated with social reward and threat perceptions, as well as explicit and implicit motives.

Adult Attachment, Relational Ambivalence and General Ambivalence

Whilst attachment insecurity has been shown to be linked to relational ambivalence, the link with general ambivalence (i.e., sensitivity to motivational conflict in both relational and non-relational contexts) is less clear. In the previously cited series of studies by Mikulincer et al. (2010), insecure individuals were found to display only the former and not the latter, which lead the researchers to conclude that attachment insecurity is unrelated to a general propensity towards motivational ambivalence. However, a number of researchers have proposed that there

may be an indirect relation between adult attachment and general motivations, mediated by relationship specific goals and motives (Gable & Gosnell, 2013; Locke, 2008). That is, individual differences in the sensitivity of global reward and threat motivational systems may be associated with variations in appetitive and aversive tendencies in close relationships, which, in turn, characterise different attachment patterns (Gable, 2006; Gable & Berkman, 2008; Locke, 2008). Therefore, the sensitivity of basic motivational systems are distinct from, but hierarchically related to and expressed through specific goals such as relational motives (Gable, 2006; Locke, 2008).

Gable (2006) reported moderated correlations between distal basic motivations and proximal relationship-specific goals. More specifically, both aversive and appetitive relational goals were positively correlated with BIS sensitivity, while appetitive relational goals were also positively correlated with BAS sensitivity (Gable, 2006). Therefore, there is some evidence that the sensitivity of global motivational systems, in particular, BIS sensitivity, are linked to relational motives, although more research into the hierarchical nature of the relations is needed.

The research reviewed thus far suggests that attachment insecurity, defined by higher levels of attachment anxiety and/or avoidance, is related to relational ambivalence, which in turn, is theorised to be related to greater sensitivity towards general ambivalence. The present thesis, however, is focally interested in the relations between individual differences in adult attachment and the sensitivity of the basic motivational systems – in this case, the BIS, which mediates response to general motivational conflict. Therefore, the next sections will review evidence pertaining to the nature of the direct relations between adult attachment and BIS sensitivity, drawing upon research on BIS-related constructs such as neuroticism and trait anxiety, as well as studies that directly assess BIS sensitivity.

Adult Attachment and BIS-related Constructs of Neuroticism and Trait Anxiety

Firstly, a number of studies have examined links between attachment patterns and neuroticism. Neuroticism has been directly related to BIS sensitivity, with the latter dimension conceptualised as a slight psychometric rotation of the former dimension (Gray, 1970). Given the intimate relation, many studies have measured neuroticism as a proxy index of BIS sensitivity (e.g., Perkins et al., 2007). Conventionally, the personality dimension of neuroticism refers to the general tendency to experience distress, report negative and unpleasant moods, and complain about emotional problems and adjustment difficulties (McCrae & Costa, 1992). As a broad dimension, neuroticism consists of a number of facets, which include Anxiety (tendency to experience free floating anxiety), Angry Hostility (tendency to experience anger, frustration, and bitterness), Depression (feelings of guilt, sadness, despondency, and loneliness), Self-consciousness (shyness or social anxiety), and Vulnerability (general susceptibility to stress). In sum, the dimension of neuroticism, constituted by the aforementioned five facets, is regarded as parsimonious trait representation of BIS sensitivity.

Across a large number of studies that have examined the association between adult attachment and neuroticism, all have consistently found moderate to strong positive associations (averaging around $r = .40$) between all facets of neuroticism and anxious attachment style (e.g., Shaver & Brennan, 1992; Noftle & Shaver, 2006) and attachment anxiety dimension (See Mikulincer & Shaver, 2010; Noftle & Shaver, 2006, for reviews). This is in line with the anxious individual's heightened experience and expression of distress. Comparatively, in about two-thirds of studies, attachment avoidance has also been linked to higher levels of neuroticism, but the size of these associations tend to be smaller (averaging around $r = .20$) (See Mikulincer & Shaver, 2010; Noftle & Shaver, 2006, for reviews). At the facet level, the avoidance dimension is

related mainly to Depression and Vulnerability aspects of neuroticism, and more variably to other facets (Noftle & Shaver, 2006; Shaver & Brennan, 1992). This may reflect the avoidant individual's attempt to suppress distress. In general, both attachment dimensions are related to neuroticism, although the association appears to be stronger and more consistent for attachment anxiety.

A large number of studies have been also been conducted on the links between attachment patterns and trait anxiety. As with neuroticism, trait anxiety has often been used as a proxy measure of BIS sensitivity. Gray (1970) originally proposed that trait anxiety is closely aligned with BIS sensitivity, and this connection was enhanced in Gray and McNaughton's (2000) theoretical revision whereby trait anxiety is regarded as a direct manifestation of BIS activation. Indeed, trait anxiety has been evidenced to be highly intercorrelated with neuroticism and BIS (Cooper et al., 2007; Perkins et al., 2007); show discriminant validity from FFFS-related constructs such as fear-proneness and harm avoidance (Cooper et al., 2007; Sylvers, Lilienfeld, & LaPrairie, 2011); predict orientation away from threat in line with BIS functioning (Perkins & Corr, 2006); as well as predict behavioural performance parameters on tasks involving uncertain reinforcement and goal conflict (Leue & Beauducel, 2008). Therefore, trait anxiety serves as a good proxy measure of BIS sensitivity.

Both attachment anxiety and attachment avoidance have been related to trait anxiety. In Mikulincer and Shaver's (2007) review, preoccupied attachment style, anxious attachment style and attachment anxiety dimension were consistently associated with higher levels of trait anxiety, across all 38 studies. These attachment orientations commonly involve higher levels of attachment anxiety, and so it appears that insecurity regarding the attachment figure's availability is coupled with a disposition towards general anxiety. Links with attachment

avoidance are less consistent, with half of the studies in Mikulincer and Shaver's (2007) review reporting a positive relation with trait anxiety. Moreover, the reported association is often with fearful-avoidant attachment style (i.e., high levels of attachment anxiety and avoidance), which suggests that it may still be the attachment anxiety component that is related to trait anxiety. Nonetheless, recent studies continue to provide evidence of links between both attachment dimensions and trait anxiety, although the association is weaker for attachment avoidance (e.g., Dilmaç, Hamarta, & Arslan, 2009; Surcinelli, Rossi, Montebarocci, & Baldaro, 2010).

Relatedly, attachment insecurity has been also been linked to anxiety disorders. In their meta-analysis of 46 studies, Colonnesi et al. (2011) showed that there was an overall effect size of $r = .30$ between attachment insecurity and anxiety symptoms in children. The ambivalent attachment style had the strongest associations with childhood and adolescent anxiety. This association has also been replicated in adults (see Mukulincer & Shaver, 2007, for a review). Adults with anxiety disorders tend to report rejecting, unavailable and unsupportive parents (Cassidy, 1995; Enns, Cox, & Clara, 2002; Gotlib, Mount, Cordy, & Whiffen, 1988). It is speculated that attachment insecurity plays a role in the development of anxiety by influencing self-perceptions (e.g., low self-worth), maladaptive emotion-focused coping (e.g., pessimistic expectations and exaggerated distress), and interpersonal difficulties (e.g., excessive reassurance seeking and feelings of loneliness), as well as other personal and contextual factors (Mikulincer & Shaver, 2007). Regardless of the multiple mediation pathways, attachment insecurity appears to be related to the presence of anxiety disorder symptoms, especially for individuals with an anxious/ambivalent attachment.

In summary, the research suggests that attachment insecurity, in the form of either attachment anxiety and/or attachment avoidance, is linked to relational ambivalence,

neuroticism, trait anxiety and anxiety disorders. The results are summarised in Table 3.4. As these constructs have been variably related to or used as proxy measure of BIS sensitivity, the research provides indirect evidence of links between attachment insecurity and BIS sensitivity. Notably, as can be seen from Table 3.4, all the BIS-related constructs had stronger and more consistent associations with attachment anxiety, than with attachment avoidance. The next section will consider evidence that directly pertain to links between attachment and BIS sensitivity.

Adult Attachment and BIS sensitivity: Literature Review

Given the focal interest of this thesis is on the nature of the relation between adult attachment and BIS sensitivity, this section presents a review of the extant direct evidence concerning this relation. As very few studies have examined links between attachment theory and reinforcement sensitivity, let alone specifically adult attachment and the revised version of RST, studies looking at infant or adult attachment, and those that utilise the classical or revised conceptualisation of BIS sensitivity, were included in the review.

A literature search was conducted on PsycINFO, ScienceDirect and Web of Science databases in October 2015 for any articles with title or abstract keywords (1)"reinforcement sensitivity" or "BIS" or "Behavioural Inhibition System" and (2) "attachment" This initially yielded 1338 references. Subsequently, the title and abstracts (and article, where the title and abstract were unclear) of these references was screened for the following exclusion criteria: studies that (a) used a proxy measure of BIS, such as neuroticism or trait anxiety; (b) focused on the childhood temperament of behavioural inhibition; or (c) did not report direct links between attachment and BIS sensitivity. This yielded only three relevant papers. By examining the

Table 3.4

Summary of Links between the Attachment Dimensions and BIS-Related Constructs

	Attachment anxiety	**Attachment avoidance**
Relational ambivalence	✓	✓ (weaker, subconscious level)
Neuroticism	✓	✓ (weaker)
Trait anxiety	✓	✓ (weaker)
Anxiety disorders	✓	✓ (weaker)

Note. ✓ = evidence of positive links.

reference lists and publications of prominent researchers in the area, an additional two papers were found, resulting in a final total of five papers. A summary of these studies are presented in Table 3.2.

As can be seen from Table 3.2, all of the studies reported a moderate and positive correlation (ranging from $r = .37$ to .48, $p < .01$) between attachment anxiety and BIS sensitivity. This is consistent with the already reviewed research that attests to robust links between attachment anxiety and relational ambivalence, neuroticism and trait anxiety. Therefore, attachment anxiety appears to be notably characterised by stronger aversive motivational tendencies. Interestingly, one study [1] further found that attachment anxiety was associated with chronically higher levels of distress, while BIS sensitivity was associated with greater distress only in situations of medium to high threat. Therefore, while both constructs were moderately correlated, their differing predictions to distress levels under varying degrees of threat intensity suggest that they remain functionally independent.

In contrast, none of the studies listed in Table 3.2 reported any significant associations between attachment avoidance and BIS sensitivity. This is contrary to previous studies that have found that attachment avoidance is also characterised by some degree of relational ambivalence, neuroticism and trait anxiety, although these links tend to be less consistent and smaller than those reported for attachment anxiety and BIS sensitivity. These weaker or absent associations could reflect the more complex nature of attachment avoidance defence mechanisms that involves suppression and denial of distress, attachment needs, and, presumably, BIS-mediated ambivalence, which entails aversive motivational tension. Therefore, although the reviewed studies did not find direct associations between attachment avoidance and BIS sensitivity, the broader literature suggests that attachment avoidance may still involve conflicting motivations.

Critically, all these studies once again utilised Carver and White's (1994) BIS scale, which does not assess sensitivity to motivational conflict. Rather, it confounds FFFS and BIS sensitivity as defined by the r-RST (Heym et al., 2008). Instead, high scores on Carver and White's (1994) BIS measure has been interpreted as indicative of greater aversive motivation, irrespective of defensive direction. Therefore, the data do not actually attest to the relations between adult attachment and the BIS sensitivity as defined by the r-RST, which remains to be examined in the present thesis.

Research Question and Hypothesis

The present thesis aimed to examine the nature of the relations between individual differences in adult attachment and BIS sensitivity. A large body of literature suggest that attachment insecurity in the form of both attachment anxiety and attachment avoidance is related to a number of BIS-related constructs such as neuroticism, trait anxiety, and anxiety disorders.

The associations are stronger with attachment anxiety, than with attachment avoidance. Furthermore, there is some direct evidence of links between attachment anxiety and BIS sensitivity, although the measure of the latter construct did not take into account Gray and McNaughton's (2000) theoretical revisions. The present research programme will examine the nature of the relations between adult attachment and the revised conceptualisation of BIS sensitivity at the self-report, behavioural, and neurophysiological levels. The hypotheses were as follows:

It was hypothesised that both dimensions of attachment anxiety and attachment avoidance would be positively related to BIS sensitivity, with stronger relations expected for attachment anxiety.

Thesis Overview and Chapter Summary

This chapter began by highlighting the striking theoretical overlaps between attachment theory and r-RST: both are essentially theories of motivation and personality, assume ethological and evolutionary perspectives, and explain behaviour with reference to behavioural systems and approach-avoidance processes. The theories do, however, differ in explanatory scope such that r-RST describes global motivational systems while attachment theory is concerned with stress regulation in the context of intimate relationships. An integrative exploration of the two theories may importantly inform upon how individual differences in attachment behaviour is related to the differential functioning of biologically-based global motivational systems. Therefore, the broad research aim of this present thesis is stated as follows:

Broad thesis aim:

To examine the nature of the relations between individual differences in adult attachment and reinforcement sensitivity

Few studies have directly examined the intersection of the attachment and r-RST motivational systems. Nonetheless, both theory and research suggest intimate relations between attachment orientation and approach-oriented exploratory behaviour (mapping onto BAS sensitivity) and the fear response (mapping onto FFFS sensitivity). Furthermore, there is evidence to suggest that attachment insecurity is characterised by relational ambivalence, which may implicate links with BIS sensitivity. Based on the extant theory and research, the following general hypotheses were proposed:

Main hypotheses:

1. Attachment avoidance was expected to be inversely related to BAS sensitivity. No significant association was expected between attachment anxiety and BAS sensitivity.

2. Attachment anxiety was expected to be positively related to FFFS sensitivity. No significant association was expected between attachment avoidance and FFFS sensitivity.

3. Both attachment anxiety and attachment avoidance were expected to be positively related to BIS sensitivity, with stronger relations expected for attachment anxiety.

This thesis extends the existing literature by (1) examining links between attachment patterns and the sensitivity of all three r-RST motivational systems, (2) using measures that take into account Gray and McNaughton's (2000) theoretical revisions, and (3) examining links beyond the self-report level, by incorporating behavioural and neurophysiological data. Study 1 provides preliminary self-report data on links between individual differences in adult attachment and the sensitivity of all three r-RST motivational systems, using both purpose-built and proxy measures of reinforcement sensitivity that take into account Gray and McNaughton's (2000) theoretical revision. Extending the self-report findings of Study 1, Study 2 simulates a virtual separation scenario to examine the comparative prediction of individual differences in adult attachment and reinforcement sensitivity to a critical attachment-related scenario. Finally, given that r-RST describes biologically-based behavioural systems, Study 3 assesses whether individual differences in adult attachment and reinforcement sensitivity map onto EEG-derived neurophysiological indices of approach and avoidance motivation. Together, these studies provide a multi-facet examination of the nature of the relations between the fundamental biobehavioural systems that underpin adult attachment and reinforcement sensitivity.

Chapter 4: Study 1 – Self-Reported Links between Individual Differences in Adult Attachment and Reinforcement Sensitivity

The following study is a copy of the publication:

> Jiang, Y., & Tiliopoulos, N. (2014). Individual differences in adult attachment and reinforcement sensitivity. *Personality and Individual Differences*, *68*, 205-210.

Introduction

Although attachment theory postulates that individuals normally seek close others when distressed, there are well-established individual differences in the degree a person approaches or even avoids their attachment figure (Bowlby, 1969/1982; Mikulincer & Shaver, 2007). One biological theory of personality that may further our understanding of these individual differences is the revised Reinforcement Sensitivity Theory (r-RST), which describes behavioural systems that mediate appetitive and aversive behaviour (Gray & McNaughton, 2000). This paper investigates the nature of the relations between self-reported individual differences in adult romantic attachment and sensitivities of the r-RST motivational systems.

When a child or adult is distressed, the attachment behavioural system is argued to prompt proximity-seeking and/or mental representations of one's attachment figure, who may be a caregiver, romantic partner or other familiar person (Bowlby, 1969/1982; Mikulincer & Shaver, 2007). Alleviation of distress is obtained from the sense of security provided by the attachment figure, but compounded distress may result if the attachment figure is unavailable and/or unresponsive (Shaver & Mikulincer, 2002). Over time, these repeated attachment experiences are argued to produce stable trait-like expectations and behaviours within close relationships. Individual differences in adult attachment are commonly described by the

orthogonal dimensions of *attachment anxiety*, which refers to the degree of worry over one's attachment figure's availability, and *attachment avoidance*, which refers to the degree of discomfort with intimacy (Brennan, Clark, & Shaver, 1998).

At the more general level of behavioural regulation, the r-RST proposes three largely independent, though interacting, neurobiologically-based motivational systems (Gray & McNaughton, 2000). They include the *Behavioural Approach System* (BAS), which mediates anticipatory approach to appetitive stimuli; the *Fight-Flight-Freeze System* (FFFS), which mediates fearful avoidance of aversive stimuli; and the *Behavioural Inhibition System* (BIS), which prompts anxiety and is involved in motivational conflict resolution.

Both attachment theory and r-RST are proposed to be theories of motivation, have their origins in ethological research, and describe biologically-based behavioural systems that have been evolved for survival. Furthermore, intrinsic to both accounts of behaviour are approach and avoidance motivational dynamics. Bowlby (1969/1982) described that avoiding threat and approaching the attachment figure as the "twin processes of survival" (p. 151), and variations in this behavioural pattern characterise individual differences in attachment behaviour. Therefore, an integrative study may provide a better understanding of the underlying motivational mechanisms of adult attachment orientations.

Attachment dimensions have been generally related to threat appraisal and motivational processes. In one study, MacDonald and Kingsbury (2006) found that attachment anxiety was linked to higher levels of self-reported pain affect, suggestive of greater FFFS sensitivity. Moreover, Karantzas, Kambouropoulos, and Ure (2010) found that both attachment anxiety and avoidance were associated with heightened response to threatening stimuli, which converges with research that has linked both attachment dimensions to stronger defensive motivation (Ein-

Dor et al., 2011a; Ein-Dor, Mikulincer, & Shaver, 2011b). Finally, both attachment dimensions have been associated with motivational ambivalence, in terms of conflicting approach-avoidance behaviour and threat and reward appraisals toward the attachment figure (e.g., MacDonald et al., 2012; Mikulincer et al., 2010), as well as higher levels of trait anxiety (see Mikulincer & Shaver, 2007, for a review), which may be indicative of a more sensitive BIS.

However, very few empirical studies have directly examined the nature of the relations between attachment orientations and reinforcement sensitivity. Evidence suggests that attachment avoidance is inversely correlated with BAS sensitivity (Carnelley & Story, 2008; Meyer et al., 2005; Mikulincer & Shaver, 2007). These same studies have found attachment anxiety to be positively correlated with scores on Carver and White's (1994) BIS scale. However, this scale, which is based on the original conceptualisation of the RST (Gray, 1982), has been found to contain items that assess both FFFS and BIS sensitivities as defined by the r-RST (Heym et al., 2008). Therefore, in these studies, it is unclear whether attachment anxiety is related to FFFS-mediated avoidance, BIS-mediated conflict resolution, or both. Two other studies suggest that attachment anxiety is related to greater FFFS sensitivity (Harnett & Penn, 2012; Karantzas et al., 2010), although both of these studies employed scales from the Jackson-5 (Jackson, 2009) measure of r-RST and reported modest internal reliabilities (e.g., Cronbach's α of .58 for the FFFS-Freeze scale; Karantzas et al., 2010).

Given the conceptual and psychometric limitations in operationalising r-RST in previous studies, the present research aimed to further investigate the nature of the relations between individual differences in adult romantic attachment and reinforcement sensitivity by using a number of self-report measures of the latter construct that are conceptually more consistent with the revised theory. Furthermore, whereas previous studies tended to focus on one or two

motivational systems, this study examined links with all three r-RST motivational systems. It was hypothesised that (a) BAS sensitivity would be inversely related to attachment avoidance, (b) FFFS sensitivity would be positively related to attachment anxiety, and (c) greater BIS sensitivity would be positively associated with both attachment dimensions.

Method

Participants

The sample comprised of 225 first-year psychology undergraduates (153 females; 68%) at the University of Sydney who participated in exchange for course credit. Age ranged from 17 to 41 (M = 19.52, SD = 3.44). The majority were Australian residents (95.1%), with 88 (39.1%) endorsing Asian as their ethnicity, 66 (29.3%) as European, 54 (24%) as Oceanian, 13 (5.8%) as African or Middle Eastern and 4 (1.8%) as American. The relationship status of 131 participants (58.2%) was single, 85 (37.8%) dating, 4 (1.8%) engaged, 4 (1.8%) married or cohabitating, and 1 (0.4%) divorced. Average current relationship length was 19.44 months (SD = 21.42, range = 2 to 138 months).

Measures

Copies of the following questionnaires can be found in Appendix A.

Experiences in Close Relationships – Revised (ECR-R; Fraley, Waller, & Brennan, 2000). This well-established dimensional measure of adult attachment consists of an attachment-related anxiety scale (18 items) and an attachment-related avoidance scale (18 items), with each item assessed on a 7-point Likert-type rating (1 = strongly disagree; 7 = strongly agree). Both scales demonstrate high Cronbach's alphas that tend to exceed .90, and validity in predicting

attachment representations during daily social interactions with romantic partners and not with non-attachment figures such as close friends (Sibley & Liu, 2004).

BAS scale from the BIS/BAS scales (CW-BAS; Carver & White, 1994). Comprising of three scales, this self-report measure assesses Drive (four items), Fun Seeking (four items), and Reward Responsiveness (five items). Items were rated on a 4-point scale (1 = very false; 4 = very true for me), and scores across the scales were also summed to produce an overall index of BAS sensitivity. The reported Cronbach's alphas range from .66 to .73, and all three BAS scales demonstrate convergent validity with measures of extraversion and positive affect, as well as predictive validity to happiness in anticipation of reward (Carver & White, 1994). The BIS scale from Carver and White's (1994) measure was not used as it conflates BIS and FFFS according to the r-RST (Heym et al., 2008).

Fear Survey Schedule II (FSS-II; Geer, 1965). This version of the phobic checklist was devised for research purposes to assess trait fearfulness, and was used in this study as a proxy index of FFFS sensitivity. It consists of 51 items that represent a broad range of specific and potentially threatening stimuli, which are rated on a 7-point scale (1 = none; 7 = terror). The reported KR.20 internal consistency reliability was .94 (Greer, 1965). Trait fearfulness, as assessed by various versions of the FSS, has been shown to be psychometrically separable to trait anxiety and neuroticism, and serves as a better proxy index of FFFS than Eysenck's personality constructs in predicting military performance (Perkins et al., 2007).

Y2 trait scale from the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The trait version of the STAI assesses pervasive feelings of anxiety. The r-RST proposes that motivational conflict is marked by anxiety (contrary to fear for the FFFS), and thus the STAI has been previously employed as a proxy index of BIS sensitivity

(e.g., Perkins et al., 2007). It presents 20 statements that describe general experiences of apprehension, tension, nervousness, and worry, which were rated on a 4-point scale (1 = almost never; 4 = almost always). Cronbach's alphas have ranged from .86 to .95 (Spielberger et al., 1983).

Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ; Corr & Cooper, 2016). This is a recently developed 79-item instrument specifically designed to assess r-RST motivations. It comprises of four scales measuring BAS sensitivity: Reward Interest (7 items), Goal-Drive Persistence (7 items), Reward Reactivity (10 items), and Impulsivity (8 items). Additionally, there is a 10-item FFFS scale, a 23-item BIS scale, a 6-item Panic scale (which loads highly on both FFFS and BIS), and an 8-item Defensive Fight scale (which loads highly on BAS). Responses were recorded on a 4-point scale (1 = not at all, 4 = highly). Ratings on the four BAS scales were also summed to provide an overall index of BAS sensitivity. The eight scales possess recoverable factor structure across different samples, and very acceptable psychometric properties, although published reports of normative reliabilities are not yet available (P. Corr, personal communication, September 24, 2012).

Procedure

The measures were administered online and completed in a self-paced fashion, taking on average 45 minutes to complete. Participants were instructed to take a break midway through the study. The questionnaires were counterbalanced, with demographic information collected at the survey's conclusion. The study was approved by the University of Sydney Human Research Ethics Committee, and data were treated in accordance with the university's data protection guidelines.

The data were analysed in IBM SPSS Statistics 22 using Pearson correlations and hierarchical multiple linear regressions to test the hypotheses, with significance level set at $p = .05$.

Results

Descriptives and Preliminary Analyses

The scales possessed acceptable to excellent internal consistency reliabilities, which are presented in Table 4.1, along with their descriptives. Age was significantly correlated with CW-BAS Drive ($r = .16$, $p = .016$), and RST-PQ BAS Impulsivity ($r = -.15$, $p = .022$). On average, compared to females, males had significantly lower scores on CW-BAS Reward Responsiveness [males: $M = 16.19$, $SD = 2.09$; females: $M = 17.52$, $SD = 2.25$; $F(1, 223) = 17.67$, $p < .001$, $\eta^2 = .07$, $\text{power}_{.05} = .99$], RST-PQ BAS Reward Reactivity [males: $M = 28.39$, $SD = 5.46$; females: $M = 29.80$, $SD = 4.70$; $F(1, 223) = 3.95$, $p = .048$, $\eta^2 = .02$, $\text{power}_{.05} = .52$], FSS [males: $M = 147.71$, $SD = 47.65$; females: $M = 169.41$, $SD = 41.66$; $F(1, 223) = 12.10$, $p = .001$, $\eta^2 = .05$, $\text{power}_{.05} = .91$], and RST-PQ FFFS [males: $M = 21.39$, $SD = 5.96$; females: $M = 24.96$, $SD = 5.43$; $F(1, 223) = 19.90$, $p < .001$, $\eta^2 = .08$, $\text{power}_{.05} = .99$].

Construct Bivariate Relationships

The bivariate correlations between the study variables are displayed in Table 4.1. There were consistent significant and negative correlations between attachment avoidance and all BAS measures (though this was marginally significant for RST-PQ BAS Impulsivity), with *r* values ranging from -.11 to -.29. Attachment anxiety also had significant correlations with some BAS measures, but these were generally less consistent and weaker. Attachment anxiety was

Table 4.1

Descriptives, Cronbach's Reliabilities, and Pearson's Product Moment Correlation Coefficients between Measures of Attachment and r-RST (N = 225)

Measure	Scale	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ECR-R	1 Anxiety	(.93)																
	2 Avoidance	.35***	(.94)															
CW	3 BAS-D	-.15*	-.21**	(.79)														
	4 BAS-FS	-.07	-.26***	.49***	(.71)													
	5 BAS-RR	-.10	-.24***	.48***	.44***	(.76)												
	6 BAS Total	-.13*	-.29***	.82***	.80***	.79***	(.85)											
FSS	7 FSS	.31***	.08	-.06	-.24***	-.04	-.14*	(.95)										
STAI	8 STAI	.62***	.34***	-.31***	-.22**	-.23***	-.32***	.39***	(.91)									
RST-PQ	9 BAS-RI	-.26***	-.23***	.56***	.56***	.38***	.62***	-.21**	-.42***	(.82)								
	10 BAS-GDP	-.30***	-.22**	.53***	.13	.45***	.46***	.01	-.48***	.51***	(.87)							
	11 BAS-RR	-.07	-.22**	.43***	.42***	.62***	.61***	.08	-.27***	.46***	.45***	(.80)						
	12 BAS-I	.12†	-.11	.40***	.52***	.27***	.50***	-.01	.03	.36***	.05	.45***	(.74)					
	13 BAS Total	-.17*	-.26***	.65***	.55***	.59***	.75***	-.04	-.39***	.78***	.68***	.82***	.64***	(.89)				
	14 FFFS	.10	.07	.07	-.12	.08	.02	.63***	.22**	-.09	.07	.09	.16*	.08	(.78)			
	15 BIS	.56***	.20**	-.17*	-.15*	-.08	-.17*	.46***	.81***	-.27***	-.26***	-.01	.15*	-.13†	.32***	(.91)		
	16 Panic	.36***	.06	.01	-.04	-.01	-.02	.46***	.54***	.06	-.05	.09	.30***	.10	.36***	.68***	(.67)	
	17 Defensive Fight	-.06	-.10	.42**	.19**	.30***	.38***	-.04	-.11	.27***	.29***	.39***	.28***	.42***	.08	.03	.09	(.73)
	Mean	3.85	3.05	10.59	11.70	17.09	39.38	162.47	46.2	17.97	20.46	29.35	19.68	87.45	23.82	59.72	13.49	22.35
	SD	1.13	1.08	2.42	2.30	2.28	5.62	44.73	10.11	4.36	4.42	4.99	4.57	13.45	5.83	12.39	3.55	3.96

Note. Cronbach's alpha in parentheses on the diagonal. ECR-R = Experiences in Close Relationships – Revised; CW = Carver & White (1994) measure; D = Drive; FS = Fun Seeking; RR = Reward Responsiveness/Reactivity; FSS = Fear Survey Schedule; STAI = State-Trait Anxiety Inventory; RST-PQ = Reinforcement Sensitivity Theory Personality Questionnaire; RI = Reward Interest; GDP = Goal Drive Persistence; I = Impulsivity.

positively correlated with FSS scores. No other significant correlations were observed between the attachment variables and the measures of FFFS sensitivity. Furthermore, both attachment dimensions had significant positive correlations with STAI and RST-PQ BIS, with r = .20 to .62. Hotelling's t-test revealed that the associations were significantly stronger for attachment anxiety than for attachment avoidance (for STAI: t (222) = 4.77, p < .001; and for RST-PQ BIS: t (222) = 5.61, p < .001). Finally, attachment anxiety had a significant positive correlation with RST-PQ Panic. No other correlations were significant between the attachment dimensions and r-RST measures.

Hierarchical Multiple Regressions

A series of hierarchical multiple linear regressions were conducted with gender (Males = 0, females = 1), age, and relationship status (Single = 0, In a Relationship = 1) covariates in the first step; r-RST variables as predictors in the second step; and the attachment dimensions as the criterion outcomes. Given that the measures of r-RST represent the sensitivities of basic motivational systems, they were used as predictors of the more construct narrow attachment orientations. Tests for multicollinearity indicated that low levels of multicollinearity were present across the models (Tolerance ranged from .43 to .96, and VIF ranged from 1.04 to 2.31).[7]

Table 4.2 summarises the results of the regression models that included the CW-BAS scales, FSS and STAI as predictors (the RST-PQ scales, as parallel measures of r-RST, were included in a separate series of regression models, which are described later). STAI emerged

[7] Although low levels of multicollinearity were present, a separate series of hierarchical multiple linear regression analyses were conducted that included the attachment dimension that was not the criterion outcome as a covariate in Step 2, and the r-RST variables in Step 3, in order to partial out the prediction of attachment anxiety to attachment avoidance (and vice versa). The results are not meaningfully different (some associations between r-RST and the attachment dimensions are slightly stronger) and are presented in Appendix D.

Table 4.2

Hierarchical Regressions Predicting Attachment Dimensions from CW-BAS, FSS and STAI (N = 225)

Predictors	Attachment Avoidance				Attachment Anxiety			
	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
Step 1				$.17^{***}$				$.13^{***}$
Gender	-.12	.15	-.05		-.01	.16	-.01	
Age	.01	.02	.05		.00	.02	.01	
Relationship status	-.88	.14	$-.40^{***}$		-.84	.15	$-.36^{***}$	
Step 2				$.10^{***}$				$.34^{***}$
CW-BAS Drive	.03	.03	.07		.02	.03	.04	
CW-BAS-FS	-.06	.03	$-.13^{\dagger}$		.06	.03	$.12^{\dagger}$	
CW-BAS RR	-.05	.04	-.10		.01	.03	.02	
FSS	.00	.00	-.09		.00	.00	$.10^{\dagger}$	
STAI	.03	.01	$.27^{***}$		.06	.01	$.57^{***}$	
Model statistics	$R^2 = .26$, $F\ (8, 216) = 9.69^{***}$				$R^2 = .47$, $F\ (8, 216) = 23.89^{***}$			

Note. CW-BAS = Carver & White's (1994) BAS measure; FS = Fun-Seeking; RR = Reward Responsiveness; FSS = Fear Survey Schedule; STAI = State-Trait Anxiety Inventory. $^{\dagger}p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

as the sole significant variable that was positively associated with both attachment avoidance and attachment anxiety. Step 2 of the regression model containing the r-RST measures explained a substantial 34% of variance in attachment anxiety.

Table 4.3 summarises the results of regression models that included the RST-PQ scales as predictors. The RST-PQ measure explained only a small amount of variance in attachment avoidance, as distinguished by a significant negative association with RST-PQ BAS Reward

Table 4.3

Hierarchical Regressions Predicting Attachment Dimensions from RST-PQ Measures (N = 225)

Predictors		Attachment Avoidance				Attachment Anxiety			
		B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
Step 1					.17***				.13***
	Gender	-.12	.15	-.05		-.01	.16	-.01	
	Age	.01	.02	.05		.00	.02	.01	
	Relationship status	-.88	.14	-.40***		-.84	.15	-.36***	
Step 2					.06*				.28***
	BAS Reward Interest	-.01	.02	-.05		-.03	.02	-.11	
	BAS Goal-Drive Persistence	.01	.02	-.04		-.02	.02	-.08	
	BAS Reward Reactivity	-.04	.02	-.18*		-.01	.02	-.02	
	BAS Impulsivity	.01	.02	.06		.05	.02	.19**	
	FFFS	.02	.01	.09		-.01	.01	-.06	
	BIS	.01	.01	.12		.04	.01	.45***	
	Panic	-.03	.03	-.09		.00	.03	.00	
	Defensive Fight	.01	.02	.02		-.01	.02	-.03	
Model statistics		R^2 = .23, F (11, 213) = 5.71***				R^2 = .42, F (11, 213) = 13.77***			

Note. †$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Reactivity. In contrast, the r-RST variables explained nearly a third of the variance in attachment anxiety, with a primary positive association with RST-PQ BIS and, a secondary positive association with RST-PQ BAS Impulsivity.

Discussion

This study yielded preliminary self-report data on the nature of the relations between individual differences in adult attachment and reinforcement sensitivity. The results of the correlations, and, to a lesser extent, regressions, suggest differential links between attachment avoidance and BAS sensitivity, and between attachment anxiety and FFFS sensitivity, though both of these associations were modest. More notably, both attachment dimensions were marked by the sensitivity of the BIS, which suggests that motivational ambivalence may centrally characterise attachment insecurity.

In partial support of the hypothesis, the indices of BAS sensitivity were consistently and inversely correlated with attachment avoidance. This is in line with previous correlational studies (Carnelley & Story, 2008; Meyer et al., 2005; Mikulincer & Shaver, 2007), though the present study provides convergent evidence using the RST-PQ BAS scales, along with the CW-BAS scales. Although, when the r-RST measures were simultaneously entered into a regression model that also controlled for gender, age, and relationship status, only RST-PQ BAS Reward Reactivity remained significantly associated with attachment avoidance. This suggests that individuals who are less likely to seek out potential rewarding experiences and have lower levels of positive response to actual rewards, are more likely to feel uncomfortable with intimacy. Indeed, attachment avoidance has been associated with the absence or reduction of positive emotional experiences (Shiota, Keltner, & John, 2006), and more specifically, devaluation of intimate relationships and lower levels of relationship satisfaction (Mikulincer & Shaver, 2007). Therefore, the generally reduced sensitivity to reward may extend to evaluating one's attachment figure as less rewarding, which may underlie the avoidant individual's discomfort with intimacy.

Unexpectedly, attachment anxiety also exhibited significant correlations with some of the BAS measures, but these were less consistent and weaker in magnitude. Furthermore, most of these (inverse) associations were not recovered in the regression analyses, with the exception of RST-PQ BAS Impulsivity. Therefore, attachment anxiety appears to be weakly characterised by the sensitivity of the BAS, but in contrast with attachment avoidance, the primary relevant motivational aspect is that of impulsivity. The lack of behavioural restraint towards rewards is in line with the behavioural dysregulatory and hyperactivating features of attachment anxiety.

Furthermore, in weak support of the hypothesis, FFFS sensitivity as indexed by FSS ratings, but not RST-PQ FFFS scores, was positively correlated with attachment anxiety. Both measures of FFFS sensitivity were also not significantly associated with attachment anxiety in the regression models. Although previous studies have implicated attachment anxiety with a heightened FFFS (Harnett & Penn, 2012; Karantzas et al., 2010; MacDonald & Kingsbury, 2006), the present data suggest the association may be modest or of a rather general or abstract nature. In the current study, both the FSS and RST-PQ FFFS scales tap response towards a wide-range of specific aversive stimuli and situations, and it appears that such generalised fearfulness do not necessarily translate to fear of rejection from an attachment figure.

Finally, in line with expectations, both attachment dimensions were positively and robustly associated with BIS sensitivity, as operationalised by the STAI trait anxiety and RST-PQ BIS scales, with stronger associations observed for attachment anxiety than for attachment avoidance. Although previous research have related the attachment dimensions to trait anxiety (see Mikulincer & Shaver, 2007, for a review), this study additionally established links with BIS sensitivity as assessed using a purpose-built r-RST measure, the RST-PQ BIS scale. Furthermore, previous studies on adult attachment and reinforcement sensitivity have given little

attention to BIS sensitivity, or have otherwise adopted outdated operationalisations, which conflate BIS and FFFS sensitivities in the context of the r-RST. Therefore, the present data importantly points to a central role for BIS in relation to attachment insecurity, whereby individuals who are more sensitive to motivational conflict also tend to display higher levels of attachment anxiety and/or avoidance. Greater BIS sensitivity may heighten relational ambivalence for the insecurely attached person whereby automatic attachment-related thoughts and action tendencies (i.e., proximity seeking) are triggered in situations of threat and are coupled with negative appraisals of the attachment figure's availability. Indeed, both attachment dimensions have been related to conflicting approach-avoidance behaviour and threat and reward appraisals toward one's attachment figure (e.g., MacDonald et al., 2013; Mikulincer et al., 2010). Furthermore, the fact that BIS sensitivity was more strongly associated with attachment anxiety than with attachment avoidance is consistent with MacDonald et al. (2013) who found that attachment anxiety was linked to increased threat perception toward relationships and greater resultant ambivalence, while attachment avoidance was associated with reduced reward perception and lower levels of ambivalence. Therefore, the present study highlights the primary relation between the attachment dimensions, especially attachment anxiety, and BIS sensitivity. It is of interest in future research to give greater attention to the role of the BIS and examine the source of motivational conflict associated with attachment insecurity.

A number of caveats need to be noted alongside the study's interpretations. Firstly, the use of self-report measures of r-RST may be especially problematic and attenuate or conceal existing links between adult attachment and reinforcement sensitivity. Aside from the usual limitations inherent to self-report methodology, such as social desirability, individuals with high attachment avoidance may be less aware of and/or report FFFS or BIS-related experiences such

as fear and anxiety, though they may manifest physiological markers of distress (Diamond, Hicks, & Otter-Henderson, 2006). Furthermore, while the r-RST measures have been validated psychometrically, behaviourally, and physiologically to some extent, it is still questionable as to how well self-report assessments can capture the sensitivities of the motivational systems that are proposed to be neurobiologically based (Smillie et al., 2006). Therefore, given these considerations, it is necessary to extend beyond self-report assessments and include behavioural and physiological measures of r-RST in order to assess links with adult attachment at multiple levels of analysis.

Secondly, the ECR-R measure of adult attachment focuses on negative attachment-related experiences of avoidance and anxiety, which may bias results toward links with the aversive motivational systems. The rewarding properties of close relationships and the role of BAS in initiating and maintaining adult attachment may be underestimated. Indeed, Fraley et al. (2001) demonstrated that the ECR-R, along with other existing adult attachment questionnaires, suffer from measurement imprecision at the secure end of the continuum. Future research should therefore endeavour to capture variation at the positive end of attachment experiences in relation to reinforcement sensitivity. Relatedly, it is of interest to consider how "avoidance" and "anxiety" as used in the attachment literature map onto r-RST terms (approach, fear and anxiety), which in turn may provide more nuanced descriptions of attachment dynamics.

Thirdly, the study's correlational and cross-sectional design does not permit robust causal interpretations. The relationship between reinforcement sensitivity and attachment is unlikely to be simple: BAS, FFFS, and BIS sensitivities may predispose a person towards particular attachment orientations, and conversely, attachment experiences may influence the development of the basic motivational systems. It would be of value in future investigations to include

experimental manipulations of attachment orientations or motivations (e.g., via a priming paradigm) and examine the effects on the other domain, as well as incorporate longitudinal designs.

The present study importantly attests to self-reported individual differences in reinforcement sensitivity with respect to adult attachment orientations, highlighting that greater BIS sensitivity centrally characterise both attachment dimensions. These findings affirm links between more basic motivational systems and attachment behavioural patterns, and, as such, offer a more fundamental account of the latter in accord with Bowlby's (1969/1982) original conceptualisation of the attachment system from a biological and motivational standpoint.

Chapter 5: Study 2 – Adult Attachment and Reinforcement Sensitivity as Predictors of Behaviour in a Virtual Separation Scenario

The following study is a copy of the submitted manuscript:

> Jiang, Y., Schönbrodt, F., Fayn, K., & Tiliopoulos, N. (Submitted Manuscript). Adult attachment and reinforcement sensitivity as predictors of behaviour in a virtual separation scenario. *Journal of Personal Relationships.*

Introduction

Assuming the evolutionary perspective of "safety in numbers", attachment theory proposes that humans seek out close and trusted others for comfort and protection in threatening situations (Bowlby, 1968/1982). Conversely, separation from others, and in particular, attachment figures such as caregivers and romantic partners, can threaten one's physical and emotional well-being. Therefore, separation critically activates the attachment system, although there are marked individual differences in affective and behavioural responses to separation. Additionally, Gray and McNaughton's (2000) revised reinforcement sensitivity theory (r-RST) proposes general motivational systems that regulate behaviour in response to threatening and rewarding stimuli. The sensitivity of these fundamental motivational systems may play a role in influencing individual differences in attachment behaviour, in particular, in the context of response to separation. This paper investigates the prediction of individual differences in adult attachment and reinforcement sensitivity to behavioural and affective responses to an attachment-related separation scenario.

Adult Attachment and Reinforcement Sensitivity

Attachment theory (Bowlby, 1969/1982, 1973, 1980) proposes that humans are endowed with an innate biobehavioural system that regulates behaviour in response to threats. Critically, when a child or adult is distressed, the system prompts the proximity-seeking of attachment figures for physical protection and/or emotion regulation (Bowlby, 1969/1982; Mikulincer & Shaver, 2007). The attachment figure acts as a safe haven by providing a sense of "felt security" and alleviation from distress (Sroufe & Waters, 1977). However, varied experiences of the availability and responsiveness of attachment figures over time create stable individual differences in expectations and behaviour in close attachment relationships. In regards to adult romantic attachment, which is the focus of the present study, these individual differences are usually described in terms of two orthogonal dimensions. The first dimension is called *attachment anxiety*, which refers to the degree to which a person worries about their attachment figure's availability and responsiveness; and the second dimension is called *attachment avoidance,* which refers to the degree to which a person is uncomfortable with intimacy (Brennan, Clark, & Shaver, 1998).

As a more general theory of dispositional motivation, Gray and McNaughton's (2000) r-RST proposes that individual differences in approach, avoidance and motivational ambivalence arise from the varied sensitivities of three different neurobiologically-based motivational systems. Firstly, the Behavioural Approach System (BAS) mediates approach towards rewarding stimuli, and individuals with a more sensitive BAS exhibit greater reward-orientation and hopeful anticipation. Secondly, the Fight Flight Freeze System (FFFS) mediates avoidance of threats, and individuals with a more sensitive FFFS have higher levels of trait fearfulness. Thirdly, the Behaviour Inhibition System (BIS) is proposed to be responsible for conflict

resolution (e.g., between simultaneously activated approach and avoidance tendencies), and greater BIS sensitivity corresponds with higher levels of trait anxiety. As reviewed in Chapter 2, there are few purpose-built measures of the r-RST. Given weak internal reliabilities and associations with attachment dimensions obtained in Study 1 for some scales from Corr and Cooper's (2016) RST-PQ measure, the present study adopted the proxy measures of r-RST that were also used in Study 1.

Both attachment theory and r-RST are theories of motivation that describe fundamental biobehavioural systems characterised by approach and avoidance dynamics. Given the theoretical overlaps, a number of studies have tried to establish the nature of the empirical relation between individual differences in adult attachment and reinforcement sensitivity. On one hand, attachment anxiety has been generally related to greater aversive motivation, including higher self-reported FFFS and/or BIS sensitivities (e.g., Carnelley & Story, 2008; Harnett & Penn, 2012; Jiang & Tiliopoulos, 2014; Meyer et al., 2005; Mikulincer & Shaver, 2007) and heightened response to painful and threatening stimuli (McDonald & Kingsbury, 2006; Karantzas et al., 2010). On the other hand, the same studies have found attachment avoidance to be negatively and modestly correlated with self-reported BAS sensitivity (Carnelley & Story, 2008; Jiang & Tiliopoulos, 2014; Meyer et al., 2005; Mikulincer & Shaver, 2007). More notably, both attachment dimensions have been related to motivational ambivalence, manifest as conflicting behaviours and appraisals toward the attachment figure (e.g., MacDonald, Locke, Spielmann, & Joel, 2013; Mikulincer et al., 2010), as well as higher scores on measures of trait anxiety (for a review, see Mikulincer & Shaver, 2007) and BIS (Jiang & Tiliopoulos, 2014). Therefore, the studies to date, which are mostly based on self-report data, suggest that the attachment dimensions have modest links to FFFS and BAS sensitivities, and stronger

associations with BIS sensitivity. To further investigate how general motivational tendencies as embodied by reinforcement sensitivities intersect with attachment behaviour, it is of interest to examine the prediction of reinforcement sensitivity to behavioural and affective responses to separation – a scenario that is known to critically activate the attachment system.

Adult Attachment, Reinforcement Sensitivity and Response to Separation

One of the key propositions of attachment theory is that attachment behaviour is most strongly manifest in situations of distress, and in particular, during separation from one's attachment figure (Bowlby, 1973). Separations can be temporary or prolonged, and due to various reasons such as work-related, illness, relationship dissolution and loss. Regardless of the duration and cause, such occasions signify the unavailability and unresponsiveness of the attachment figure, prompting attachment concerns and distress. A number of studies have shown that separation elicits normative increases in emotional distress (Diamond et al., 2008; Fraley & Shaver, 1998; Schönbrodt & Asendorpf, 2012; also see Vormbrock, 1993, for a review), as well as proximity-seeking attempts such as clinging, following and remote contact behaviour (Diamond et al., 2008; Fraley & Shaver, 1998).

Moreover, of focal relevance to the present study, there are pronounced variation in affective and behavioural responses to separation as a function of attachment orientations. Specifically, attachment avoidance has been found to be negatively related to proximity-seeking behaviour. In a naturalistic observation of behaviour of separating couples at an airport, Fraley and Shaver (1998) found that women with higher levels of attachment avoidance initiated fewer instances of proximity-seeking and maintenance behaviour (e.g., holding onto each other and maintaining eye contact). Moreover, these women displayed more withdrawal strategies such as

pulling away and avoiding close contact. Similarly, in a study of temporary travel-related separation among cohabitating couples, Diamond et al. (2008) found that homebound partners with higher levels of attachment avoidance reported less of an increase in remote contact behaviour (e.g., phone calls) during separation. In sum, the results of these studies converge to suggest that the dimension of attachment avoidance is negatively related to levels of proximity-seeking in response to separation.

With regards to attachment anxiety, a number of studies suggest that the dimension may be associated with greater distress and negative affect levels during separation. Feeney (1998) found that attachment anxiety was associated with greater self-reported despair in response to a separation episode from their dating partners as recalled by participants. Likewise, Fraley and Shaver's (1998) found that women with higher levels of attachment anxiety reported greater separation distress when parting from their partners at the airport, although attachment anxiety was not predictive of actual proximity-seeking behaviour. Furthermore, attachment anxiety has been associated with lower levels of self-reported positive affect in response to both real-life (Diamond et al., 2008) and virtual computer-simulated (Schönbrodt & Asendorpf, 2012) separations. These findings have led some researchers to conclude that attachment anxiety captures the affective appraisal component of response to threat/separation, while attachment avoidance is more predictive of behavioural regulation (that is, proximity-maintenance behaviour) (Fraley & Shaver, 1998; Simpson et al., 1992). However, there have been some instances where attachment anxiety has also predicted behavioural responses to separation, such as reduced remote contact and less positive interactions with one's partner (Diamond et al., 2008), reduced proximity-maintenance and increased withdrawal behaviour for men (Fraley & Shaver, 2008), and, paradoxically, thinking of one's spouse more during a virtual separation

scenario (Schönbrodt & Asendorpf, 2012). However, Simpson et al. (1992, 2002) found no association between attachment anxiety and proximity-seeking behaviour when expecting an anxiety-provoking laboratory task. Therefore, the dimension of attachment anxiety appears to be consistently related to the subjective experience of separation distress, and less clearly linked to behavioural responses.

No studies have been conducted on individual differences in reinforcement sensitivity and response to attachment-related separation. However, given the evidence of an inverse association between attachment avoidance and BAS sensitivity, it may be hypothesised that the latter construct is positively associated with proximity-seeking during separation. Individuals with a more sensitive BAS may appraise the attachment figure more positively as a source of comfort during separation, despite their apparent unavailability and so display more approach-oriented proximity-seeking behaviour. Conversely, it may be hypothesised that individuals with a more sensitive FFFS may feel particularly threatened by the unavailability of the attachment figure that leaves them in a state of physical and/or emotional vulnerability. Therefore, converging with the predictions for attachment anxiety, FFFS sensitivity may predict greater distress in response to separation.

Adult Attachment, Reinforcement Sensitivity, and Response to Reunion

Following separation, reunion with the attachment figure is proposed to result in the alleviation of distress (Bowlby, 1969/1982). Reunion once again signals the availability of the attachment figure as a secure base, and the attachment figure is usually greeted with positive emotions and behaviour. Indeed, studies have found a normative rebound in positive affect and decline in negative affect from separation to reunion (Schönbrodt & Asendorpf, 2012; Diamond

et al., 2008). Diamond et al. (2008) also showed that reunion elicited a general increase in positive interactions with the attachment figure.

Furthermore, differential attachment patterns are also observable during reunion, which Ainsworth et al. (1978) argued is more diagnostic of the quality of the attachment, since distress and proximity-seeking are somewhat normative responses to separation. However, few studies have examined the relation between individual differences in adult attachment and reunion behaviour. Nonetheless, there is some evidence to suggest that attachment avoidance is associated with overall lower levels of engagement with the attachment figure during reunion, specifically manifest as greater physical distance, fewer partner-directed positive actions, and fewer partner interactions in general in a virtual scenario (Schönbrodt & Asendorpf, 2012). Higher levels of attachment avoidance has also been associated with greater self-reported distress (Diamond et al., 2008) and reduced positive affect (Schönbrodt & Asendorpf, 2012). Conversely, attachment anxiety has been associated with an increase in partner interactional positivity and, simultaneously, higher levels of interactional negativity (e.g., criticism and conflict), as well as lower levels of contact behaviour (Diamond et al., 2008). In this case, attachment avoidance appears to be more clearly associated with fewer partner interactions and, to a degree, greater negative affect. Attachment anxiety appears to be associated with conflicting approach-avoidance behaviour.

No studies have examined differential behavioural and affective response to reunion as a function of individual differences in reinforcement sensitivity. On one hand, it may be hypothesised that for individuals with higher BAS sensitivity, post-separation reunion with the attachment figure may be regarded more positively, and in turn, elicit greater approach behaviour and positive affect. This would also be consistent with the modest inverse association between

BAS sensitivity and attachment avoidance, such that the latter construct has been found to predict lower levels of overall proximity-seeking (Diamond et al., 2008; Fraley and Shaver, 1998; Schönbrodt & Asendorpf, 2012). On the other hand, individuals with higher levels of BIS sensitivity may be expected to be sensitive to both the threatening aspect of the situation (the rejection and unavailability of the attachment figure) as well as the rewarding aspect of the situation (the presence and return of the attachment figure). This motivational ambivalence may result in less clear behavioural manifestations, involving conflicting approach and avoidance behaviour and mixed emotional appraisals.

Study Overview

The aim of this study was to compare the predictions of individual differences in adult attachment and reinforcement sensitivity to behavioural and emotional response to a virtual attachment-related separation scenario. In doing so, this may help clarify the nature of the relations between individual differences in general motivational tendencies and attachment behaviour, and thereby, the degree to which the two systems overlap. In all hypotheses, we expect a normative attachment-related reaction, and a moderation of this normative effect by trait measures. During separation, it was hypothesised that (1) there would be a normative increase in negative affect (i.e., distress); both (2a) attachment anxiety and (2b) FFFS sensitivity would be associated with heightened negative affect; (3a) attachment avoidance and (3b) BAS sensitivity would have negative and positive associations, respectively, with proximity-seeking. Following reunion with the attachment figure, compared with baseline activity during the pre-separation period, it was hypothesised that (4) there would be a normative decrease in negative affect (i.e., emotional relief); (5a) attachment avoidance would be related to less of an decrease in negative

affect, while (5b) BAS sensitivity would be related to greater reduction in negative affect, upon reunion. With regards to behavioural responses following reunion, it was hypothesised that individuals would normatively engage in (6a) increased proximity-seeking and more positive interactions, as well as (6b) experience less negative affect. Additionally, it was hypothesised that (7a) attachment avoidance would be related to reduced proximity-seeking and more negative and less positive interactions; while (7b) BAS sensitivity would be related to increased proximity-seeking and interactional positivity; and (7c) BIS sensitivity would be related to simultaneous increase of both negative and positive interactions.

Method

Participants

The sample consisted of 200 undergraduates (74% females) at the University of Sydney who participated in exchange for first year psychology course credit. Their ages ranged from 17 to 51 (M = 19.72, SD = 4.13). Participants were predominantly Australian residents (96.5%), and ethnicity breakdown were as follows: 29.5% North-West European, 20% Oceanian, 18% South-East Asian, 13.5% Southern and Central Asian, 10.5% Southern and Eastern European, 5.5% North African and Middle Eastern, 0.5% People of the Americas, 0.5% Sub-Saharan African, and 2% unspecified. Of the sample, 45.5% indicated that they were in a current exclusive romantic relationship, with 53.5% classifying themselves as single, 41.5% dating, 0.5% engaged, 3.5% married or cohabitating, 0.5% divorced, and 0.5% unspecified. Average relationship length was 20.53 months (range = 0 to 234, SD = 34.46).

The "Simoland" Game

The Virtual Social Environment (VSE) used in the present study was called "Simoland", which is a 15 minute computer-based game created by Schönbrodt and Asendorpf (2011, 2012). It allows for interactions with a virtual spouse and contains critical separation and reunion scenes, analogous to the infant SSP.[8] Participants were first guided through a self-paced tutorial (about 3-6 minutes), which introduced the game as one about social relationships that takes place in a virtual environment called "Simoland." They were able to control a specific character (the "protagonist", who was matched to the participant's sex), and were given the opportunity to practice giving behavioural commands (for examples, listen to music, eat, walk, and chat; see Schönbrodt & Asendorpf, 2011, for full list of actions) to this character. Following this, participants were provided with general instructions of game handling, such as adjusting the volume and screen view. To promote spontaneous behaviour, participants were not directed as to how they should behave in the game (for example, that they should treat the virtual spouse as their real-life partner) nor given any explicit goals, but were instructed to play freely. However, they were told that the virtual characters had motivations (that is, both physical and social needs), and that their behavioural choices had consequences on the mood and behaviour of other characters in the game. The game consists of five scenes (Introduction, Dyad, All Together, Separation, Reunion, and Outro), which are described as follows.

Introduction. The game starts with the protagonist by him- or herself, and the participant can direct him or her to engage in solitary actions or explore the environment. This scene allows the participant to familiarise with Simoland.

[8]The VSE created by Schönbrodt and Asendorpf (2012) also contains two other attachment-related scenarios – one involving relationship conflict and the other involving illness. The current study focuses on the separation scenario as one of the most classic and critical situations known to activate the attachment system.

Dyad. After 1 minute and 40 seconds into the game, the virtual spouse (who is of the opposite-sex) is introduced with the words, "These two Simos have a romantic relationship." The participant is able to guide the protagonist to interact with the spouse via a diverse number of actions (e.g., dance together, kiss, talk about various topics). This scene lasts for three minutes.

All Together. Other characters ("Simos") are now introduced into the game to provide alternative options for social interactions and prevent spouse-directed interactions due to boredom. This scene lasts for two and half minutes.

Separation. Seven minutes into the game, a critical separation scenario occurs, presented as a prescripted cut scene where the participant is unable to give commands to the protagonist. During this scene, the virtual spouse approaches the protagonist and tells him or her that a near relative of the virtual spouse had died. Consequently, the virtual spouse has to go on a dangerous journey to a faraway town and is uncertain when s/he will return. The spouse starts to cry and walks away, but returns to give her or his partner a kiss, and finally departs, still crying. A sad song, "Ne me quitte pas" by Jacques Brel, accompanies this scene. After the spouse's departure, the screen faded out to black, signifying the end of the prescripted cut scene. A new day beings (with the fade-in of the screen) where the participant can once more give commands to the protagonist. However, for the next three minutes, the virtual spouse is absent. In this scene, the participant was unable to engage in interactions with the absent virtual spouse except for the option, "think of the spouse" and a new action, "write a letter to the spouse." The participant was still able to engage in solitary actions and interactions with other Simos in the game.

Reunion. Following the three minute period, a message announces the safe return of the spouse, who approaches the protagonist from the edge of the game world. This scene lasts for four minutes.

Outro. A message announces that the game will end in one minute, following which the game slowly fades out to black.

A timeline of the game and its various scenes are depicted in Figure 1. Furthermore, a number of indices were recorded during the game and they are described as follows:

Interactional choices. Participants were able to engage in a range of actions and interactions throughout the game. These interactions were categorised a priori into positive (11 actions; e.g., kiss, talk about one's mood, talk about the relationship, say "I love you!"), neutral (6 actions; e.g., talk about hobbies, tell a vision), and negative (7 actions; e.g., start an argument, criticise, annoy) (for the full list of actions, see Schönbrodt and Asendorpf, 2011). For each scene (except for the Separation scene), three behavioural indices were calculated from the aggregated action choices: 1) a *positivity* index was calculated as the ratio of positive actions directed towards the spouse to all actions, 2) a *negativity* index was calculated as the ratio of negative actions directed towards the spouse to all actions, and 3) *spouse-directedness* was calculated as the ratio of actions (positive, negative or neutral) directed towards the spouse to all actions. Therefore, each behavioural index was standardised to the overall number of actions performed by the protagonist. During the separation scene, the aforementioned three indices could not be calculated as few actions directed towards the spouse were possible. Instead, the frequency of engaging in thinking about or writing a letter to the virtual spouse was recorded.

Interspousal distance. The mean physical distance between the protagonist and virtual spouse for each scene was also calculated. This provides a behavioural measure of degree of physical proximity to the virtual spouse.

Emotion ascriptions. At five predetermined time points (see Figure 5.1), the game was paused and participants were asked to imagine and rate the emotions presently experienced by the protagonist. Participants were presented with seven pairs of emotions: sad-happy, lonely-safe, angry-peaceful, anxious-confident, tense-relieved, disappointed-trustful, and weak-strong. Each pair of emotion was rated on a 7-point bipolar Likert-type scales, with endpoints = "very," and the midpoint = "undecided." The presentation of the positive and negative emotions on the left and right sides of the scale were counterbalanced. As in a previous study by Schönbrodt and Asendorpf (2012), emotion ratings on the seven bipolar Likert-type scales were highly homogenous, with Cronbach's alpha internal reliabilities of .81 (Alone), .88 (All Together), .84 (Separation), .90 (Reunion), and .92 (Outro). Therefore, ratings were averaged to form an overall index of affectivity for each scene, with higher scores indicating more positive emotion ascriptions, and lower scores indicating more negative emotion ascriptions.

Measures

The *Experiences in Close Relationships – Revised* (ECR-R; Fraley, Waller, & Brennan, 2000) was used to assess adult attachment. The measure consists of 18 items assessing attachment-related avoidance (e.g., "I prefer not to show a partner how I feel deep down") and 18 items assessing attachment-related anxiety (e.g., "I'm afraid that I will lose my partner's love"). Participants are asked to reflect on how they generally feel in romantic relationships, and rate the items on a 7-point Likert-type scale (from 1 = strongly disagree to 7 = strongly agree).

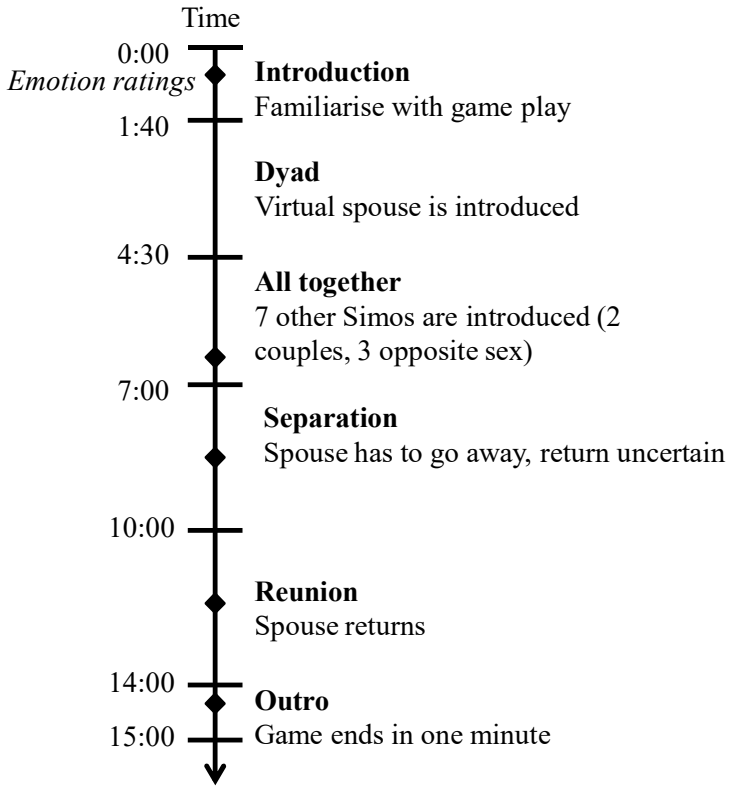

Figure 5.1. Timeline of scenes and emotion ratings in the "Simoland" game.

The Cronbach's alpha internal reliability were .94 and .91 for the attachment avoidance and attachment anxiety scales respectively.

The *Behavioural Approach System (BAS) scale* from the *BIS/BAS scales* (Carver & White, 1994) was used to assess the sensitivity of the BAS. It consists of three scales: four items assessing Drive, which describes persistent pursuit of desired goals (for example, "I go out of my way to get things I want"); four items assessing Fun Seeking, which reflects desire for new rewards and willingness to approach potentially rewarding events (for example, "I'm always willing to try something new if I think it will be fun"); and five items assessing Reward

Responsiveness, which capture positive responses to anticipation or occurrence of reward (for example, “When I get something I want, I feel excited and energised”). Each item was rated on a 4-point Likert-type scale (from 1 = very false for me, to 4 = very true for me). Ratings on the items across the three scales were averaged to produce an overall index of BAS sensitivity, and the Cronbach’s alpha internal reliability for this index was .81.

The *Fear Survey Schedule* (FSS; Geer, 1965) was used to assess fear-proneness as a proxy index of the sensitivity of the Fight-Flight-Freeze System. It consists of a checklist of 51 items reflecting a broad range of specific and potentially threatening stimuli (e.g., “sharp objects”, “suffocating”, and “looking foolish”). Each item was rated on the degree to which it elicits fear on a 7-point Likert scale (from 1 = none, to 7 = terror). Ratings across the 51 items were summed to provide an index of general dispositional fear, which has been used in previous research as a proxy measure of FFFS sensitivity (Perkins et al., 2007). The Cronbach’s alpha internal reliability for the scale was .94.

Y2 trait scale from the *State-Trait Anxiety Inventory* (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was used to assess pervasive feelings of anxiety. Since the r-RST proposes that BIS sensitivity is marked by higher levels of trait anxiety, the STAI has been previously employed as a proxy index of the former construct (e.g., Perkins et al., 2007). It consists of 20 statements that describe general experiences of apprehension, tension, nervousness and worry (e.g., “I feel nervous and restless”). Each statement is rated on a 4-point Likert-type scale (from 1 = almost never, to 4 = almost always). The Cronbach’s alpha internal reliability for the scale was .93.

An *Identification with Protagonist and Game Presence Scale* was constructed specifically for the study to assess the degree to which participants identified themselves with the

protagonist and had feeling of presence (involvement) in the game. There were 10 items modelled upon existing game presence measures and items used in previous Simoland research (Schönbrodt & Asendorpf, 2011, 2012; Van Baren & Ijsselsteijn, 2004). Each item was rated on a 5 point Likert-type scale (from 1 = not at all, to 5 = very much). Example items are, "I identified myself with my Simo," and "I got completely involved in the game" (see Appendix B for the full list of items). Ratings were averaged to provide an overall index of identification and game presence, with an acceptable Cronbach's alpha internal reliability of .70.

Procedure

After being provided with some instructions and a brief tutorial, participants played the 15 minute virtual social interaction game, "Simoland." Following this, participants completed the self-report measures of attachment, reinforcement sensitivity, game experience, and sociodemographic background, along with a number of other personality questions not relevant to the present study. The study was completed in a single session via a computer in a laboratory room of 1 to 10 persons. The study took between 30 to 45 minutes to complete, and was approved and administered in accordance with the University of Sydney Human Research Ethics Committee's guidelines.

Statistical Analyses

To assess Hypothesis 1, concerning mean differences in emotion ascription in the Separation versus pre-separation scenes, a one-way repeated measures ANOVA was conducted in IBM SPSS Statistics 22. Then, using the same software, to assess the prediction of adult attachment and reinforcement sensitivity to emotion ascription during separation (Hypotheses 2a

and 2b) and the likelihood of engaging in proximity-seeking during separation (Hypothesis 3a and 3b), a hierarchical regression and a logistic regression were conducted respectively. To test Hypotheses 4 to 7, which concerned behavioural and affective responses following reunion compared with the pre-separation period, multivariate multilevel random slopes and intercepts modelling was conducted. This statistical technique is suitable for multilevel data structures in which observations at one level of analysis (i.e., in-game responses for each of the two pre-separation and two post-separation scenes) are nested within higher levels of analysis (i.e., individuals). Thus, it allows for the simultaneous estimation of both within-person state effects and between-person individual differences effects. Four multilevel slope-and-intercept models were conducted to test whether adult attachment and reinforcement sensitivity moderates the within-person changes in pre- versus post-separation levels of in-game responses of emotion ascription (Model 1), spouse-directedness (Model 2), positivity (Model 3), and negativity (Model 4). Across these models, Level 1 analyses tested whether a person's mean levels of in-game responses changed from the pre-separation scenes (Dyad and All Together) to the post-separation scenes (Reunion and Outro). For Model 2 concerning spouse-directedness, comparisons were made between the pre-separation All Together scene and the post-separation Reunion and Outro scenes, given that the Dyad scene restricted interactions to the virtual spouse only (thus, inflating spouse-directedness). Level 2 analyses tested whether adult attachment (anxiety and avoidance) and reinforcement sensitivity (BAS, FFFS and BIS) moderated within-person differences in (a) mean levels of in-game responses, and (b) the change in mean levels of in-game responses from pre-separation to post-separation. Adult attachment and reinforcement sensitivity variables were standardised. The multilevel models were conducted using Mplus 7 (Muthén & Muthén, 2012).

Basic structure for Multilevel Models 1-5

Within-person

$$\text{In-game response}_{ij}^{*} = \beta_{0j} + \beta_{1j}\,(\text{post- vs pre-separation}) + r_{ij}$$

Between-people

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\,(\text{attachment anxiety}) + \gamma_{02}\,(\text{attachment avoidance}) + \gamma_{03}\,(\text{BAS}) + \gamma_{04}\,(\text{FFFS}) + \gamma_{05}\,(\text{BIS}) + \mu_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}\,(\text{attachment anxiety}) + \gamma_{12}\,(\text{attachment avoidance}) + \gamma_{13}\,(\text{BAS}) + \gamma_{14}\,(\text{FFFS}) + \gamma_{15}\,(\text{BIS}) + \mu_{1j}$$

*The predicted outcome (in-game response) for each model was emotion ascription (Model 1), spouse-directness (Model 2), spouse-directed positivity (Model 3), and spouse-directed negativity (Model 4).

Lastly, to test Hypotheses 7a and 7b pertaining to levels of proximity-seeking during reunion, multiple regression analysis was conducted using SPSS with interspousal distance during the reunion scene as the criterion outcome, and adult attachment and reinforcement sensitivity as predictors.

Results

Descriptive Statistics

The descriptive statistics for the Simoland in-game indices for each scene is displayed in Table 5.1. Although there was a drop in the number of spouse-directed actions in the All Together scene, possibly due to re-directed attention to other new characters in the game, participants generally instructed the protagonist to engage in a greater proportion of actions

Table 5.1

Means and Standard Deviations (in Brackets) for the Frequency of Behavioural Choices, Physical Distance and Emotion Ascriptions across the Whole Game and for Each Scene

Game index	Dyad	All Together	Separation	Reunion	Outro
Positivity of Emotion ascription	3.73 (0.96)	4.23 (1.09)	1.85 (0.99)	4.72 (1.04)	4.47 (1.11)
All actions	6.83 (2.68)	4.51 (2.02)	3.77 (2.09)	8.17 (3.27)	1.82 (1.05)
Spouse-directed interactions	5.71 (2.65)	1.58 (1.33)	-	5.27 (2.95)	1.21 (1.13)
% Positivity to spouse	40.9 (0.18)	19.86 (22.20)	-	42.29 (20.56)	52.30 (45.21)
% Negativity to spouse	4.63 (0.09)	1.41 (5.22)	-	1.94 (5.93)	1.75 (12.46)
% Spouse-directedness	-	34.86 (27.83)	-	64.85 (23.42)	66.11 (44.04)
Interspousal distance	83.43 (41.03)	153.89 (116.43)	-	181.52 (101.81)	285.50 (288.63)

toward the spouse. Notably, participants instructed the protagonist to engage in very few spouse-directed negative actions in each of the four scenes where the virtual spouse was present (less than five percent of all in-game actions).

Table 5.2 displays the descriptives and standard deviations for measures of adult attachment and reinforcement and the in-game indices averaged across the whole game, as well as correlations between these measures. The majority of participants reported an identification with the protagonist and experienced game presence, with 59.3% providing a mean rating above

Table 5.2

Pearson's Correlations between Self-Report Measures and Aggregated In-Game Indices (N = 195 to 200)

	1	2	3	4	5	6	7	8	9	10
1 Attachment anxiety	1									
2 Attachment avoidance	.40***	1								
3 BAS	.04	.03	1							
4 FFFS	.32***	-.05	-.04	1						
5 BIS	.57***	.36***	-.04	.29***	1					
6 Emotion ascription	-.24***	-.08	.16**	-.14*	-.14	1				
7 Spouse-directedness	-.05	-.10	.03	.09	-.05	.13	1			
8 Spouse-directed positivity	-.07	-.15*	.10	.09	-.08	.20**	.74***	1		
9 Spouse-directed negativity	.02	.18**	-.01	.05	.05	-.30***	-.06	-.25***	1	
10 Interspousal distance	-.11	-.00	.17*	-.04	-.02	-.14*	-.22**	-.16*	.15*	1
Mean	3.72	3.07	3.08	3.35	2.30	173.41	54.95	31.86	2.43	3.80
SD	1.05	1.14	0.39	0.80	0.55	82.15	13.80	10.86	3.71	0.63

Note. *$p < .05$; **$p < .01$; ***$p < .001$. CW-BAS = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule (Geer, 1965).

the scale midpoint of 3. Overall, the mean rating was 3.15 (*SD* = 0.62). Identification and game presence were significantly correlated with attachment avoidance ($r = -.30$, $p < .001$), and FFFS sensitivity ($r = .17$, $p < .05$).

The majority of participants reported an identification with the protagonist and experienced game presence, with 59.3% providing a mean rating above the scale midpoint of 3. Overall, the mean rating was 3.15 (SD = 0.62). Identification and game presence were significantly correlated with attachment avoidance (r = -.30, p < .001), and FFFS sensitivity (r = .17, p < .05).

Emotion Ascription during Separation

A MLM model was conducted to assess within-person mean differences in emotion ascription between the Separation scene and the other four scenes, as well as whether between-person individual differences in adult attachment and reinforcement sensitivity moderated this difference. An unconditional model showed that a negligible amount of variance in emotion ascriptions was at the between-person level (ICC = .002), with almost all of the variance at the within-person level. This indicates that most of the variance in spouse-directedness was at the within-person, rather than between person levels. As such adult attachment and reinforcement sensitivity did not account for a meaningful amount of variance in emotion ascriptions, contrary to Hypotheses 2a-b. Therefore, only the results of the Level 1 analyses are reported.

In accordance with Hypothesis 1, the Separation versus non-separation scenes predicted a significant difference in mean levels of emotion ascription. On average, participants gave lower emotional ascriptions during the separation scene compared with the other four scenes, indicative of more negative affect and less positive affect (β_{1j} = 1.950, SE = .071, p < .001).

Proximity-Seeking during Separation

Although no face-to-face interactions with the spouse were possible during the separation

scene, participants could instruct the protagonist to write a letter to the spouse or think about him or her. Of the sample, 68 participants selected the former action once, and 3 participants twice, while the rest did not engage in letter-writing. With regards to thinking about the spouse, 67 participants instructed the protagonist to do so once, 1 participant twice, and 1 other participant four times, while the rest did not instruct the protagonist to engage in this action. As very few participants instructed the protagonist to engage in either letter-writing to or thinking of the spouse more than once, the two indices were combined and dichotomised into participants who select neither actions (= 0; n = 74) and participants who selected either or both actions (= 1; n = 126; a subset of 15 participants engaged in both actions), forming a single proximity-seeking variable.

A logistic regression analysis was conducted with the proximity-seeking variable as the criterion outcome, and measures of adult attachment and reinforcement sensitivity as predictors. The overall model was not statistically significant, indicating that the predictors as a set did not reliably distinguish between participants who directed the protagonist to engage in proximity-seeking and those who did not, χ^2 (5) = 6.263, p = .281. The model explained a very small amount of variance in proximity-seeking (Nagelkerke's R^2 = 4.5%) and correctly classified 62.4% of cases (93.3% of the proximity-seeking group and 10% of the no proximity-seeking group). Table 5.3 summaries the odds ratio for each predictor.

Contrary to Hypothesis 3a, attachment avoidance did not significantly predict the likelihood of proximity-seeking during separation. Attachment anxiety was also not a significant predictor. However, in support of Hypothesis 3b, BAS sensitivity had a significant prediction such that for every one unit increase in BAS sensitivity, participants were 2.32 times more likely to instruct the protagonist to write a letter and/or think of the spouse, although it needs to be

Table 5.3

Summary of Logistic Regression Analysis for Adult Attachment and r-RST Variables Predicting Proximity-Seeking Behaviour during Separation

	B	*SE B*	Wald χ^2	OR	95% CI	*p* value
Attachment anxiety	-.08	.19	.18	.92	0.64 – 1.34	.673
Attachment avoidance	-.17	.16	1.22	.84	0.62 – 1.14	.270
BAS	.84	.39	4.52	2.32	1.07 – 5.03	.033*
FFFS	-.02	.21	.01	.98	0.65 – 1.49	.933
BIS	.24	.36	.46	1.27	0.63 – 2.56	.498

Note. BAS = Behavioural Approach System; FFFS = Fight-Flight-Freeze System; and BIS = Behavioural Inhibition System. *$p < .05$

remembered that the overall model was not significant.

Post- versus Pre-separation Differences in Behavioural Response and Emotional Ascription

Multilevel modelling was used to assess within-person mean differences in levels of spouse-directedness, positivity, negativity and emotional ascription between the pre-separation scenes (Dyad and All Together) and post-separation (Reunion and Outro) scenes. Furthermore, at the between-person level, we examined whether individual differences in adult attachment and reinforcement sensitivity moderated the mean difference in in-game responses from pre-separation to post-separation.

Model 1: Emotion ascription

An unconditional model indicated that the between-person level (consisting of the

predictors of adult attachment and reinforcement sensitivity) accounted for a significant amount of variance in emotion ascription (ICC = .273). Therefore, both Level 1 and 2 analyses were conducted.

At Level 1, the post- versus pre-separation scenes predicted a significant difference in mean levels of emotion ascription (β_{1j} = .306, *SE* = .032, $p < .001$). That is, in support of Hypothesis 4, participants tended to provide higher emotion ascriptions (more positive affect and/or less negative affect) to the protagonist during the post-separation scenes compared with the pre-separation scenes.

Furthermore, the Level 2 analyses revealed that attachment anxiety predicted the intercept for emotion ascription (γ_{02} = -.154, *SE* = .076, p = .044). That is, individuals with higher levels of attachment anxiety tended to ascribe lower emotional ascriptions (less positive affect and/or more negative affect) on average over the game. BAS sensitivity was also a significant predictor of the intercept, such that individuals with higher levels of appetitive motivation ascribed higher emotion ascriptions (more positive affect and/or less negative affect) to the protagonist on average over the game (γ_{03} = .149, *SE* = .062, p = .015). Moreover, there was a moderation effect of attachment avoidance on the change in emotion ascription from pre-separation to post-separation (γ_{12} = -.107, *SE* = .037, p = .004). Supporting Hypothesis 5a, individuals with higher levels of attachment avoidance seemed to ascribe less of a rebound in positive affect and/or decrease in negative affect to the protagonist during the post-separation scenes compared with the pre-separation scenes. However, contrary to Hypothesis 5b, BAS sensitivity did not predict a stronger rebound in positive affect ascribed to the protagonist during the post-separation scenes. There were no other significant between-person predictors.

Model 2: Spouse-directedness

An unconditional model showed that a negligible amount of variance explained in spouse-directedness was at the between-person level (ICC = .021), with almost all of the variance explained at the within-person level. This indicates that variance in spouse-directedness was primarily observed between scenes, rather than between people, contrary to Hypotheses 7a-b. Therefore, only the results of the Level 1 analyses are reported.

In accordance with Hypothesis 6, the post-separation scenes (Reunion and Outro) versus the pre-separation scene (All Together) predicted a significant difference in mean levels of spouse-directedness. On average across participants, the mean level of spouse-directedness increased from the All Together scene to post-separation Reunion and Outro scenes (β_{1j} = .20, *SE* = .017, $p < .001$).

Model 3: Spouse-directed positivity

An unconditional model showed that a negligible amount of variance in spouse-directed positivity was due to between-person variations (ICC = .006), with almost all of the variance due to within-person differences. As such, Level 2 analyses could not be meaningfully modelled and, contrary to Hypotheses 7a-c, there were no meaningful effects of adult attachment and/or reinforcement sensitivity. However, at Level 1, the post- versus pre-separation scenes predicted a significant difference in mean levels of spouse-directed positivity. That is, in support of Hypothesis 6, participants tended to direct the protagonist to engage in more positive actions toward the spouse during the post-separations scenes than during the pre-separation scenes (β_{1j} = .080, *SE* = .010, $p < .001$).

Model 4: Spouse-directed negativity

With regards to spouse-directed negativity, the unconditional model indicated that a substantial amount of variance could be attributed to the between-person variables of adult attachment and reinforcement sensitivity (ICC = .116). Therefore, predictor variables were included at both Levels 1 and 2 were conducted.

At Level 1, the post- versus pre-separation scenes predicted a significant difference in mean levels of spouse-directed negativity (β_{1j} = -.006, *SE* = .003, *p* = .022). That is, in support of Hypothesis 6, participants tended to direct the protagonist to engage in fewer negative actions toward the virtual spouse during the post-separation scenes compared to the pre-separation scenes.

Furthermore, the Level 2 analyses revealed that attachment avoidance predicted the intercept for spouse-directed negativity (γ_{02} = .014, *SE* = .007, *p* = .029). This suggests that individuals with higher levels of attachment avoidance tended to direct the protagonist to engage in more spouse-directed negativity on average across the game. Neither attachment anxiety nor reinforcement sensitivity predicted the intercept. Furthermore, contrary to hypotheses 7b-c, neither attachment anxiety nor reinforcement sensitivity moderated the slope representing the change in mean levels of spouse-directed negativity from pre-separation to post-separation.

Multiple Regressions: Interspousal Distance

A multiple regression was conducted for the Reunion scene with interspousal distance as the criterion outcome, and measures of adult attachment and reinforcement sensitivity as predictors. The overall model was not statistically significant, indicating that individual differences variables as a set did not meaningfully predict interspousal distance in the Reunion

Table 5.4

Multiple Regressions Predicting Interspousal Distance in the Reunion Scene from Attachment Anxiety and Reinforcement Sensitivity Variables (N = 188)

	B	***SE B***	**β**	***p* value**
Attachment anxiety	-8.99	9.13	-.09	.33
Attachment avoidance	0.53	7.51	.01	.94
BAS	-29.33	18.60	-.12	.12
FFFS	0.91	10.03	.01	.93
BIS	3.95	16.87	.02	.82
Model statistics	F (5, 183) = 0.78, p = .56, R^2 =.02			

scene. None of the individual predictors in the models were also statistically significant. Therefore, contrary to Hypothesis 7a, attachment avoidance was not associated with greater interspousal distance during reunion. Moreover, contrary to Hypothesis 7b, BAS sensitivity was not associated with smaller interspousal distance during reunion. It appears that neither adult attachment nor reinforcement sensitivity meaningfully predict interspousal distance during reunion. Table 5.4 summaries the results of the regression.

Discussion

This study examined the prediction of adult attachment and reinforcement sensitivity to behavioural and affective responses to a critical attachment-relevant scenario involving separation from, and subsequent reunion with, the attachment figure. The experimental scenario elicited powerful normative responses, whereby the separation event was associated with

increased negative affect, while the reunion scene was linked to increased proximity-seeking, spouse-directed positivity, and positive affect, as well as reduced spouse-directed negativity. Attachment orientation moderated some responses, such that attachment anxiety was associated with more negative affect, overall and during separation; and attachment avoidance was associated with more spouse-directed negativity overall, and less of a rebound in positive affect during reunion. In contrast, reinforcement sensitivity had negligible influence, aside from a weak prediction of BAS sensitivity to proximity-seeking during separation.

Normative Responses to Separation and Reunion

The most robust findings of the present study pertained to normative affective and behavioural responses to separation from, and subsequent reunion with, the attachment figure. Firstly, as hypothesised, participants tended to report increased negative affect during separation. This is consistent with data reported by Diamond et al. (2008) and Schönbrodt and Asendorpf (2012), and affirms Bowlby's (1973) view that distress is a normative response to separation, even for securely attached individuals, as the event signals the unavailability of the attachment figure. Secondly, also as hypothesised, individuals generally experienced more positive affect following reunion compared with the pre-separation period. This normative rebound in positive affect converges with the results of previous studies (Diamond et al., 2008; Schönbrodt & Asendorpf, 2012), and supports attachment theory's basic tenet that reunion with the attachment figure, who serves as a secure base, results in the alleviation of distress (Bowlby, 1969/1982). Moreover, upon reunion with the attachment figure, individuals exhibited a general tendency to engage in more spouse-directed behaviours that were characterised by increased positivity and reduced negativity. This is consistent with our hypothesis, as well as Diamond et al.'s (2008)

study, which also found an increase in positive interactions upon reunion. Overall, the virtual separation scenario in the present study elicited the expected normative responses: increased distress during separation, and emotional relief and more (positive) interactions with the attachment figure upon reunion.

Adult Attachment Patterns and Responses to Separation and Reunion

The study's focal hypotheses of interest concerned individual differences, and adult attachment was found to moderate affective responses to separation and reunion. On one hand, attachment anxiety was associated with greater negative affect during separation, consistent with previous findings (e.g., Diamond et al., 2008; Feeney, 1998; Fraley & Shaver, 1998; Schönbrodt & Asendorpf, 2012). Given that individuals who have higher levels of attachment anxiety are hypersensitive to cues of rejection and attachment figure's unavailability, it is unsurprising that they react with heightened distress to separation. On the other hand, attachment avoidance moderated distress alleviation following reunion, such that it was associated with reporting less of an increase in positive affect. Higher levels of attachment avoidance is characterised by discomfort with closeness, and so the return of the attachment figure may be viewed as aversive rather than providing emotional relief. Indeed, hostility and emotional and physical distancing are classical responses that have been observed for both highly avoidant children and adults during reunion (Ainsworth et al., 1978; Diamond et al., 2008; Schönbrodt & Asendorpf, 2012). Therefore, the attachment dimensions predicted differential affective responses, such that attachment anxiety was linked to heightened distress during separation, while attachment avoidance was linked to less emotional relief following reunion.

Contrary to expectations, the attachment dimensions were unrelated to actual behaviour in response to separation or following reunion. Neither attachment anxiety nor avoidance predicted the likelihood of engaging in proximity-seeking (writing a letter to, or thinking of, the virtual spouse) during separation, nor the frequency or nature of interactions toward the attachment figure following reunion. This is at odds with attachment theory, which proposes that the separation and reunion events should elicit differential behavioural responses that are diagnostic of one's attachment orientation (Ainsworth et al., 1978; Bowlby, 1973). Moreover, the data deviate from previous studies of separation in adults that have shown attachment avoidance to be inversely related to proximity-seeking during both separation and reunion, and attachment anxiety to be linked to mixed approach-withdrawal behaviour following reunion (Diamond et al., 2008; Fraley & Shaver, 1998; Schönbrodt & Asendorpf, 2012). Although affective responses to separation and reunion did vary as a function of attachment orientation, the virtual separation scenario may not have been sufficiently stressful to elicit differential attachment behaviour in the current sample. Feeney (1998) argued that adults require more extreme stressors to activate the attachment system. In the current sample, participants generally reported a moderate, but not high, degree of game presence and identification with the protagonist. Consequently, they may not have experienced a strong attachment bond with the virtual spouse, nor were intensely affected by the separation and reunion episodes to elicit attachment behaviour. Therefore, the lack of predictions of adult attachment to behavioural responses to separation and reunion potentially suggests that the events only weakly activated the attachment system – a caveat that needs to be kept in mind while interpreting the results of the study.

Despite the lack of prediction of attachment dimensions to behavioural responses contingent upon the separation and reunion events, there is some evidence in support of Fraley and Shaver's (1998) proposal that attachment anxiety and avoidance maps onto affective and behavioural regulation respectively at the more general dispositional level. Attachment anxiety was linked to greater overall negative affect, while attachment avoidance was related to more negative spouse-directed actions in general. This is consistent with previous studies that have found attachment anxiety to be predictive of only affective responses, while attachment avoidance has greater predictive power to behaviour (Fraley & Shaver, 1998; Schönbrodt et al., 2012; Simpson et al., 1992). However, in the present study, attachment avoidance was only related to a higher proportion of negative spouse-directed behaviours, and was unrelated to any other behaviour indices including the number of spouse-directed behaviours, positive spouse-directed behaviours, and physical distance. Nonetheless, the data are consistent with the differential prediction of attachment avoidance and attachment anxiety to behavioural outcomes and distress levels respectively, at the level of generalised dyadic interaction, but not specific to the critical separation and reunion events.

Reinforcement Sensitivity and Responses to Separation and Reunion

In addition to adult attachment, this study was the first to examine the prediction of reinforcement sensitivity to behaviour in an attachment-relevant separation scenario. Reinforcement sensitivity was generally unrelated to behavioural and affective responses to separation from, and subsequent reunion with, the attachment figure, although there was a weak prediction of BAS sensitivity to proximity-seeking during separation. As hypothesised, individuals with greater BAS sensitivity, who are oriented towards approach behaviour, were

more likely to instruct the protagonist to send a letter to or think of the spouse during separation. However, this could also be attributed to the novelty of the action of sending a letter to the spouse in the separation scene, as opposed to heightened proximity-seeking per se. The association was also modest, as the r-RST constructs together did not account for a significant proportion of variance in proximity-seeking. Moreover, contrary to hypotheses, BAS sensitivity was unrelated to increased proximity-seeking, positive interactions and positive affect upon reunion. This could be because participants did not form a strong enough attachment bond to the virtual spouse to elicit increased levels of appetitive responses during reunion. Alternatively, BAS sensitivity, as a domain-general index of motivation, may have weaker predictive power to behaviour in the attachment-related separation scenario, compared to domain-specific attachment constructs. In sum, BAS sensitivity had negligible prediction to responses in the separation scenario.

Also contrary to hypotheses, both FFFS and BIS sensitivities were not associated with either affective or behavioural responses to separation and reunion. Specifically, FFFS sensitivity was not related to increased distress during separation and BIS sensitivity was not predictive of both increased positivity and negativity upon reunion. Once again, as with attachment behaviour, the separation scenario may not have been sufficiently aversive to activate the FFFS, nor simultaneously appetitive and aversive enough to activate the BIS. Additionally, it is difficult to assess the manifestation of BIS sensitivity, as it involves behavioural and affective ambivalence. In the present study, BIS-mediated response was operationalised as increased spouse-directed positivity and negativity, but the unidirectional indices of physical distance, spouse-directedness, and affect did not allow for the assessment of ambivalent states. Finally, as with BAS sensitivity,

FFFS and BIS sensitivities may be too domain-general to have proximal predictive validity to behaviour in the attachment-related separation scenario.

Theoretical Implications

The results of the present study suggest that adult attachment and reinforcement sensitivity possess differential predictive validity to attachment behaviour. Although the constructs have been previously found to exhibit modest correlations at the self-report level (e.g., Carnelley & Story, 2008; Jiang & Tiliopoulos, 2014; Meyer et al., 2005; Mikulincer & Shaver, 2007), they do not have overlapping predictions to responses to the virtual separation scenario. As expected, the attachment dimensions predicted responses to separation from, and subsequent reunion to, the attachment figure – events which are known to critically activate the attachment system. In contrast, reinforcement sensitivity was largely irrelevant as predictors of behavioural and affective responses to the attachment-related separation scenario, except for a weak association between BAS sensitivity and proximity-seeking during separation. This suggests that the constructs of adult attachment and reinforcement sensitivity are not highly overlapping, with only the former having predictive validity to behaviour in the separation scenario.

The differential predictive validity of adult attachment and reinforcement sensitivity to attachment behaviour could be attributed to discrepancy in the domain-specificity of the constructs. Reinforcement sensitivity pertains to the sensitivities of global motivational systems, and, accordingly, may be less relevant and powerful proximal predictors to behaviour in an attachment-relevant scenario. In contrast, the domain-specific dimensions of attachment anxiety and attachment avoidance captures the degree to which a person worries about their attachment figures availability and preference for closeness respectively, which are directly pertinent to

responses to separation and reunion. Despite the difference in domain-specificity that may account for the differential predictive validity, this does not implicate that adult attachment and reinforcement sensitivity are unrelated. Rather, as proposed by Karantzas et al. (2010), the attachment system may be hierarchically nested within the more fundamental biologically-based motivational systems. Therefore, although reinforcement sensitivity may not have a direct prediction to attachment behaviour, how attachment patterns are linked to basic motivational tendencies is a question for further investigation.

Limitations and Future Directions

A number of caveats should be noted alongside the interpretation of results. Firstly, the use of a fictional separation scenario involving a virtual spouse may have reduced the ecological validity of the study. As mentioned, the virtual scenario may not have been sufficiently stressful to strongly activate the attachment and reinforcement sensitivity systems, and this may be because it was not a personal, real-life situation. Nonetheless, Schönbrodt and Asendorpf (2012) have demonstrated that participants do transfer their real-life attachment representations to the fictional characters, and it is argued that the VSE allows for both mundane realism and experimental control. Ideally, future studies should randomly allocate couples to brief separations, as well as examine responses to other (attachment-related and -unrelated) stressful situations that are known to activate the attachment and/or reinforcement sensitivity systems.

Secondly, this study relied upon self-report proxy measures of reinforcement sensitivity. There are few purpose-built self-report measures of r-RST, none of which have been well-validated. Furthermore, although the proxy measures used in the present study have demonstrated predictive validity to behavioural outcomes, it remains difficult to accurately

assess the sensitivities of the biologically-based motivational systems with introspective self-report measures (Smillie et al., 2006). As such, future studies should triangulate self-report measures with behavioural and/or neurophysiological indices of reinforcement sensitivity.

Finally, the study's sample consisted of undergraduate psychology students, which limit the generalisability of the findings. Previous studies of adult separation tended to use couples in long-term dating relationships (e.g., Diamond et al., 2008; Fraley & Shaver, 1998). Many participants in the current study have not formed long-term romantic attachment bonds, and so may find it more difficult to transfer attachment representations to the virtual spouse, as well as be less intensely affected by the separation scenario. Relatedly, the Simoland paradigm was limited to interactions with an opposite-sex virtual spouse, which does not allow the results to be generalised to non-heterosexual relationships. Future studies should recruit individuals in long-term relationships, as well as a more diverse sociodemographic sample.

Conclusion

This study aimed to further investigate the nature of the relations between individual differences in adult attachment and reinforcement sensitivity by comparing their predictions to behaviour in a critical, attachment-relevant separation scenario. The results attested to the predictive power of the attachment dimensions, such that attachment anxiety was associated with heightened distress overall and during separation, while attachment avoidance was related to more negative interactions overall and less emotional relief following reunion. In contrast, reinforcement sensitivity was generally unrelated to behavioural and affective responses to separation and reunion. Thus, it appears that adult attachment and reinforcement sensitivity do not share overlapping predictions to attachment behaviour, with the former being more

situationally relevant. However, further research is needed to determine whether individual differences in adult attachment are related on other ways to the more fundamental, biologically-based reinforcement sensitivity motivational systems.

Chapter 6: Study 3 – Adult Attachment, Reinforcement Sensitivity and Resting Electroencephalogram (EEG) Neural Correlates

Chapter Overview

This chapter provides an introduction to Study 3, which aimed to examine the links between individual differences in adult attachment and reinforcement sensitivity and neurophysiological correlates. Specifically, the study investigated the degree to which adult attachment and reinforcement sensitivity are associated with resting asymmetric frontal cortical activity as indices of approach and avoidance motivation, using electroencephalogram (EEG). The chapter will provide some general background to the study, reviewing the relevant EEG literature in relation to approach and avoidance motivation, RST and attachment. The primary focus of the literature review will be on frontal alpha asymmetry (FAA), which has been used as the prominent model of approach and avoidance motivation. The chapter will also overview alternative EEG correlates of approach and avoidance motivation, including left versus right parietal alpha asymmetry and parietal versus frontal theta and delta activity.

General Background

For decades, asymmetric brain cortical activity has been associated with different patterns of behaviour. The first observations were clinical cases of brain injury and hemispheric lesions, extending back to Goldstein (1939). Differences in right and left frontal brain activity have been linked to dramatic contrasts in personality, motivation and emotion. The most frequently observed cases attest to associations between left cortical injury (e.g., stroke lesions) and depressive symptoms, and, to a lesser extent, right cortical injury and manic symptoms (see

Robinson & Downhill, 1995, for a review). Even in these early studies, the hemispheric differences linked to affective styles were most apparent for frontal-lobe lesions (see Silberman & Weingartner, 1986, for a review). For example, a number of studies have observed that damage to the frontal region was more likely to be associated with depression (and more severe depressive symptomotology) than damage to any other cortical regions (Robinson & Downhill, 1995; Robinson, Kubos, Starr, Rao, & Price, 1984). These early studies were suggestive of an association between asymmetric brain cortical activity, especially in the frontal regions, and differential behaviour.

The large majority of evidence pertaining to hemispheric asymmetry comes from studies using electroencephalogram (EEG). EEG is a method pioneered by Hans Berger (1929) to measure brain cortical surface electrical activity. It captures the electrical signal that arrives at the surface of the scalp as a result of the cumulative electrical activity attributed to postsynaptic potentials generated within the brain at any given time point (for a review, see Harmon-Jones & Peterson, 2012). Postsynaptic potentials refer to the discrete voltage spike that occurs when neurotransmitters released from a pre-synaptic neuron cell bind to receptors on the postsynaptic neuron cell membrane (see Figure 6.1). EEG measures the electrical activity at the scalp, which is assumed to reflect the accumulated effects of synchronous postsynaptic potentials at any moment. Furthermore, this accumulated activity is largely contributed by post-synaptic potentials at the superficial layers of the cortex (also known as the cerebrum, which constitutes the largest part of the brain), as opposed to post-synaptic potentials from deeper regions within the cortex. Therefore, while EEG allows for accessible measurement of summative electrical activity at the scalp surface, critically, it possesses poor spatial resolution such that it does not allow researchers to reliably locate the source of the electrical activity in brain regions below the scalp

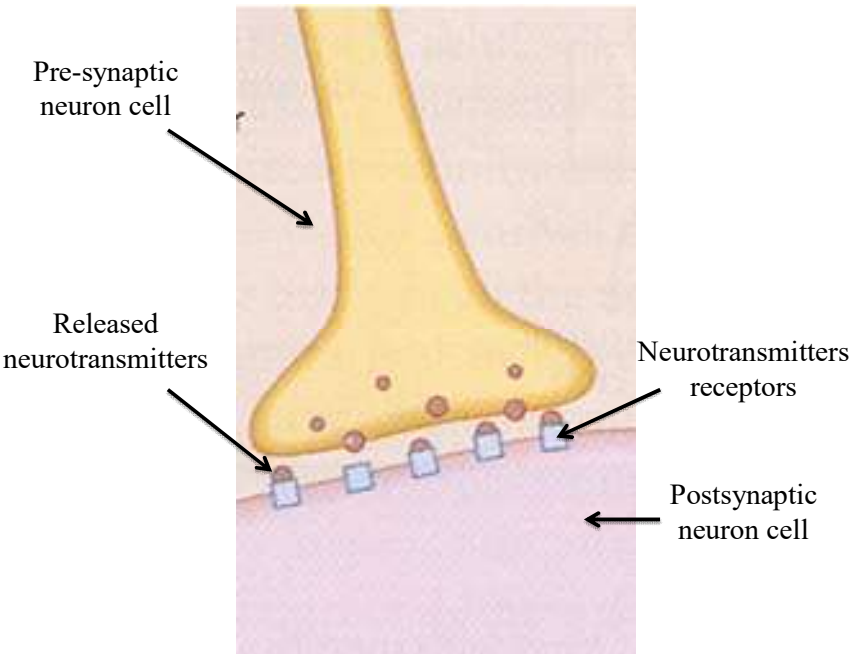

Figure 6.1. Illustration of the generation of a postsynaptic potential as neurotransmitters released from the pre-synaptic neuron cell are received by the postsynaptic neuron cell.

surface (Kondylis et al., 2014). While there are some source localisation methods such as LORETA, they are unable to avoid the 'inverse problem' of EEG, whereby the estimation of the source locations within the brain given the measure signals at only the scalp surface is 'under-determined' or 'ill-posed': that is, there is insufficient information to provide an unambiguous source localisation (Baillet, 2014). Despite this, EEG does possess excellent temporal resolution in that it is able to capture temporally precise scalp electrical activity.

There are up to 64 sites or channels across the surface of the scalp from which electrical signals can be measured (see Figure 6.2; Blom & Anneveldt, 1982). The acquired EEG recording can be viewed in either the temporal domain, which records electrical activity (composed of various frequencies) as a function of time, or the frequency wave domain, which summarises the

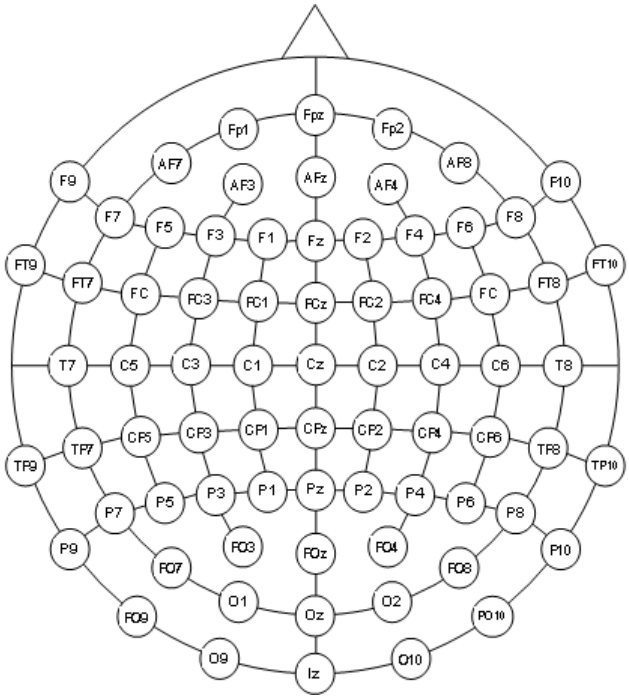

*Figure 6.2.*Topography of 64 EEG electrode sites as positioned according to the 10-20 system (American Electroencephalographic Society, 1994). Each site is denoted by one or two letters and a number, corresponding to the lobe and hemisphere location, respectively. Electrode sites on the left side of the head are labelled with odd numbers, while electrode sites on the right side of the head are labelled with even numbers. Electrode sites along the mid-line are denoted with a 'z' (e.g., Fz, Cz and Pz). The letters Fp, F, T, C, P and O stand for frontal polar, frontal, temporal, central, parietal and occipital lobes, respectively.

distribution of frequencies that are present in the data collapsed across time (Allen, Coan, & Nazarian, 2004). The latter, converted using power spectral analysis, allows the researcher to examine the power in the EEG signal at different frequency bands. Commonly, the extracted power bands are: delta (0-4 Hz), theta (4-7 Hz), alpha (8-12.75 Hz), and beta (13-30 Hz). Power in the alpha band (or 'alpha power') has been shown to be inversely related to cortical activity

using hemodynamic measures (Cook, O'Hara, Uijtdehaage, Mandelkern, & Leuchter, 1998; Oakes et al., 2004) and behavioural tasks (Davidson, Chapman, Chapman, & Henriques, 1990). In analyses, alpha power is usually log-transformed to normalise distributions. Of particular interest, frontal alpha asymmetry (FAA) is an index derived from subtracting the natural log alpha power at the left frontal site(s) (i.e., F3, F5, or F7) from the natural log alpha power at the homologous right frontal site(s) (i.e., F4, F6, or F8) (See Figure 6.1). As alpha power is inversely related to cortical activity, this provides a measure of asymmetric frontal hemispheric activity, with higher FAA scores indicating relative greater left frontal activity (LFA) and lower FAA scores indicating relative greater right frontal activity (RFA). FAA can be utilised as a state measure as a response to an event, or as a trait measure, which is usually operationalised as FAA extracted from a resting EEG recording.

State FAA and Affective Style

In a series of early studies, Richard Davidson and Nathan Fox measured state FAA in infants during exposure to various emotional stimuli. They observed that infants showed greater relative LFA when watching happy film clips (Davidson & Fox, 1982), given sugar water (Fox & Davidson, 1986), and exhibiting Duchenne smiles (authentic smiles that involve movement of the orbicularis oculi muscle around the eye region as well as the mouth; Fox & Davidson, 1988). In contrast, greater relative RFA was observed when infants exhibit expressions of disgust when given water (Fox & Davidson, 1986), smiles without orbicularis oculi activity (Fox & Davidson,

1988), crying when sad or angry (Fox & Davidson, 1988). These associations were generally restricted to frontal cortical regions, and not related to parietal asymmetry.[9]

Similar patterns of FAA in relation to emotional stimuli have been observed in healthy adult populations (see Davidson, 1984; Davidson, 1987; and Harmon-Jones, 2004 for reviews). For example, greater relative LFA have been observed during self-reported experience of positive affect while watching film clips (Davidson, Schwartz, Saron, Bennett, & Goleman, 1979), recall of happy memories (Karlin, Weinapple, Rochford, & Goldstein, 1979), Duchenne smiles expressed in response to enjoyment of pleasant films (Ekman, Davidson, & Friesen, 1990), and facial expressions of happiness while watching film clips of animals at play (Davidson et al., 1990a). Conversely, greater relative RFA have been observed during the recall of sad memories (Karlin et al., 1978), induction of depressed mood (Tucker et al., 1981), expressions of fear when viewing negative film clips (Tomarken, Davidson, & Henriques, 1990), and expressions of disgust when watching film clips of medical procedures (Davidson et al., 1990b). Together, the evidence suggests that positive and negative emotional stimuli tends to be related to greater relative LFA and RFA respectively, and once again, generally unrelated to parietal asymmetry.[10]

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[9] Early studies tended to compare asymmetry cortical activities only in the frontal and parietal regions.

[10] There is some evidence to suggest that parietal asymmetry is associated with specific forms of psychopathology. For example, right parietal hypoactivity has been associated with depression (see Stewart, Towers, Coan, & Allen, 2011, for a review) and right parietal hyperactivity has been associated with anxious arousal (Heller, 1990, 1993). This latter association will considered in further detail later on in the chapter, as it may indirectly inform upon the nature of the relations between BIS/FFFS sensitivities and asymmetric cortical activity. However, the focus of this thesis will be on alpha asymmetry in the frontal region, and references to alpha asymmetry in the parietal region will only be made for comparison rather than comprehensive examination.

Trait FAA and Affective Style

Resting frontal alpha asymmetry has been employed as an index of trait levels of frontal cortical asymmetric activation, and demonstrates some stability across time. Across four different measurement occasions, Hagemann and his colleagues determined that roughly 60% of the variance in asymmetry scores was attributable to individual differences in a stable latent trait, while 40% was attributable to situation-specific fluctuations (Hagemann, Naumann, Thayer, & Bartussek, 2002). The situation-specific fluctuations could be attributed to a range of factors, including whether participants were instructed to keep their eyes open or closed, time of day, time of year, state emotions and motivations (Hagemann et al., 2002; Harmon-Jones, Gable, & Peterson, 2010). While these situation-specific fluctuations has led some researchers to question whether resting FAA reflect a trait, a substantial proportion of resting FAA can be attributed to a stable latent trait. Moreover, there is some evidence of temporal stability for resting FAA. Tomarken, Davidson, Wheeler and Kinney (1992) found that frontal alpha asymmetry had acceptable test-retest reliability with intra-class correlations ranging from .44 to .71 over a three week period. Jones, Field, Davalos and Pickens (1997) found that the same measure of frontal asymmetry recorded at age 3 months was highly and significantly correlated ($r = .66$, $p < .01$, $N = 15$) with scores at age 3 years. Together, the evidence suggests that there are stable individual differences in resting FAA, although there is some degree of state fluctuation.

At the trait level, resting FAA has been related to individual differences in affective style (see Coan & Allen, 2003, for a review). For example, depressed individuals, as assessed by self-report measures such as the Beck Depression Inventory or diagnosed via clinical interviews, have been found to show reduced relative LFA, while non-depressed individuals show slightly greater relative LFA (Allen, Iacono, Depue, & Arbisi, 1993; Jacobs & Snyder, 1996; Henriques

& Davidson, 1990; Schaffer, Davidson, & Saron, 1983). Furthermore, in a number of studies, resting alpha asymmetry has also been related to trait positive and negative affect, which are regarded as orthogonal dimensions (Watson & Tellegen, 1985). In a sample of 90 undergraduate women, Tomarken, Davidson, Wheeler and Doss (1992) found that higher ratings of generalised experiences of positive affect on the PANAS was linked to extreme and stable relative LFA as measured over a three week period. Whilst lower levels of negative affect was also observed for individuals with greater relative dispositional LFA, this was not significant in follow-up analyses. This suggests that greater relative LFA has a more robust, positive association with positive affect, than an inverse association with negative affect.

Resting EEG has also been shown to predict reactivity to emotional stimuli. For example, greater relative resting RFA has been linked to increased self-reported negative affect in response to film clips (Tomarken, Davidson, & Henriques, 1990; Wheeler, Davidson, & Tomarken, 1993). Conversely, greater relative resting LFA has been shown to relate to increased self-reported positive affective response to film clips (Wheeler et al., 1993). In 10-month old infants, greater relative resting RFA predicts crying and greater distress in response to maternal separation (Davidson & Fox, 1989). Generally, across these studies, posterior asymmetry is not significantly related to individual differences in affective reactivity.

Emotional Valence versus Approach-Withdrawal Models of FAA

The results of these early state and trait EEG studies of FAA were interpreted in terms of emotional valence, which refers to the positivity or negativity of the experienced emotion (Davidson, 1984; Davidson & Tomarken, 1989). Across various populations and methodologies, relative RFA was observed to be linked to negative affect, while relatively greater LFA was

observed to be linked to positive affect. Thus, it was hypothesised that certain regions of the left hemisphere were responsible for the processing of positive affective stimuli, while corresponding regions of the right hemisphere were responsible for the processing of negative affective stimuli (Davidson & Fox, 1982).

However, Davidson (1984, 1992, 1993, 1995) later proposed a model of lateralisation of emotion and motivation, such that FAA is lateralised along a continuum of approach-withdrawal motivation, rather than positive-negative emotional valence. He argued that emotional valence may have been confounded with motivational direction in early studies, since most positive affective states such as excitement and happiness are approach-oriented, while most negative affect such as fear and sadness are associated with withdrawal. Therefore, relative LFA and RFA potentially correspond to approach and avoidance motivation respectively.

In view of this ambiguity, Harmon-Jones and colleagues attempted to untangle emotional valence from motivational direction in relation to FAA by conducting a series of studies on anger. While anger is regarded as an emotion with a negative valence, it also tends to elicit approach tendencies such as aggression, confrontation, or other engagement behaviour with the anger-provoking situation (Harmon-Jones, 2004). If the emotional valence model holds true, then anger, as a negatively valenced emotion, would be associated with greater relative RFA. Conversely, if the approach-withdrawal motivational direction model holds true, then anger, being approach-oriented, would be associated with greater relative LFA. Thus, anger provides a test of dissociation between emotional valence and motivational direction (Harmon-Jones, 2004).

Harmon-Jones and colleagues managed to show that both trait and state anger are consistently related to greater relative LFA (see Harmon-Jones, 2004; Harmon-Jones, Gable, & Peterson, 2010, for reviews). In a sample of 26 adolescents, higher levels of self-reported

dispositional anger were associated with greater relative LFA (Harmon-Jones & Allen, 1998). This association was replicated by Harmon-Jones (2004), who additionally showed that the relationship between greater relative LFA and anger was not due to a positive attitude towards feeling angry. In another study of 42 male undergraduates, participants who were given negative feedback on an essay they had written reported more state anger, as well as showed greater relative LFA after the anger-provoking event, while controlling for resting FAA (Harmon-Jones & Sigelman, 2001). Furthermore, these same participants manifested more aggressive behaviour by selecting more unpleasant beverages (e.g., hot sauce) for the person who ostensibly insulted them. These results appear to support the idea that FAA indexes motivational direction rather than emotional valence, as anger, an approach-oriented emotion, appears to be related to greater relative LFA despite having a negative valence.

Building upon these results, Harmon-Jones, Sigelman, Bohlig and Harmon-Jones (2003) more focally tested the idea that anger is associated with increased LFA to the degree that the emotion arouses approach motivation. In their study, 71 undergraduates listened to an editorial that argued for a tuition increase. They were assigned to either an action-possible condition, in which they were given the opportunity to sign a petition, or an action-impossible condition, in which they were told that the tuition increase would definitely occur. While across both conditions participants showed higher levels of anger, only those in the action-possible condition exhibited greater relative LFA. The data suggest that it is not anger per se that is associated with greater relative LFA, but rather, it is the degree to which the anger-provoking situation allows for approach behaviour to deal with the situation. In the case where the anger-provoking situation does not allow for approach behaviour, greater relative LFA was not observed. In another study, Harmon-Jones, Vaughn-Scott, Mohr, Sigelman and Harmon-Jones (2004) found that when

individuals were induced to feel sympathy towards a person who insulted them, the association between anger and greater relative LFA was no longer significant. Sympathy appeared to reduce approach inclinations that arise from the anger-provoking insult situation, resulting in lower levels of relative LFA. The emotional experience of anger alone, without the component of approach motivation, was not related to greater relative LFA. Thus, these studies provide further support for the motivational model whereby FAA is linked to the motivational aspect of an experienced emotion in so far as the emotion elicits approach or withdrawal motivation. The emotion alone is insufficient to elicit FAA.

Additionally, Harmon-Jones and colleagues have shown that the affective state of cognitive dissonance – which is when an individual holds two relatively important and inconsistent cognitions – is related to relatively greater LFA (see Harmon-Jones, 2004, for a review; Harmon-Jones, 2000). This state imbues a negative emotional valence and prompts approach motivational tendencies, as the individual tries to engage with the situation (for example, information gathering) in order to reduce feelings of inconsistency and negative affect, and to reach a resolution. In one study, university students who were opposed to a tuition increase were either instructed to write an essay in support of the tuition increase (low-choice condition) or told they had a choice to write such an essay but were subtly encouraged to do so (high-choice condition) (Harmon-Jones, 2004). Participants in the high-choice condition, who would experience higher levels of cognitive dissonance, exhibited greater relative LFA than participants in the low choice condition. Harmon-Jones (2004) speculated that the experience of dissonance may initially activate the anterior cingulate cortex, which monitors the presence of response conflict, and, in turn, activate the left frontal cortex to engage the approach motivational system in order to reduce the dissonance. Therefore, the study serves to provide

further evidence that greater relative LFA is linked to an emotional state to the degree that the emotion elicits approach motivation, rather than the valence of the emotion itself.

Together, the evidence strongly suggests that FAA is related to motivational direction and not emotional valence. Harmon-Jones and colleagues demonstrated that anger and cognitive dissonance, as examples of emotions with a negative valence and simultaneously eliciting approach motivation, are related to greater relative LFA (as per the motivational direction model) rather than greater relative RFA (as per the emotional valence model) (Harmon-Jones, 2004; Harmon-Jones et al., 2010). That is, greater relative LFA indexes approach motivation, regardless of the valence of the emotion. Furthermore, greater relative LFA is observed only to the extent that the emotion elicits approach motivation; in the absence of approach behaviour or inclinations, greater relative LFA is not observed. However, further research is needed to examine emotions other than anger and cognitive dissonance, and in particular, provide evidence that greater relative RFA is linked to withdrawal motivation. Nonetheless, as Harmon-Jones (2004) concludes, the valence model of FAA is no longer viable.

Reinforcement Sensitivity and Resting EEG Correlates

Reinforcement Sensitivity and FAA

Given that the literature strongly suggests that greater relative LFA indexes approach, BAS sensitivity, to the degree that it overlaps with the construct of approach, should also be related to greater relative LFA. The literature also suggests that relative RFA indexes avoidance, although the implication of this link for r-RST is less straightforward. Within the framework of the classical RST, the BIS has been mapped onto the construct of avoidance and hypothesised to be related to greater relative RFA (e.g., Sutton & Davidson, 1997). However, the r-RST critically

distinguishes between the BIS and the FFFS on the dimension of defensive direction, such that the BIS and the FFFS leads to approach and avoidance of (potential) threat, respectively. This complicates the expected relations between BIS/FFFS and FAA. In this section, I will review the existing research pertaining to the association between reinforcement sensitivity and FAA.

A literature search was conducted on PsycINFO, ScienceDirect and Web of Science databases in April 2015 for any articles with title or abstract keywords (1) "reinforcement sensitivity" or "BAS" or "FFFS" or "BIS", and (2) "alpha asymmetry" or "frontal asymmetry." This initially yielded 127 references. Subsequently, the title and abstracts (and article, where the title and abstract were unclear) of these references was screened for the following inclusion criteria: firstly, the study measured resting frontal alpha asymmetry, and secondly, the study included a questionnaire measure of trait reinforcement sensitivity (BAS, BIS or FFFS) operationalised in accordance with either the classical or revised RST. Studies that did not include a genuine resting condition, examined absolute power using frequency band analysis rather than asymmetry scores, did not report direct associations between FAA and RST constructs, or examined related personality traits such as extraversion were excluded. This yielded 13 relevant papers. By examining the reference lists of these papers, five additional studies were found, resulting in a final total of 18 papers. Of this total, 17 papers reported associations between FAA and BAS, which are summarised in Table 6.1, while 16 reported associations between FAA and BIS (as operationalised in accordance with the classical RST), which are summarised in Table 6.2. No studies examined resting FAA and FFFS, nor BIS as defined explicitly in terms of Gray and McNaughton's (2000) revised theory.

Table 6.1

A Summary of Findings on Resting Frontal Alpha Asymmetry and Trait BAS Sensitivity

	Reference	Year	Sample	Ref.	EEG sample	Electrode sites	RST measure	Key finding
1.	Harmon-Jones & Allen	1997	36 F (prescreened for high or low social anxiety)	Cz	4 OC	F3, F4	CW-BAS	r = .38
2.	Sutton & Davidson	1997	46 undergrads (23 F)	LE	2 x 8 OC	F3, F4	CW-BAS BAS-BIS difference score	BAS: r = .40 BAS-BIS: r = .53
3.	Coan & Allen	2003	32 psych undergrads	Cz, Av & LM	8 OC	F3, F4, F7, F8	CW-BAS	r = .30 to .49, over frontal, midfrontal, lateral-frontal, and frontal-temporal-central regions; for LM & average ref, but not Cz.
4.	Diego, Field, & Hernandez-Reif	2001	57 depressed mothers	Cz	3 OC	F3, F4	CW-BAS BAS-BIS difference score	BAS: r = .33 Depressed mothers with withdrawn (cf. Intrusive) style has higher BIS scores & RFA
5.	Hewig, Hagemann, Seifert, Naumann, & Bartussek	2004	59 university students (30 F)	CSD, AE	3 x 8 OC (5 weeks apart)	F3, F4, F5, F6, F7, F8	CW-BAS	n.s. for most sites Ft8-Ft7: r = .25 Bilateral activation

Table 6.1 (Continued)

	Reference	Year	Sample	Ref.	EEG sample	Electrode sites	RST measure	Key finding
6.	Hewig, Hagemann, Seifert, Naumann, & Bartussek	2006	59 university students (30 F)	CSD, AE	4 x 12 OC (separated by 4 weeks)	F3, F4, F7, F8	CW-BAS (also aggregated across the 4 occasions)	*r* = .25 (CSD, F7-F8) n.s. (linked earlobes or F3-F4) Greater bilateral frontal activity
7.	McFarland, Shankman, Tenke, Bruder, & Klein	2006	67 major depression patients (44 F)	LE, Av	6 OC	F3, F4	CW-BAS	BAS-RR: *r* = .30 BAS-FS: *r* = .27 & .28 both for P4-P3
8.	Amodio, Master, Yee, & Taylor	2008	48 undergrads or recent graduates (32 F)	AE	8 OC	F3, F4	CW-BAS	*r* = .36
9.	Hayden, Bodkins, Brenner, Shekhar, Nurnberger, O'Donnell et al.	2008	27 BPD patients (36 F) 44 controls (29 F)	Av	8 OC	F3, F4	CW-BAS	BPS: *r* = .11 (n.s.) Controls: *r* = -.31 (n.s.)

Table 6.1 (Continued)

	Reference	Year	Sample	Ref.	EEG sample	Electrode sites	RST measure	Key finding
10.	Shackman, McMenamin, Maxwell, Greischar, & Davidson	2009	51 women	Av	4 or 8 OC	F3, F4, F7, F8	CW-BAS	F4-F3: *r* = -.09 (n.s.)
11.	De Pascalis, Varriale, & D'Antuono	2010	50 women	AE	5 O	F3, F4	CW-BAS	BAS-D: *r* = .32 BAS-RR: *r* = .30
12.	Wacker, Chavanon, & Stemmler, Study 3	2010	112 healthy males, selected on high/low ARES-BAS/BIS	LM	7.5 C (1-3 sessions)	F3, F4	ARES-BAS	*r* = .13 (n.s.)
13.	Wacker, Chavanon, & Stemmler, Study 4	2010	35 students	LM	7.5 C	F3, F4	CW-BAS	*r* = -.08 (n.s.)
14.	Wacker, Chavanon, & Stemmler, Study 5	2010	125 males	LM	8 O	F3, F4	CW-BAS	*r* = .04 (n.s.)
15.	Keune, Bostanov, Kotchoubey, & Hautzinger	2012	35 university students (24 F)	LM	8 OC	F3, F4, F7, F8	CW-BAS	F3/F4: n.s. F7/F8: n.s. Some sig. correlations in frontopolar, temporal and central regions for BAS subscales

Table 6.1 (Continued)

	Reference	Year	Sample	Ref.	EEG sample	Electrode sites	RST measure	Key finding
16.	Wacker, Mueller, Pizzagalli, Hennig, & Stemmler	2013	181 male university students	Av	8 OC	F3, F4	CW-BAS	r = .27
17.	De Pascalis, Cozzuto, Caprara, & Alessandri	2013	51 healthy female students	LE	8 OC	F3, F4, F7, F8	CW-BAS	r =.44
18.	Horan, Wynn, Mathis, Miller, & Green	2014	25 schizophrenics & 25 healthy controls	LM	8 OC	F3, F4	CW-BAS	n.s. for either groups
19.	Quaedflieg, Meyer, Smulders, & Smeets	2015	70 undergrads (40 F)	A1 & A2 average	8 O	F3, F4, F7, F8	CW-BAS	F8-F7: r = .35 (BAS-D) All other n.s.

Note. F = females; Cz = Central midline; LE = Linked earlobes; Av = Average head; LM = Linked mastoids; CSD = Current Source Density; O = Eyes open; C = Eyes closed; OC = counterbalanced eyes open and eyes closed; CW-BAS = Carver and White's (1994) BAS scales; n.s. = not statistically significant; ARES-BAS = the BAS scale from the Action Regulating Emotion Systems (ARES) questionnaire (Hartig & Moosbrugger, 2003); BAS-D = BAS Drive; BAS-RR = BAS Reward Responsiveness; BAS-FS = BAS Fun Seeking.

A perusal of Table 6.1 suggests a consistent and moderate association between higher levels of trait BAS and relative greater LFA. Positive correlations between the measures were found in the majority of studies, ranging from r = .13 to .53 and averaging around .30's. This association was found across diverse samples (including from both normal and clinical populations, as well as among males and females) and variations in the EEG methodology including reference montages.[11] Furthermore, in accord with the FAA literature, the association was restricted to EEG channels in the frontal regions (i.e., frontal, mid-frontal and lateral-frontal), although it was most often examined and found for the frontal (F3/F4) sites, followed by the lateral-frontal (F7/F8) sites.

However, there is a lack of consensus on whether the greater relative LFA is due to greater absolute levels of cortical activity in the left and/or right frontal brain regions. Comparing the levels of absolute alpha power in the left and right hemispheres, the relatively greater LFA was attributed to bilateral frontal activation in three studies [1, 5, 6], greater left frontal activity in one study [4], and less right frontal activity in another study [3]. These diverging conclusions may reflect the difficulty of inferring the absolute levels of cortical activity from FAA difference scores (Coan & Allen, 2003). While the asymmetry score necessarily takes into account individual differences in skull thickness – which is a major confounding influence on alpha power – the critical disadvantage is the inability to determine whether the relative difference is

[11] Since the EEG records the voltage signal, which represents a difference between the voltages at two electrodes, a reference site or montage (calculated from a few sites) is required to record the voltage difference between that site and the site of interest. Reference montages may include the central midline (site Cz; see Figure 6.2), average earlobes (the averaged signal from the electrodes on the two earlobes), linked mastoid (the averaged signal from the electrodes placed on the mastoids behind the ears), single mastoid (using signal from either the left or right mastoid), nose reference (signal from an electrode placed on the tip of the nose), average head (the averaged signal from all recording sites on the head), and Current Source Density (CSD; the weighted average signal of neighbouring electrodes surrounding the site of interest). It is not unusual for studies to obtain different results across different reference montages.

due to greater or less cortical activity in one specific hemisphere, or the combined effects of both hemispheres. Therefore, the studies in Table 6.1 points to an association between BAS sensitivity and greater relative LFA, but do not allow for conclusions regarding absolute levels of cortical activity in the frontal regions.

Furthermore, while all studies (with one exception – [12]) used Carver and White's (1994) BAS scales, only two studies [7 and 11] reported resting FAA links with each of the three separate BAS scales, as opposed to an overall score. These two studies found evidence for greater relative LFA in association with BAS Reward Responsiveness, while one of the studies [11] found a further association with BAS Drive. In sum, the studies in Table 6.1 suggest a robust convergence between BAS, the construct of approach, and relative greater LFA. This was found using different EEG reference schemes, for different frontal regions, and across measurement occasions, although there is some variability in results. Further research is needed that utilise measures of BAS other than the CW-BAS scales (especially ones that are based on Gray and McNaughton's (2000) theoretical revisions), as well as examine associations with different facets of BAS.

A number of studies have also examined the association between resting FAA and Gray's original conceptualisation of the BIS, and their findings are summarised in Table 6.2. As can be seen in the table, the association between o-BIS and resting FAA is less consistent than that between BAS and resting FAA. On one hand, four studies [2, 3, 10, and 18] have found that o-BIS, as measured by CW-BIS scale, is negatively and moderately correlated with resting FAA scores, suggestive of relatively greater RFA. One of these studies [3] attributed the relatively greater RFA to left frontal hypoactivation. On the other hand, in two other studies [4 and 6], o-BIS exhibited a positive correlation with resting FAA, suggestive of relatively greater LFA.

Table 6.2

A Summary of Findings on Resting Frontal Alpha Asymmetry and Trait o-BIS Sensitivity

	Reference	Year	Sample	Reference scheme	FAA measure	Electrode sites	RST measure	Key finding
1.	Harmon-Jones & Allen	1997	36 F (prescreened for high or low social anxiety)	Cz	4 EO	F3, F4	CW-BIS	n.s.
2.	Sutton & Davidson	1997	46 undergrads (23 F)	AE	2 x 8 EO (6 weeks apart)	F3, F4	CW-BIS BAS-BIS difference score	r = -.41
3.	Diego, Field, & Hernandez-Reif	2001	57 depressed mothers	Cz	3 OC	F3, F4	CW-BIS	BIS: r = -.27
4.	Hewig, Hagemann, Seifert, Naumann, & Bartussek	2004	59 university students (30 F)	CSD, AE	3 x 8 OC (5 weeks apart)	F3, F4, F5, F6, F7, F8	CW-BIS	F2-F1: r = .43 (CSD) & .34 (AE) F6-F5: r = .23 (AE) (n.s. for all other associations)

Table 6.2 (Continued)

	Reference	Year	Sample	Reference scheme	FAA measure	Electrode sites	RST measure	Key finding
5.	Hewig, Hagemann, Seifert, Naumann, & Bartussek	2006	59 university students (30 F)	CSD, AE	4 x 12 OC	F3, F4, F7, F8	4 x CW-BIS (aggregated score)	n.s.
6.	McFarland, Shankman, Tenke, Bruder, & Klein	2006	67 major depression patients (44 F)	AE, Av	6 OC	F4, F3	CW-BIS	r = .29
7.	Amodio, Master, Yee, & Taylor	2008	48 undergrads or recent graduates (32 F)	AE	8 OC	F3, F4	CW-BIS	r = -.11 (n.s.)
8.	Hayden, Bodkins, Brenner, Shekhar, Nurnberger, O'Donnell et al.	2008	27 BPD patients (36 F) 44 controls (29 F)	Av	8 OC	F3, F4	CW-BIS	Controls: r = .02 (n.s.) BPD: r = .-.09 (n.s.)
9.	Wacker, Chavanon, Leue, & Stemmler	2008	106 paid, male university students, selected on high or low BIS	Cz	10 C	F3, F4	ARES-BIS	n.s.
10.	Shackman, McMenamin, Maxwell, Greischar, & Davidson	2009	51 women	Av	4 or 8 OC	F3, F4, F7, F8	CW-BIS	F4-F3: r = -.47

Table 6.2 (Continued)

	Reference	Year	Sample	Reference scheme	FAA measure	Electrode sites	RST measure	Key finding
11.	De Pascalis, Varriale, & D'Antuono	2010	50 women	AE	5 O	F4, F3	CW-BIS	n.s.
12.	Wacker, Chavanon, & Stemmler, Study 3	2010	112 healthy males, selected on high/low ARES-BAS/BIS	LM	7.5 C	F3, F4	ARES-BIS	*r* = -.004 (n.s.)
13.	Wacker, Chavanon, & Stemmler, Study 4	2010	35 students	LM	7.5 C	F3, F4	CW-BIS	*r* = .07 (n.s.)
14.	Wacker, Chavanon, & Stemmler, Study 5	2010	125 males	LM	8 O	F3, F4	CW-BIS	*r* = .08 (n.s.)
15.	Keune, Bostanov, Kotchoubey, & Hautzinger	2012	35 university students (24 F)	LM	8 OC	F3, F4, F7, F8	CW-BIS	n.s. Sign. r for C3/C4
16.	De Pascalis, Cozzuto, Caprara, & Alessandri	2013	51 healthy female students	AE	8 OC	F3, F4, F7, F8	CW-BIS	n.s.
17.	Horan, Wynn, Mathis, Miller, & Green	2014	25 schizophrenics & 25 healthy controls	LM	8 OC	F3, F4	CW-BIS	n.s. for either groups

Table 6.2 (Continued)

	Reference	Year	Sample	Reference scheme	FAA measure	Electrode sites	RST measure	Key finding
18.	Quaedflieg, Meyer, Smulders, & Smeets	2015	70 undergrads (40 F)	A1 & A2 average	8 O	F3, F4, F7, F8	CW-BIS	F8-F7: r = -.33

Note. F = females; Cz = Central midline; LE = Linked earlobes; Av = Average head; LM = Linked mastoids; CSD = Current Source Density; O = Eyes open; C = Eyes closed; OC = counterbalanced eyes open and eyes closed; CW-BIS = Carver and White's (1994) BIS scales; n.s. = not statistically significant; ARES-BIS = the BAS scale from the Action Regulating Emotion Systems (ARES) questionnaire (Hartig & Moosbrugger, 2003).

Moreover, a larger number of studies (12 out of the 16 studies listed in Table 6.2) found no significant association between o-BIS and resting FAA. Therefore, it appears that across the diverse samples, different EEG reference schemes, frontal channels and varying number of measurement occasions, there is unclear association between o-BIS and resting FAA.

Given the absent (or mixed) associations, it has been speculated that o-BIS may not fit neatly within the approach/withdrawal model (Coan & Allen, 2003; Harmon-Jones & Allen, 1997). This, in part, could be due to the heterogeneity of the o-BIS construct, which is described as involving the interruption of ongoing behaviour, increased arousal and increased attention, and not simply avoidance behaviour (Gray, 1994). Furthermore, Gray and McNaughton's (2000) r-RST conceptualised the revised BIS as being responsible for conflict resolution and mediates cautious approach. Heym et al. (2008) showed that Carver and White's (1994) BIS scale contains items that measure both BIS (involving cautious approach) and FFFS (involving avoidance) as conceptualised by the r-RST. Therefore, it is not surprising that such measures of BIS sensitivity based on the original RST conceptualisation exhibits inconsistent associations with resting FAA, with some studies reporting negative associations [e.g., 2, 3, 10, and 18], others reporting positive associations [e.g., 4 and 6], and still others reporting non-significant associations [e.g., 1, 5, 9, 11, 15, 16, and 17]. The review of the literature found no studies that have examined resting FAA and explicit measures of Gray and McNaughton's (2000) revised conceptualisations of BIS and FFFS sensitivities.

Regardless of these research limitations, within the approach-withdrawal model of FAA, it might be expected the BIS-mediated cautious approach is associated with greater relative LFA, while FFFS-mediated avoidance is associated with greater relative RFA. However, the evidence to date suggests that the link between greater relative RFA and avoidance-related constructs is not as strong and clear-cut as that between greater relative LFA and approach-related constructs. Thus, the approach-withdrawal model of FAA may not

easily account for relations between FAA and BIS and FFFS. The following section describes alternative models that have been proposed in regards to the nature of the relations between reinforcement sensitivity and resting EEG correlates.

BIS-BAS Model of Anterior Asymmetry (BBMAA)

Wacker, Heldmann and Stemmler (2003) proposed a BIS-BAS model of anterior asymmetry (BBMAA), whereby goal-directed BAS or FFFS behavioural activation, irrespective of motivational direction, was hypothesised to be related to relatively greater LFA. Conversely, BIS induced goal-conflict behaviour was proposed to be related to relatively greater RFA. Furthermore, it has been argued that most human experiences are characterised by either BAS-approach or BIS-conflict, with few instances of FFFS mediated pure avoidance (Corr, DeYoung, & McNaughton, 2013; Wacker et al., 2003). Thus, Wacker et al. (2003) proposed that most of the data pertaining to relatively greater LFA and RFA might map onto the distinction between BAS-approach and BIS-conflict respectively. Wacker et al. (2003) found partial support for their model, whereby an anger-provoking soccer game scenario that allowed for either approach (BAS) or withdrawal (FFFS) was associated with relatively greater LFA. Furthermore, Wacker et al. (2008) found that when participants were asked to imagine a scenario that involved BIS-mediated conflicting approach-avoidance motivation, this was associated with relatively greater state RFA. However, neither imagining an FFFS scenario nor self-reported trait FFFS or BIS sensitivity were associated with resting or induced FAA (Wacker et al., 2008). Moreover, as previously noted in regards to the studies summarised in Table 6.2, only a minority attest to a link between BIS and relatively greater RFA, although the former construct was not explicitly conceptualised in terms of motivational conflict. Overall, there appears to be insufficient evidence in support for the BBMAA.

Anxious Arousal versus Anxious Apprehension

Wendy Heller proposed another model that may be indirectly relevant to the nature of the relations between FAA and FFFS and BIS sensitivities. To account for the inconsistent associations between FAA and trait/state anxiety, Heller and her colleagues argued for the need to distinguish between *anxious apprehension* and *anxious arousal* as subtypes of anxiety (Heller, Etienne, & Miller, 1995; Heller, Nitschke, Etienne, & Miller, 1997). It is purported that anxious apprehension is characterised by worry, verbal rumination and generalised anxiety states and is usually captured by self-reported measures of trait anxiety; while anxious arousal involves panic, physiological hyperarousal and somatic tension that tends to manifest in high-stress situations (Heller et al., 1995). Conceptual similarity may be drawn between these subtypes of anxiety and Gray and McNaughton's (2000) BIS and FFFS. Anxious apprehension and BIS are similarly characterised by hypervigilance, risk-assessment and worry, and often operationalised as trait anxiety; while both anxious arousal and FFFS involve autonomic response and manifest as panic.

In their review of the hemispheric asymmetry literature on anxiety, Heller et al. (1997) observed that studies which tend to report greater right-hemisphere activity tend to involve panic disorders or high-stress situations evoking anxious arousal. In contrast, studies reporting greater left-hemisphere activity were more likely to involve disorders such as Obsessive Compulsive Disorder (OCD) or General Anxiety Disorder (GAD), along with self-reported trait anxiety, which are characterised by pervasive and free-floating anxious apprehension and worry. Studies in which bilateral hemispheric activation have been observed were attributed by Heller et al. (1997) to the co-occurrence of both subtypes of anxiety. Therefore, it was postulated that anxious apprehension involves greater left-hemisphere activity while anxious arousal involves greater right-hemisphere activity (Heller et al., 1997). More specifically, Heller (1990, 1993) articulated that physiological

hyperarousal and autonomic reactivity may be associated with more right parietotemporal region activation, while the language involvement and approach component of anxious apprehension may have more specialised involvement of the activation of left frontal regions. To the extent that anxious arousal and anxious apprehension correspond with FFFS and BIS activations respectively, Heller's proposed links contrasts with Wacker et al.'s (2003) BBMAA. Instead, according to Wacker et al. (2003), FFFS-mediated anxious arousal should be linked to greater relative LFA, while BIS-mediated anxious apprehension should be linked to greater relative RFA. However, as previously reviewed, there is limited evidence to support Wacker et al.'s (2003) BBMAA.

There is substantial evidence for Heller et al.'s (1995, 1997) proposal that anxious arousal is related to right hemispheric activity (see Heller & Nitschke, 1998, for a review). More particularly, greater relative right hemispheric activity as measured by EEG has been linked to anxious arousal states in various populations including spider phobic patients (Merckelbach, Muris, Pool, & De Jong, 1998); panic disorder patients (Wiedemann et al., 1999); psychology undergraduates (Nitschke, Heller, Palmieri, & Miller, 1999) and general community members (Mathersul, Williams, Hopkinson, & Kemp, 2008); as well as PTSD arousal symptoms among Vietnam War nurse veterans (Metzger et al., 2004). In Merckelbach et al.'s (1998) and Mathersul et al.'s (2008) studies, the greater right hemispheric activity was specific to the parietal regions. Similarly, Heller et al. (1997) found that the high trait anxiety person showed increased relative right parietal activation while listening to fearful and sad narratives designed to increase state anxious arousal. These results are in line with Heller's (1990, 1993) proposal that anxious arousal is related to greater relative right hemispheric activity, particularly in the parietotemporal regions. However, parietal asymmetry was not observed in all cases. For example, Wiedemann et al. (1999) and Mathersul et al. (2008) found greater relative right activation in the frontal regions. While not

contrary to Heller's arousal-valence model, this is more aligned with Davidson's approach-withdrawal model of FAA that proposes the involvement of right frontal cortical areas in association with FFFS-mediated avoidance behaviour.

The evidence for Heller's proposed link between anxious apprehension and left hemispheric activity is more limited. In support of this link, Heller et al. (1997) found that participants selected as high on trait anxiety (apprehension) as measured by the STAI displayed relative greater LFA during rest and while listening to emotional narratives, although this was attributed to decreased absolute RFA. Mathersul et al. (2008) also found that higher levels of self-reported anxious apprehension correlated with greater relative LFA. However, when the participants were grouped based on alpha EEG asymmetry scores, anxious apprehension was associated with relative greater right parietotemporal activation. The mixed findings are reminiscent of the reported links between o-BIS and resting FAA, and may point to the heterogeneity of the related constructs of trait anxiety and BIS that implicates less straightforward links with asymmetric cortical activity.

In summary, the data appear to provide stronger support for the association between anxious arousal and relatively greater right hemispheric activity than for the association between anxious apprehension and relatively greater left hemispheric activity. Nonetheless, the distinction between the subtypes of anxiety and the supporting data may provide a useful parallel when making hypotheses in regards to FFFS and BIS. In this vein, FFFS sensitivity, to the extent that it is similar to anxious arousal and involves autonomic arousal, panic, and avoidance tendencies, may be hypothesised to be related to relatively greater right parietal activation, as well as frontal regions in accord with Davidson's model. In contrast, BIS sensitivity, to the extent that it is similar to anxious apprehension and involves hypervigilance, language-based risk assessment and approach tendencies, it may be linked to relatively greater left frontal activity.

Posterior versus Frontal Theta and Delta Activity

More recently, resting posterior versus frontal delta and theta EEG activity have been evidenced to be a marker of individual differences in dopamine functioning associated with *agentic extraversion* – a facet of extraversion that is characterised by goal-directedness, achievement striving, assertiveness, and positive affective emotional states – and BAS sensitivity (e.g., Chavanon, Wacker, & Stemmler, 2009; Wacker & Gatt, 2010).[12] This index is calculated as the difference between ln-transformed delta or theta power at the parietal midline (Pz) and frontal midline (Fz) regions of the scalp, that is, "Pz-Fz" = [ln(delta/theta power@Pz) – ln(delta/theta power@Fz]. Across a number of studies, individuals with higher levels of approach-oriented agentic extraversion or BAS have been found to display greater relative parietal theta activity, while individuals with lower levels of BAS and agentic extraversion display greater relative frontal activity (e.g., Wacker et al., 2006; Chavanon et al., 2009; Wacker et al., 2010; Koehler et al., 2011; Chavanon, Wacker, & Stemmler, 2011; Chavanon, Wacker, & Stemmler, 2013). This same pattern has been observed for delta activity, as well as being replicated across varied samples and EEG methodologies (e.g., Wacker et al., 2010; Wacker & Gatt, 2010; Koehler et al., 2011; Chavanon et al., 2011). In a meta-analysis, Wacker et al. (2010) found that the effect sizes for the association were stable and exceeded those observed for FAA, with a significant mean weighted correlation of r = -.21 (p = .001). The strongest effects were observed in the 3-5 Hz range. Although it is yet inconclusive as to what neurological processes underpin posterior versus frontal slow oscillations, Chavanon et al. (2011) used low-resolution electromagnetic tomography (LORETA), which estimates the intracerebral activity in various brain regions, and obtained preliminary evidence that the higher posterior theta activity may be due to stronger theta

[12] Agentic extraversion contrasts with affiliative extraversion, which is characterised by social warmth and valuing and engaging with social relationships (Depue & Collins, 1999).

densities in the ventral-rostral anterior cingulate cortex (rACC), which is a central part of the reward pathway.

In further support of the association with approach motivation, resting posterior versus frontal delta and theta activity have been shown to be modulated by pharmacologically induced changes in brain dopamine levels, as well as linked to relevant genetic correlates. Studies have shown that when participants are administered the dopamine D2 antagonist sulpiride, the observed association under neutral conditions is reversed such that individuals with higher agentic extraversion or BAS sensitivity exhibit more frontal theta and delta activity, while individuals with lower agentic extraversion or BAS sensitivity exhibit more posterior theta and delta activity (Wacker et al., 2006; Wacker et al., 2010; Chavanon et al., 2013). Furthermore, Wacker and Gatt (2010) found that increased posterior versus frontal delta and theta activity was associated with the Val genetic allele of the COMT VAL^{158}MET polymorphism involved in dopamine catabolism, which, in turn, was associated with higher extraversion scores. Koehler et al. (2011) additionally found significant associations with two variants of the DRD2 dopamine receptor gene (and marginally significant association with the third variant). The variants with the stronger associations with relative greater posterior delta and theta activity were also more strongly associated with trait extraversion.

Together, these data suggest that resting posterior versus anterior theta and delta activity is a marker of phenotypic traits that are mediated by the dopaminergic system such as agentic extraversion and BAS sensitivity. In particular, it may be expected that BAS sensitivity would be related to greater relative posterior theta and delta activity.

Section Summary and Hypotheses

The previous sections have reviewed a number of models and their related empirical literature concerning EEG neural indices of approach and avoidance. The primary focus was

on frontal alpha asymmetry (FAA), which has a long-standing theoretical and empirical literature. Davidson's approach-withdrawal model of FAA has received the strongest empirical support, such that both research from Harmon-Jones' laboratory and the literature review reported in this section attest to an association between approach motivation/BAS sensitivity and greater relative LFA. The evidence for the link between BIS sensitivity and greater relative RFA is less clear, implicating that BIS may not fit neatly within the approach-withdrawal model. This could be due to all studies to date employing outdated operationalisations of the BIS that do not take into account Gray and McNaughton's (2000) theoretical revisions. Alternatively, in view of the r-RST, Wacker and his colleagues proposed a BIS-BAS Model of Alpha Asymmetry (BBMAA) whereby both goal-direct BIS and FFFS behavioural activation, irrespective of motivational direction, is related to greater relative LFA; while BIS induced goal-conflict is related to greater relative RFA. However, there is limited empirical evidence in support of the BBMAA. In contrast, there is substantial evidence to support Heller's proposal that anxious arousal (which may conceptually map onto FFFS sensitivity) is related to greater relative right hemispheric activity, and this is also aligned with Davidson's proposed link between withdrawal and greater relative RFA. Heller additionally theorised that anxious apprehension (which may conceptually map onto BIS sensitivity) may be related to greater relative left hemispheric activity, but the empirical evidence is less clear. Finally, this section also outlined research by Wacker and his colleagues on posterior versus frontal theta and delta activity as another correlate of approach motivation. Specifically, there is evidence based on self-report and pharmacological manipulation to suggest that BAS sensitivity is related to greater parietal theta activity. Based on the reviewed theoretical and empirical literature, the following hypotheses were made:

Hypotheses

1a) BAS sensitivity was expected to link to relatively greater resting LFA (positive association with FAA scores), in accordance with Davidson's approach-withdrawal model of FAA

1b) FFFS sensitivity was expected to be related to relatively greater resting right frontal and right parietal activation (negative association with asymmetry scores in frontal and parietal sites), in accordance with the approach-withdrawal and anxious arousal models of FAA respectively.

1c) The association between BIS sensitivity and resting FAA is less clear-cut, but might be expected to be related to relatively greater resting LFA (positive association with FAA scores), in accordance with the anxious apprehension model of FAA.

1d) BAS sensitivity is additionally expected to be related to greater relative parietal versus frontal theta and delta activity.

Attachment Behaviour and FAA

Surprisingly few studies have examined frontal alpha asymmetry (FAA) and individual differences in infant or adult attachment patterns. A literature search on PSYCInfo for the terms "frontal alpha asymmetry" and "attachment" returned no research studies. Nonetheless, over a five year period, Fox and Davidson embarked on a series of studies to examine the physiological substrates related to infant attachment behaviour. They hypothesised that variation in the occurrence and intensity of an infant's emotional response to separation from their attachment figure may be due to individual differences in cerebral activation and lateralisation (see Fox & Davidson, 1991, for a review). In support of this hypothesis, Fox and Davidson (1987) found that 10-month old infants who cried in response to maternal separation showed greater relative RFA, as well as facial expressions of anger,

distress and sadness. These same infants showed greater relative LFA, expressions of joy and increased vocalisation when their mothers approached and reached for them. Interestingly, infants who did not cry in response to maternal separation were more likely to show greater inhibition of RFA, and this was accompanied by facial expressions of interest rather than distress. In another study, Fox and Davidson (1988) found that infants were far more likely to display Duchenne or "felt" smiles (that involve the movement of both the mouth and eye muscles) when approached by their mother, and this was linked to greater relative LFA. In contrast, "unfelt" smiles (involving the movement of the mouth only) were more frequently observed during stranger approach and linked to greater relative RFA. Together, the data suggests that differential attachment behaviour and associated affective experiences are linked to lateralised frontal hemispheric activity. Greater relative LFA appears to accompany proximity-seeking behaviour (e.g., smiling, vocalisation) during the approach of an attachment figure, while greater relative RFA is observed when maternal separation and stranger approach elicits distress. This pattern of associations is in accord with the approach-withdrawal model of FAA, such that relative LFA is associated with appetitive-approach states and relative RFA is associated with aversive-withdrawal states.

In one of the earlier trait-resting EEG association studies, Davidson and Fox (1989) assessed whether individual differences in infant stress reactivity temperament, as measured by crying response to maternal separation, was related to resting FAA. They found that infants who cried upon maternal separation showed relatively greater resting RFA, while non-criers displayed relatively greater resting LFA. Although Bowlby (1973) regarded crying as a normative separation response that does not necessarily differentiate between attachment patterns, Davidson and Fox (1989) argued that the propensity to cry in response to maternal separation may signify greater reactivity to stressful events. Furthermore, there are some data to suggest that infants who show greater distress during separation were more likely to be

rated as insecure (Shiller, Izard, & Hembree, 1986). Therefore, Davidson and Fox's (1989) study provides preliminary evidence of an association between resting FAA and attachment behaviour, although individual differences in attachment style was not directly assessed. To date, the only FAA study that measured infant attachment style was conducted by Dawson et al. (2001). Dawson et al. found that insecurely attached infants, regardless of their mother's depression status, showed lower FAA scores than securely attached infants during rest and at play. The lower FAA scores were interpreted as reduced LFA, such that insecure infants engage less in approach-oriented behaviours. This study unfortunately did not differentiate between different insecure attachment patterns.

With regards to adult attachment, the limited existing studies consistently point to relatively greater LFA for securely attached individuals. In a sample of 39 volunteers, Rognoni, Galati, Costa and Crini (2008) found that securely attached individuals had mean FAA score close to zero indicating generally symmetrical frontal activity, though trending towards relative LFA. Similarly, among 18 women, Fraedrich, Lakatos and Spangler (2010) found that secure individuals showed a trend towards more LFA. In both Rognoni et al.'s (2008) and Fraedrich et al.'s (2010) studies, the small sample sizes may have resulted in insufficient statistical power to find significant associations (although the associations appear to be modest in any case). Finally, Stanley (2006) found that securely attached college females showed greater LFA while viewing video clips of reunion scenes between children and their attachment figures. Therefore, there is some evidence suggesting that secure attachment might be modestly associated with relatively greater LFA, indicative of higher levels of approach motivation.

In contrast, insecure adult attachment patterns tend to be associated with relative RFA. Rognoni et al. (2008) found that dismissing attachment was linked to relative RFA at rest as well as while viewing happy films, while Fraedrich et al. (2010) observed a trend

towards reduced LFA at rest. Similarly, preoccupied individuals were found to exhibit relative RFA at rest and while viewing fearful film clips (Rognoni et al., 2008). They also showed relative RFA while viewing film clips of various reunion scenes between caregivers and their children (Stanley, 2006). Both the fearful and reunion film clips may be distressing to the preoccupied individual, and thus elicit RFA-based avoidance motivation. Preoccupied individuals, however, did show relative LFA when viewing happy films suggestive of mixed motivational states (Rognoni et al., 2008). Finally, fearful-avoidant individuals were found to have near zero resting FAA scores, with a trend towards relative RFA, as well as significantly greater relative RFA when viewing fearful film clips (Rognoni et al., 2008). The overall picture suggests that insecurely attached individuals show relative RFA at rest and during aversive emotional states.

In sum, the limited child and adult attachment studies provide some evidence that secure attachment is linked to higher FAA scores, which is most likely due to increased LFA. Conversely, insecure attachment patterns appear to be inversely related to FAA scores, possibly due to reduced LFA or increased RFA. All of the cited studies, except for Stanley's (2006) dissertation, suffer from small sample sizes and tended to focus exclusively on the F3/F4 and/or F6/F5 sites, which may not be representative of asymmetrical cortical activity at other electrode sites in the frontal region. Therefore, more EEG studies of adult attachment need to be conducted that utilise larger sample sizes and examine FAA scores across the frontal region at the F3/F4, F5/F6 and F7/F8 electrode sites.

Moreover, no research has been conducted on the nature of the relations between resting FAA and the adult attachment dimensions of anxiety and avoidance. To the extent that the attachment dimensions map onto approach-avoidance tendencies, they should be related to resting FAA in accordance with Davidson's (1984, 1992, 1993) approach-withdrawal model. Given that attachment anxiety involves fear of the attachment figure's

unavailability, and has been empirically related to more sensitive threat appraisal (e.g., McDonald & Kingsbury, 2006) and FFFS (Jiang & Tiliopoulos, 2014), the dimension might be characterised by higher levels of aversive motivation and, accordingly, correspond to relatively greater resting RFA (i.e., lower FAA scores). Conversely, attachment avoidance has been associated with reduced sensitivity to social reward (e.g., Troisi et al., 2010) and BAS hypoactivation (Jiang & Tiliopoulos, 2014), indicative of lower levels of approach/appetitive motivation. As such, the dimension may be expected to be related to lower levels of LFA (i.e., exhibit a negative association with FAA scores). Therefore, both attachment anxiety and avoidance may be inversely related to FAA scores, while lower levels of both attachment dimensions (corresponding with attachment security) would be positively associated with FAA scores.

Section Summary and Hypotheses

In summary, there are few empirical studies that have examined individual differences in attachment behaviour and EEG correlates of approach and avoidance motivation. Early studies on infants have found that relative LFA is associated with appetitive-approach states (e.g., proximity-seeking and the approach of an attachment figure) and relative RFA is associated with aversive-withdrawal states (e.g., maternal separation and stranger approach) (Fox & Davidson, 1987, 1988, 1991). Furthermore, infants who are insecurely attached and experience greater separation distress were observed to display greater RFA and reduced LFA (Davidson & Fox, 1989; Dawson et al., 2001). Finally, across the only three studies that have examined individual differences in adult attachment and FAA, secure attachment is generally linked to greater relative LFA, while insecure attachment is generally linked to greater relative RFA. No studies have examined the attachment dimensions of anxiety and avoidance in relation to resting FAA. Given that, in the present thesis, attachment anxiety and

attachment avoidance were hypothesised to be related to increased FFFS sensitivity and reduced BAS sensitivity respectively, the following hypotheses were made:

Hypotheses

2a) Attachment anxiety was expected to be linked to relatively greater RFA, manifest as an inverse association with FAA scores.

2b) Attachment avoidance was expected to be linked to relatively lower LFA, also manifest as an inverse association with FAA scores.

Study Overview and Chapter Summary

The aim of the present study was to examine individual differences in adult attachment and reinforcement sensitivity in relations to neurophysiological indices as measured by an EEG. In particular, the study focuses on resting frontal alpha asymmetry, which has been associated with dispositional approach and withdrawal tendencies. The theoretical background on FAA was reviewed, including previous empirical studies that have looked at FAA in relations to reinforcement sensitivity and attachment separately. The chapter also reviewed alternative relevant models including the BIS-BAS model of Alpha Asymmetry, anxious arousal versus anxious apprehension, and parietal versus frontal delta and theta activity. The goal of the present study was to look at the relations between resting EEG correlates and reinforcement sensitivity and adult attachment concurrently.

Chapter 7: Study 3 - Methodology

Participants

Participants were 73 healthy, right-handed volunteers (68.5% females) recruited in response to advertisements placed around the University of Melbourne. The advertisement outlined that interested participants needed to be healthy, over the age of 18 years, and predominantly right-handed. The mean age was 23.48 years (*SD* = 5.18), with a range of 18 to 41 years. One participant was excluded from the sample due to left-handedness. Due to technical issues, two other participants did not have EEG data recordings. A further seven participants were excluded due to either very noisy EEG data and/or heavy interpolation of six or more electrode channels of interest.[13] The remaining sample of 63 participants with valid EEG recordings included 44 (68.8%) females and had a mean age of 23.35 years (*SD* = 5.05, range = 18 to 41). Participants were paid $30 for approximately 2.5 hours of their time. The study was approved by the University of Melbourne's Behavioural and Social Sciences Human Ethics Sub-Committee.

Of the sample, 38 (60.3%) participants indicated that they were single, 14 (22.2%) were dating exclusively, 5 (7.9%) were married, 1 (1.6%) was divorced, 2 (3.2%) were cohabitating, and 2 (3.2%) were dating multiple partners. Furthermore, participants who were in a current, exclusive romantic relationship (dating, married, or cohabitating) reported a mean relationship length of 43.33 months (*SD* = 51.58 months, range = 4 to 216 months). Majority of the sample (56, 88.9%) were students, followed by 4 (6.3%) professional/technical, 1 (1.6%) in sales, 1 (1.6%) in crafts/trades and 1 (1.6%) were

[13] When these seven participants were included in the analyses, the results were similar but generally accounted for smaller amounts of variance compared to the results obtained when these participants were excluded.

unemployed. Furthermore, 12 participants (19%) described their ethnicity as Oceanian, 15 (23.8%) described themselves as NW European, 3 (4.8%) as European, 2 (3.2%) as North African and Middle Eastern, 22 (34.9%) as South East Asian, 5 (7.9%) as Southern and Central Asian, 2 (3.2%) as People of the Americas, and 2 (3.2%) of mixed ethnicity.

Measures

As in Study 1, this present study employed the *Experiences in Close Relationships – Revised scale* (ECR-R; Fraley, Waller & Brennan, 2000), and the proxy measures of r-RST – the *State-Trait Anxiety Inventory* (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and the *BIS/BAS scales* (CW-BIS/BAS; Carver & White, 1994). Descriptions of these measures are provided in the Method section of Study 1. The present study also included two additional measures (which can be found in Appendix C) as follows:

Fear Survey Schedule-III (FSS-III; Wolpe & Lang, 1964)

This phobic checklist was devised for clinical use but is widely adopted in research. It consists of 72 items that represent a broad range of specific and potentially threatening stimuli. To facilitate clinical use, the items were classified based on face validity into those representing animal fears (9 items; e.g., bats and dogs); social or interpersonal fears (17 items; e.g., being teased); tissue damage fears, illness and death fears, and their associations (18 items; e.g., receiving injections); fear of noises (4 items; e.g., sirens); other classical phobias (16 items; e.g., high places on land); and miscellaneous fears (8 items; e.g., strange places, failure, and dull weather). Various versions of the FSS have been used as a proxy index of FFFS sensitivity (e.g., Cooper et al., 2007; Perkins et al., 2010; Perkins et al., 2007). In the current study, we used the FSS-III (as opposed to FSS-II that was used in Study 1 to measure overall fearfulness) in order to assess specific types of fears as in Cooper et al.'s

(2007) study. Perkins et al. (2007) has shown that FSS fear scores are psychometrically separable to trait anxiety and neuroticism, and in particular, the tissue damage fear component appears to be a valid predictor of outcomes related to FSS-III sensitivity. We assess both general fear-proneness and domain-specific fears as proxy indices of FFFS sensitivity.

The factor structure of the FSS-III has been evaluated across numerous studies. Generally, these studies have used relatively large samples (upwards of 200 participants) and via Principal Axis Factoring or Principle Component Analysis obtained between 4 and 6 factors that account for a third to half of the variance (e.g., Arrindell, 1980; Beck, Carmin, & Henninger, 1998; Brown & Crawford, 1988; Gulas, McClanahan, & Poetter, 1975; Kartsounis, Mervyn-Smith, & Pickersgill, 1983; Landy & Gaupp, 1971; Oei, Cavallo, & Evans, 1987; Spinks, 1980). Factors reflecting interpersonal fears, tissue damage fears, and animal fears are consistently recovered across all of these studies. Although not as universal, agoraphobia also emerged repeatedly as a factor (Arrindell, 1980; Brown & Crawford, 1988; Carmin & Henninger, 1998; Oei, Cavallo, & Evans, 1987). The categories of fear of noises, classical phobias, and miscellaneous fears, as proposed by Wolpe and Lang (1964), have not been well-supported by factor analytic studies. Given that factor analytic studies have demonstrated the existence of lower-order factors, and in particular of the aforementioned four categories, it is strongly argued that studies should look at fear scores for each domain rather than a total fear score since the items on the FSS-III are heterogeneous and each domain does not equally contribute to the overall fear score (Arrindell, 1980; Arrindell, van der Ende, & Emmelkamp, 1984).

In the present study, the factors established by Arrindell (1980) and Arrindell et al. (1984) were used as the basis of calculating fear scores. Arrindell et al. (1984) conducted a large scale review of more than 3000 participants from 10 independent clinical and

nonclinical samples to examine the replicability of the factor structure of the FSS-III. The recovered dimensions, first established by Arrindell (1980), were 1) Social (13 items; e.g., speaking in public, being teased), 2) Agoraphobia (e.g., 13 items; being alone, being in a strange place), 3) Blood Injury, Illness and Death (12 items; e.g., open wounds, dead people), 4) Sex and Aggression (8 items; e.g., tough-looking people, nude men), and 5) Harmless Animals (6 items; e.g., worms, bats) (Arrindell et al., 1984). The total number of items was 52 [an additional 12 items are listed in the appendix of Arrindell et al. (1984), which were included for further research purposes]. The remaining 20 items from the original FSS-III did not reliably map onto any dimensions. Nonetheless, the five factor structure has evidence cross-sample invariance across student, non-institutionised phobic, and psychiatric inpatient populations, as well as across cultures and genders (Arrindell & van der Ende, 1986; Arrindell et al., 1984; Brown & Crawford, 1988).

The FSS-III has demonstrated high internal reliability for both overall fear score as well as for factors recovered in various factor analytic studies. Despite low to medium inter-item correlations, the FSS-III total score has Cronbach's alpha reliabilities ranging .62 to .95 (Johnsen & Hugdahl, 1990; Spiegler & Liebert, 1970; Spinks, 1980; Wolpe & Lang, 1977). Furthermore, high internal consistency has been demonstrated for the specific fear subscales, with Cronbach's alphas generally in the 80s and 90s (Arrindell et al., 1984). In particular, the Cronbach's alphas range from .85 to .91 for the five factors recovered by Arrindell (1980), while test-retest reliability range from r = .72 to .90 for 3 – 10 week intervals (Arrindell et al., 1984).

Therefore, in the current study, we adopted the subset of 52 items that map onto the five categories of fear established by Arrindell (1980) and Arrindell et al. (1984). Participants rated their fearfulness towards each item on a 5-point Likert-type scale (from 1 = not at all, to 5 = very much). Scores were summed for each of the five subscale, as well for whole scale.

The overall fear score can range from 52 to 260, with higher scores indexing greater overall level of fear proneness, implicating a more sensitivity FFFS.

Heym-RST (Heym, Skatova, Ferguson, & Lawrence, 2016)

The R-RST questionnaire by Heym et al. (2016) is based on Carver and White's (1994) BIS/BAS scales, but has been modified and extended to take into account Gray and McNaughton's (2000) revisions to the RST. This measure was available during the present study (the measure was unavailable during Studies 1 and 2) and so was included as an alternative purpose-built measure of r-RST to Corr and Cooper's (2016) RST-PQ measure (which had weak associations with attachment dimensions). It includes 7 scales that form a total of 30 items. The BAS Drive scale is the same as Carver and White's (1994) original scale and contains four items (e.g., "I go out of my way to get things I want"). The BAS Reward Reactivity scale is also similar to Carver and White's (1994) original version, although it contains two additional items that formerly belonged to Carver and White's (1994) BAS Fun Seeking scale. The new version contains five items (e.g., "I'm always willing to try something new if I think it will be fun"). The other two original BAS Fun Seeking items were removed by expert ratings as they seemed to assess impulsivity, which is maintained as distinct from reward sensitivity (Depue & Collins, 1999). The BIS Anxiety scale is similar to Carver and White's (1994) original BIS scale (4 items; e.g., "I generally worry a lot"). Furthermore, a newly devised BIS Appraisal scale (3 items; e.g., "I always like to carefully appraise any situation before making a decision") assesses the hypervigilance and risk assessment component of BIS. Importantly, in line with the r-RST, there are three newly developed FFFS scales: a 4-item FFFS Flight scale that assesses avoidance or running away from threatening situations (e.g., "When I get startled, I often start to run"); a 4-item FFFS Freeze scale that assesses freezing behaviour in the presence of threat (e.g., "I often

freeze/tense up in extremely threatening situations"); and a 6-item FFFS Fight scale which assesses defensive fight (e.g., "If someone attacks me, I hit out").

Item generation for the new scales took an expert rating approach. A number of Comprehensive Exploratory Factor Analyses and Confirmatory Factor Analyses were conducted on large samples. Both a seven factor structure and a six factor structure fitted the data well, with FFFS Flight and FFFS Freeze items mapping onto one factor in the six factor structure. However, a hierarchical model in which the subscales are subsumed into higher order BIS, FFFS and BAS factors did not achieve good fit. Therefore, the separate BIS, FFFS and BAS scales are retained. (Heym, personal communication, December 8, 2014).

The Heym-RST scales have shown good psychometric properties, including internal and test-retest reliability, and construct and predictive validity (Heym, personal communication, December 8, 2014). Reported test-retest reliability was .70 (Heym et al., 2016). The scales show expected convergent associations with other measures of RST (e.g., SPSRQ, AMS, RST-PQ, and Jackson-5) as well as predictive validity to relevant self-report outcomes (e.g., personality, coping mechanisms, impulsivity, and psychopathology). Furthermore, the scales have demonstrated predictive validity to a number of experimental paradigms including the dot-probe task; attentional focus on sad, fearful and happy faces; affective startle modulation, go/no go task; effort expenditure for rewards task; gambling/risk tasks; and approach-avoidance paradigm (Heym, personal communication, December 8, 2014).

In the present study, all items were rated on a 4-point Likert-like scale, from 1 = Very False For Me to 4 = Very True For Me. The mean of each scale was calculated, with higher scores suggesting higher levels of the measured trait.

EEG Acquisition

EEG activity was recorded using a 64-channel BioSemi Active-Two system (BioSemi, Amsterdam: The Netherlands), positioned according to the 10-20 system (American Electroencephalographic Society, 1994; Blom & Anneveldt, 1982). In accordance with this system, Fz was placed at 10% of the inion-nasion distance, and Cz was placed at half way between the inion-nasion and left-right mastoid distances. Two additional external electrodes were attached to the mastoids.[14] A stretch lycra electrode cap (Electro-Cap International Inc., Eaton: OHIO) embedded with pin-type active Ag/AgCl electrodes was used, and Sigma gel (Parker Laboratories Inc., Fairfield: New Jersey) was used as the conductive medium. As active electrodes amplify signals at the electrode site in order to maintain good signal-to-noise ratio, electrode-scalp impedances were less of a concern and procedures used to reduce electrode-scalp impedances such as scrubbing were not necessary (MettingVanRijn, Kuiper, Dankers, & Grimbergen, 1996). Likewise, impendence measurements were not necessary (MettingVanRijn et al., 1996). EEG recordings were referenced online to the Common Mode Sense (CMS) active electrode and Driven Right Leg (DRL) passive electrode, which were located midway between POz and PO3 electrodes and POz and PO4 electrodes respectively. To control for ocular artefacts, vertical and horizontal electrooculograms (EOG) were recorded by placing active Ag/AgCl electrodes approximately 1 cm above and below the middle of the right eye, and as close as possible to the left and right outer canthi of the eyes. EEG was recorded for eight minutes in total during which participants were seated and at rest in a quiet room by themselves. Participants were verbally instructed to keep their eyes-open (O) or eyes-closed (C) for alternating 60 second

[14] Originally, it was intended that the data were to be referenced offline to linked mastoids. However, during data collection, the external electrode attached to the left mastoid was unable to record for n = 20 participants due to technical problems. Thus, as our interest was in asymmetric cortical activity, average head reference was used as a more objective reference that is unbiased to hemispheric activity, as opposed to referencing to the right mastoid alone.

periods, with two counterbalanced orders: OCOCOCOC and COCOCOCO. Also, before the start of the recording, they were asked to relax, limit large muscle movements and avoid excessive blinks. The EEG and EOG signals were bandpass filtered (cutoffs: 0.16-100Hz) and the data sampling rate was 512 Hz.

EEG Preprocessing

The EEG data were preprocessed offline using BrainVision Analyzer v.2.0.2 (Brain Products GmbH, 2013). Due to equipment hardware issues, a number of electrodes became dysfunctional over the period of data collection. These dysfunctional, non-recording channels were initially excluded. There were between 1 and 14 dysfunctional channels across the 51 participants, and of these cases, 39 participants had six or fewer channels missing. Given that we were interested in only a few channels to calculate alpha asymmetry (frontal: F3, F4, F5, F5, F6, F7, F8; central/temporal: C3, C4, C5, C6, T7, T8; parietal: P3, P4, P5, P6, P7, P8), in most instances data for these channels were available or could be interpolated, and thus most cases were retained.

Initial (Low Cutoff) Filter

The EEG data are contaminated by various electrical noises (e.g., from electrical devices) in addition to brain cortical signals. The electrical noises are often of a much higher or lower frequency than the frequencies of brain cortical signals of interest (0.01 Hz and 30 Hz), and therefore, filtering is used to attenuate certain frequencies and reduce noise in the data. Nonetheless, there are instances where the frequency content of the signal and noise becomes similar and overlapping, in which case it is more difficult to eliminate the noise.

An important concern when applying any filter is that it can potentially distort the data and lead to valuable loss of information. As Luck (2005) emphasises, “Precision in the

time domain is inversely related to precision in the frequency domain" (p. 182). The idea is that the more heavily one constrains frequencies (i.e., by eliminating a broad range of frequencies), the more distortions to the data. Specifically, the data becomes 'smeared' and spread out in the time domain. Therefore, it is recommended that the least restrictive filter is applied where possible, especially in the initial stages of data preprocessing (Luck, 2005).

In the present case, the data were initially passed through a low cutoff (high-pass) filter of .50 Hz, such that all frequencies below this cutoff were excluded. Very low frequencies below this cutoff are usually slow, non-neural electrical potentials such as skin potentials and slow drifts caused by sweating, poor electrode contact or dirty electrodes (Luck, 2005). A notch filter of 50 Hz, which eliminates 50 Hz frequencies and passes all other frequencies, was applied to nine cases with extremely noisy data. This specific frequency corresponds to electrical activity from mains power sources in Australia. The extremely noisy data of the nine cases may be due to the presence of nearby heavy construction work during the EEG recording. Application of the notch filter substantially improved the data. The notch filter was not applied to all cases at this stage to avoid distortion of the data.

Re-referencing to Cz

EEG signals are measured in terms of voltage, which refers to the potential for a current to move between two points, in this case, two electrodes (Luck, 2005). During data acquisition, a reference electrode (i.e., the CMS active electrode) and a ground electrode (i.e., the DRL passive electrode) are placed on the scalp. The voltages between the active site of interest and reference electrode as well as between the reference and ground electrodes are calculated. Then the difference between these two voltages is amplified to take into account the ambient electrical activity common to both voltages.

After data acquisition, an offline reference was applied. Luck (2005) recommended that this reference should be 1) comfortably located and can be conveniently recorded, 2) not biased to one hemisphere, and 3) traditionally used in other similar studies. In accordance with these recommendations, the Cz site was applied as an initial offline reference. Furthermore, the Cz reference has the advantage of being centrally located and outside the regions of interest. However, due to equipment issues, the Cz electrode failed to record for nine participants. In seven of these cases, CPz was used instead as the initial offline reference, and FCz and Pz were used in the other two cases where the CPz channel was noisy. At a later stage, the data will be re-referenced to average head. However, Cz is used here as an initial reference as it allows for administering Independent Component Analysis (ICA) for ocular correction, which requires all channels to be independent from each other.

Raw Data Inspection

Manual inspection of the data was then performed to remove very obvious artefacts such as muscle movement, severe and abnormal blinking, and speech artefact. Such artefacts are usually quite distinct and appear atypical to the regular, rhythmic EEG data. For example, muscle movements may appear as dramatic ‘spikes’ in one or a few channels, while speech artefact may appear as high peaked and densely packed waves in defined blocks across many or all channels (Luck, 2005). Severe or abnormal blinking may involve a series of rapid blink activity and blinks that involve muscle activity across other channels. Regular blinks, however, were ignored as they would be corrected in the next step. At this stage, only a rough data inspection and artifact rejection are conducted, as another artifact rejection process will be done after ocular correction and further filtering. Nonetheless, large muscle movements and obvious abnormal activity do need to be removed in preparation for ocular correction,

which is sensitive to such abnormalities in the data. Following this, the data were segmented into eyes open epochs and eyes closed epochs, which totalled four minutes each.

Ocular Artefact Correction

Independent Component Analysis (ICA; Vigário, 1997) was used to correct for ocular artefacts such as blinks and saccades. More commonly, artefact rejection methods are used in which portions of EEG data are discarded based on certain attributes (e.g., predetermined criterion thresholds for amplitude peak, variance and slope) of the activity in the EOG channels. However, these methods may lead to large and often systematic loss of data. Furthermore, not all eye activity may be identified by the criterion thresholds, and so result in artefact-reduced but not artefact-free data. For these reasons, artefact correction methods such as ICA are preferable over artefact rejection for ocular activity (Vigário, 1997).

The goal of ICA is to decompose the EEG waveform into separate and independent sources arising from neural and artefact activity. The basic assumption is that "the brain and eye activities are anatomically and physiologically separate processes, and that their independence is reflected in the statistical relation between the electrical signals generated by those processes" (Vigário, 1997, p. 396). Given this assumption, ICA extracts and removes the sources related to ocular artefacts present in EOC signals from the EEG data.

Statistically, ICA is an extension of the standard Principle Component Analysis (PCA). Like PCA, ICA assumes that the estimated signal sources or components are uncorrelated. However, ICA further assumes that the components are statistically independent and combine in an unknown, linear fashion (Hoffmann, 2007). In the present case, Classic PCA with Restricted Infomax was applied to the whole length of data separately for eyes open and eyes closed segments. The first few components usually represent the

contribution of ocular artefacts, since these movements tend to have the largest impact on the waveform.

In the current study, inverse ICA in semi-automatic mode was performed. The first step involved decomposing the waveform into orthogonal components. Subsequently, the components reflecting ocular artifacts were identified via visual inspection of the scalp distribution of the components' activity: vertical eye movements were indicated by positive fields above the eyes and negative fields below the eyes (or vice versa), and horizontal eye moments were indicated by a positive field on one side and a negative field on the other side in the frontal regions. Finally, the EEG waveform was recomposed with the identified artifactual components omitted.

Topographic Interpolation

After ocular artefact correction, topographic interpolation was performed on the channels of interest that had excessive noise or electrodes that failed to record (previously excluded as dysfunctional channels). Topographic interpolation obtains a value for a missing channel based on the values of surrounding existing channels. In this case, the Spherical Spline method was used, which takes into account the shape of the skull and location of channels (Perrin, Pernier, Bertrand, & Echallier, 1989). Only channels of interest (Cz, F3, F4, F5, F6, F7, F8, C3, C4, C5, C6, T7, T8, Pz, P3, P4, P5, P6, P7 and P8) that were missing were interpolated. Between 1 and 6 channels were interpolated for 62 cases. Of these cases, 34 had only 1 or 2 channels interpolated.

High Cutoff and Notch Filter

In addition to the low cutoff filter applied earlier, to further reduce noise, a high cutoff filter was used to attenuate very high frequencies that usually originate from muscle activity

and external electrical devices. A high cutoff or low-pass filter removes frequencies above and passes through frequencies below the specified cutoff. In selecting the cutoff frequency, two aspects need to be taken into account. Firstly, Nyguist Theorem states that the sampling rate during data acquisition needs to be at least twice as great as the highest frequency in the signal to capture all the information (Luck, 2005). This sets the upper bound of the high cutoff frequency. In the present case, the sampling rate was 512 Hz, and thus the highest frequency retained in the signal data can potentially be 256 Hz. Secondly, a lower sampling rate may lead to loss of information and induce artefactoral low frequencies in the data (Luck, 2005). Therefore, in selecting a filter, a higher cutoff frequency will require a higher sampling rate, while a lower cutoff frequency may introduce distortion to the data. Luck (2005) suggests a cutoff frequency between 30 and 100 Hz. In the present study, a high cutoff filter of 50 Hz with slope of 12 was applied to all cases. Furthermore, a notch filter of 50 Hz was uniformly applied, to remove all line-frequency noise at 50 Hz that corresponds to electrical noise from alternating current (AC) sources such as computers in Australia.

Average Head Reference

The data were then re-referenced to an average of all 64 channels. This provides a neutral reference that is unbiased to one hemisphere, and less biased than a particular reference such as Cz. The average reference could not be implemented an initial offline reference before ICA as channels need to be independent for ICA to be performed.

Segmentation and Artefact Rejection

The data were then segmented into 2 second epochs with 50% (1 second) overlapping segments. A second artefact rejection procedure was conducted to check for any remaining artefacts in the data that have not been corrected or removed in previous steps. The artefact

rejection procedure was conducted in semiautomatic mode. A number of rejection criteria were set, each targeting different types of artefacts. Firstly, the gradient criterion, which is the maximum absolute voltage difference between two adjacent sample data points, was set to 50 μV/ms. This removes any sudden, dramatic spikes in the voltage. Secondly, max-min criterion, which is the maximum permissible difference between two data points within a segment, was set to 200 μV. In contrast to examining just peak amplitude from baseline, peak-to-peak amplitude (max-min voltage difference) takes into account variations in baseline voltage. This criterion detects and removes segments that contain large voltage drifts, due to blinks or other movements. Finally, the low activity criterion was set to 0.5 μV, which specifies the lowest allowable voltage difference between data points. This criterion detects flat lined segments such as slow voltage drifts caused by changes in impedance of the skin (e.g., due to sweating) or electrodes (e.g., shifts in position). Violations of these criteria were marked as an artefact at 200 ms before and after the event.

Power Spectral Analysis

Following this, power spectral analysis was conducted using Fast Fourier Transform (FFT; Allen, Coan, & Nazarian, 2004). FFT converts the data from the time domain to the frequency domain to provide an indication of the extent to which individual frequencies between 0 and 256 Hz (half the sampling rate) are represented in the EEG data. In the current data, no frequencies above 50 Hz and below 0.5 Hz will be present due to the high-cutoff and low cut-off filters respectively. The maximum resolution, which refers to the width of frequency 'bins' that comprise the power spectral analysis, is calculated as the sampling rate divided by segment length. So, given that the sampling rate was 512 Hz and the segment length was 2 seconds in the current data, the maximum resolution would normally be 0.5 Hz. However, it is possible to select a resolution that is higher than the 'maximum' resolution. A

related requirement of FFT is that segments must contain 2^n data points (for example, 2^{25} = 512 or 2^{26} = 1024). If the number of data points is not a power of two, the segments are automatically extended by zero-padding, whereby zeroes are added symmetrically to both sides of the segment until the requisite number of 2^n data points. For example, in an instance where the segment length is 2 seconds and the sample rate is 500 Hz, this will result in 1000 original data points. BVA will zero-pad 24 data additional points to make 1024 data points in total and enable FFT to be performed. This interpolation of the data allows for a higher resolution to be obtained via the power spectral analysis, relative to the original data set. Zero-padding does not meaningfully impact on the results based on the FFT due to 'windowing', which will be explained in further detail below. In the present case, the resolution was set to 0.25 Hz, to allow for a more fine-grained analysis of frequency band-widths such as 8 – 12.75 Hz (requiring bins of 0.25 Hz). This resolution is higher than the 'maximum' resolution of 0.5 Hz permissible from the original 1024 data points, and accordingly, the data were zero-padded up to 2048 data points (Harmon-Jones & Amodio, 2012; Ramirez, 1985).

FFT further assumes a periodic signal that can be decomposed into a series of sine and cosine functions of various frequencies (Harmon-Jones & Amodio, 2012). However, the EEG signal is not exactly periodic as the repetition of features is not uniformly spaced. To address this issue, small overlapping segments or epochs of data are used to render the data with more repeating features. Central to this process, *windowing* is applied to avoid the creation of artefactual frequencies (or 'leakage') as a result of overlapping epochs. Windowing tapers the power of signals at the endpoints of an epoch, reducing it to near-zero values so that discontinuities will not occur when the epochs are overlapped. Many kinds of window functions are available, but the most commonly adopted (and the one used in the present study) is the Hamming window. The window length was set to 100, which means that

it overlaps 100% with the epoch, and symmetrical tapering to near-zero values starts immediately from the centre to both endpoints of the epoch. It is also important for zero-padded data that, via tapering, the signals at the endpoints are dampened to reduce the influence of artificial zeroes on the estimates of spectral power. A 50% overlap between epochs was also specified to prevent data loss due to the attenuation of data at the endpoints. At the same time, this allows the signal to conform to the FFT assumption that each epoch repeats infinitely, both forward and backward in time (Harmon-Jones & Amodio, 2012).

The average power density for each channel over the artefact-free segments across the whole phase was calculated separately for eyes open and eyes closed conditions. Then averaged power from the following frequency domains were extracted: delta (0 – 4 Hz), theta (4 – 7 Hz), alpha (8 – 12.75 Hz), and beta (13 – 30 Hz).

Asymmetry Scores

Averaged power values tend to be positively skewed and so were first natural log transformed to normalise distributions (Davidson et al., 1990b). Asymmetry scores were then calculated by subtracting the natural log transformed average power at the left site from the natural log transformed average power at the right homologous site (i.e., ln[Right]-ln[Left]). Therefore, higher asymmetry scores indicate relatively greater right alpha power, and interpreted as relatively greater left activation (Cook et al., 1998; Davidson et al., 1990b; Oakes et al., 2004). Asymmetry scores were calculated for homologous pains in the frontal (F8 and F7, F6 and F5, F4 and F3), temporal-central (T8 and T7, C6 and C5, C4 and C3) and parietal (P8 and P7, P6 and P5, P4 and P3) regions. Three composite asymmetry indexes were also created by averaging the asymmetry values for the frontal, temporal-central and parietal electrode pairs. Asymmetry values were computed separately for Eyes Open and Eyes Closed conditions, as well as averaged across all conditions.

Additionally, we calculated posterior versus frontal theta-delta activity by subtracting the natural log transformed theta or delta power at Fz from the natural log transformed theta or delta power at Pz (i.e., ln[power@Pz]-ln[power@Fz]) (Wacker et al., 2006). Larger difference scores are indicative of greater power in the posterior region, suggestive of more frontal activation relative to posterior activation.

Procedure

Prior to the laboratory session, interested participants were confirmed either by email or over the phone that they satisfied the selection criteria. They were further informed that the EEG procedure would be non-invasive and require a cap with water-soluble conductive gel to be placed on their head. If this was not objectionable, they were given a few minor preparation instructions: 1) ensure no hair products are in their hair, and if possible, wash their hair with shampoo only before the testing session as excess scalp oil may lead to less accurate measurements, 2) wear glasses instead of contact lenses if corrected vision is needed, and 3) that make up needs to be removed around the eyes and cheeks area for measuring eye movements. When participants arrived in the laboratory, they were given more general information about the study, and then asked to sign a consent form. Following this, they completed computerised versions of the questionnaires administered via Qualtrics. The questionnaires took approximately 30 minute to complete, and consisted of measures not relevant to the present study. After completing the questionnaires, EEG recording equipment was set up and participants completed four one-minute eyes-opened baselines and four one-minute eyes-closed baselines in an alternating, counterbalanced fashion. Following this, participants completed a number of behavioural tasks and additional EG recordings as part of a larger research protocol and not relevant to the present study.

Statistical Analyses

All data were imputed into and primarily analysed using IBM SPSS (v20). Firstly, the meaningful characteristics of the data were explored. This included (i) evaluating data quality (descriptives) at both item and variable levels; (ii) assessing the psychometric properties (including internal reliability) of the self-report scales and EEG indices; (iii) using independent t-tests and correlations to compare any significant differences on study measures as a function of sex, age and relationship status; (iv) examining bivariate relationships between study variables using Pearson's correlations; and (iv) conducting assumptions tests, including screening for multivariate outliers and multicollinearity, in preparation for regression analyses. To test the study's focal hypotheses, along with the bivariate Pearson's correlations, a number of multiple hierarchical linear regressions were conducted. A regression model was conducted for each EEG index, with reinforcement sensitivity and adult attachment as predictors. The more general r-RST motivations were entered in the first step, while adult attachment dimensions were added in an incremental second step. The results are detailed in the next chapter.

Chapter 8: Study 3 – Results

Chapter Overview

This chapter details the results of the exploratory and confirmatory data analyses for Study 3. Firstly, descriptives and internal reliabilities for the self-report measures and EEG indices are provided, along with preliminary analyses to explore whether there were any significant differences on the study measures as a function of sex, age, and relationship status. Following this, the chapter reports a number of correlational analyses pertaining to bivariate links between self-reported reinforcement sensitivity, self-reported adult attachment, and EEG correlates of approach and avoidance. Finally, the chapter presents a series of multiple hierarchical regression models that assesses the multivariate relations between adult attachment, reinforcement sensitivity, and EEG indices.

Descriptives and Internal Reliabilities for Self-Report Measures

Table 8.1 reports the descriptives for the self-report measures of adult attachment and reinforcement sensitivity, which were comparable to previous research. The Cronbach's alpha internal consistency reliabilities, also reported in Table 8.1, were generally high across the measures, with the exception of the Heym et al.'s (2016) r-RST scales. Reliabilities for these scales were around the .70's, which is acceptable for research purposes. However, the FFFS Freeze scale exhibited a much lower reliability of .47, similar to low estimates found for the Freeze scale from the Jackson-5 measure in some studies (e.g., Harnett et al., 2013). Therefore, results derived from the Heym et al. (2016) measure needs to be interpreted with caution.

Table 8.1

Descriptives and Cronbach's Alpha Reliabilities for the Self-Report Measures (N = 63)

Measure	Scale	*M*	*SD*	Min	Max	Cronbach's α
ECR-R	Attachment anxiety	3.82	1.26	1.00	6.17	.94
	Attachment avoidance	3.03	1.11	1.00	5.67	.93
Heym's r-RST	BAS reward reactivity	3.41	.46	2.00	4.00	.73
	BAS drive[a]	2.81	.53	1.50	3.75	.78
	FFFS flight	2.40	.62	1.00	3.75	.74
	FFFS freeze	2.22	.57	1.00	3.50	.47
	FFFS fight	2.06	.59	1.00	3.33	.69
	BIS anxiety	3.12	.63	1.25	4.00	.75
	BIS appraisal	3.15	.60	1.33	4.00	.76
CW	BAS fun seeking	3.17	.59	1.25	4.00	.76
	BAS reward responsiveness	3.52	.45	2.40	4.00	.70
FSS	Social anxiety	2.67	.72	1.15	4.38	.88
	Agoraphobia	1.61	.43	1.00	3.00	.75
	Bodily harm	1.85	.61	1.00	3.58	.83
	Sex/aggression	1.95	.62	1.00	4.50	.76
	Animals	1.96	.93	1.00	4.67	.86
	Overall scale mean	1.97	.50	1.17	3.68	.89
STAI	Trait anxiety	2.26	.48	1.15	3.60	.91

Note. ECR-R = Experiences in Close Relationships – Revised Scale (Fraley et al., 2000); Heym's r-RST = Heym et al.'s (2016) r-RST scales; CW = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule-III (Wolpe & Lang, 1964); STAI = State Trait Anxiety Inventory (Spielberger et al., 1983). [a]As the BAS drive scale is identical in Heym et al.'s (2016) and Carver and White's (1994) measures, results for this scale is only reported in the first instance.

Descriptives and Internal Reliabilities for EEG Indices

The means and standard deviations for the eyes closed (EC) and eyes open (EO) conditions are presented separately in Table 8.2. Paired samples t-tests revealed a sole significant difference between the EC and EO conditions on parietal versus frontal theta activity, such that, on average, the asymmetry score was lower (indicative of greater relative frontal activity) in the EO condition [$t(61) = -.3.76$, $p < .001$]. Given that asymmetry scores

Table 8.2

Means, Standard Deviations and Internal Consistency Cronbach's Alpha Reliabilities for EEG Alpha Asymmetry Scores and Posterior vs Frontal Theta and Delta Difference Scores as Referenced to Average Head[15] *(N = 63)*

	Eyes Open (4 min)	Eyes Closed (4 min)			Overall (8 min)	
	Mean (*SD*)	Mean (*SD*)	t	*P* value	Mean (*SD*)	Cronbach's α[16]
F4/F3	-.20 (1.66)	-.17 (1.00)	-0.12	.90	-.22 (1.17)	.79
F6/F5	.22 (1.77)	-.05 (0.58)	1.11	.27	.02 (1.06)	.76
F8/F7	-.14 (1.51)	-.16 (1.01)	0.07	.95	-.16 (.97)	.74
C4/C3	-.07 (1.37)	.19 (1.27)	-1.15	.26	-.05 (1.24)	.57
C6/C5	-.05 (1.03)	-.07 (0.69)	-0.15	.88	.07 (0.90)	.54
T8/T7	-.35 (1.74)	-.03 (0.28)	-1.35	.18	-.03 (1.11)	.66
P4/P3	.07 (1.09)	-.01 (0.72)	0.48	.63	.04 (0.65)	.66
P6/P5	.06 (1.24)	.18 (0.50)	-0.80	.43	.12 (0.71)	.73
P8/P7	.24 (1.00)	.31 (0.64)	-0.58	.56	.27 (0.69)	.79
Composite FAA	.00 (1.06)	-.14 (0.67)	0.94	.35	-.09 (0.69)	.22
Composite CAA	-.16 (1.00)	.10 (0.86)	-1.60	.12	.00 (0.80)	.57
Composite PAA	.11 (0.70)	.15 (0.54)	-.42	.68	.13 (0.54)	.56
Pz/Fz theta	-.34 (0.61)	-.20 (0.68)	-3.76	.00***	-.28 (.62)	.98
Pz/Fz delta	-.01 (0.92)	.05 (0.90)	-1.44	.15	.00 (.90)	.98

Note. Frontal asymmetry scores calculated by ln(Right) – ln(Left). Composite FAA = mean frontal alpha asymmetry score across F4/F3, F6/F5 and F8/F7 sites; Composite CAA = mean central alpha asymmetry scores across C4/C3, C6/C5 and T8/T7 sites; Composite PAA = mean parietal alpha asymmetry scores across P4/P3, P6/P5 and P8/P7 sites. Posterior vs frontal theta-delta activity was calculated by ln(Power@Pz) – ln(Power@Fz). ***$p < .001$.

generally did not significantly differ between EC and EO conditions, the scores were averaged across the two conditions in subsequent analyses.

The descriptives for the alpha asymmetry scores averaged across EC and EO conditions for the frontal, central and parietal sites, along with posterior vs frontal theta-delta

[15] The mean alpha asymmetry scores did not defer significantly when the data were referenced to linked mastoids.

[16] Cronbach's alphas were also calculated for the EO and EC conditions separately. Values were similar and acceptable, ranging from .50 to .83 for EO conditions, and .53 to .93 for EC conditions.

asymmetry activity are also shown in Table 8.2. Although internal reliabilities for EEG alpha asymmetry scores are not conventionally calculated, it was examined in the present study. Following Allen, Urry, Hitt and Coan (2004), the internal reliabilities of the alpha asymmetry scores were assessed by dividing the eight minutes of resting EEG data into one minute epochs, and then treating each epoch as an item on an eight item scale. Table 8.2 displays the internal reliabilities for the alpha asymmetry scores across the frontal, central and parietal sites, as well as for the posterior vs frontal theta-delta asymmetry scores, when referenced to averaged head. Internal reliabilities for the alpha asymmetry scores were generally acceptable, ranging from 54.to .79. In particular, the Cronbach's alphas for the frontal sites of interest (F4/F3, F6/F5 and F8/F7) were acceptable and towards the higher end of the range, with a mean of .76. These reliabilities were slightly lower than but still comparable to those reported by Allen et al. (2004) for their eight minute resting EEG data in a sample of 30 women. For resting baseline referenced to average head, they found a mean Cronbach's alpha of .87 across all regions, and Cronbach's alphas of .89 for both F4/F3 and F8/F7. As shown in Table 8.2, Cronbach's alpha internal reliabilities were also calculated for the composite asymmetry scores across the frontal (FAA: F4/F3, F6/F5, and F8/F7), central (CAA: C4/C3, C6/C5, and T8/F7), and parietal (PAA: P4/P3, P6/P5, and P8/P7) regions. The Cronbach's alpha for these composite indices were generally lower than for each contributing homologous pair, and was extremely low for the composite alpha asymmetry score for the frontal region (Cronbach's $\alpha = .22$). Therefore, subsequent analyses included asymmetry scores calculated from individual homologous pairs of electrodes rather than the composite score.

Table 8.2 also displays the internal reliabilities for parietal versus frontal delta and theta asymmetry scores. As with the FAA scores, the eight minutes of resting delta and theta asymmetry scores were divided into one minute epochs, and each one minute epoch was

treated as an item on an eight-item scale. In contrast to FAA, both parietal versus frontal delta and theta asymmetry scores possessed excellent internal reliability. This is in accord with high reliability estimates found in previous studies (Wacker et al., 2008; Wacker & Gatt, 2010).

Background Analyses

The means and standard deviations for males and females are presented separately in Table 8.3 for the self-report measures, and in Table 8.4 for the EEG indices. Independent samples t-tests revealed that, compared to males, females had significantly higher mean scores for FFFS Flight, FFFS freeze, and BIS anxiety. There were no significant sex differences on any of the other self-report measures, nor for the EEG indices of interest (see Table 8.4).

Table 8.3 and 8.4 also shows the descriptives for individuals who in a current relationship and for individuals who are not in a current relationship, for the self-report measures and EEG indices respectively. Independent samples t-tests revealed that, compared to those who were not in a current relationship, individuals who were currently romantically involved had significantly lower levels of attachment anxiety, attachment avoidance, and agoraphobic fears. There were no significant differences between the two groups on the measures of reinforcement sensitivity or EEG indices (although the difference approached significance for alpha asymmetry scores at C4/C3).

The correlations between age and self-reported measures and asymmetry indices are displayed in Table 8.5. Older participants tended to report significantly higher levels of BIS appraisal (r = -.31, p = .01). There were no significant correlations between age and any of the EEG indices.

As the sociodemographic variables (age, gender, and relationship status) were

Table 8.3

Means, Standard Deviations and Independent T-Tests for Gender and Relationship Status Groups on the Self-Report Measures

		Sex				Relationship status			
		Male (n = 19)	Female (n = 44)			Not in a Relationship (n = 41)	In a Relationship (n = 22)		
Measure	Scale	Mean (SD)	Mean (SD)	t	*P* value	Mean (SD)	Mean (SD)	t	*P* value
ECR-R	Anxiety	3.76 (1.33)	3.84 (1.24)	-0.25	.81	4.21 (1.05)	3.09 (1.32)	3.70	.00***
	Avoidance	3.17 (1.05)	2.97 (1.14)	0.67	.51	3.42 (0.96)	2.30 (1.00)	4.36	.00***
Heym's r-RST	BAS reward	3.32 (0.50)	3.45 (0.45)	-1.02	.31	3.39 (0.43)	3.45 (0.53)	-0.49	.63
	BAS drive	2.72 (0.59)	2.84 (0.51)	-0.80	.43	2.76 (0.49)	2.90 (0.60)	-1.01	.32
	FFFS flight	2.14 (0.68)	2.51 (0.57)	-2.17	.03*	2.46 (0.57)	2.28 (0.72)	1.05	.30
	FFFS freeze	1.99 (0.53)	2.32 (0.56)	-2.21	.03*	2.25 (0.51)	2.17 (0.68)	0.52	.60
	FFFS fight	2.14 (0.56)	2.02 (0.60)	0.75	.46	2.04 (0.63)	2.08 (0.52)	-0.20	.84
	BIS anxiety	2.75 (0.69)	3.27 (0.53)	-3.27	.00***	3.19 (0.54)	2.98 (0.76)	1.19	.20
	BIS appraisal	3.14 (0.61)	3.16 (0.60)	-0.11	.91	3.19 (0.60)	3.09 (0.61)	0.60	.55
CW-BAS	BAS fun-seeking	3.17 (0.51)	3.16 (0.62)	0.04	.97	3.13 (0.64)	3.24 (0.48)	-0.71	.48
	BAS reward	3.31 (0.48)	3.61 (0.40)	-2.60	.01	3.48 (0.43)	3.58 (0.47)	-0.84	.41
FSS	Social anxiety	2.47 (0.76)	2.76 (0.70)	-1.46	.15	2.80 (0.76)	2.43 (0.59)	1.98	.05
	Agoraphobia	1.53 (0.37)	1.65 (0.46)	-0.96	.34	1.70 (0.46)	1.46 (0.33)	2.11	.04*
	Bodily harm	1.88 (0.74)	1.84 (0.55)	0.25	.80	1.86 (0.60)	1.82 (0.63)	0.25	.81
	Sex/aggression	1.90 (0.86)	1.97 (0.50	-0.42	.67	2.03 (0.63)	1.81 (0.60)	1.37	.18
	Animals	1.70 (0.88)	2.06 (0.94)	-1.43	.16	1.93 (0.91)	1.99 (0.99)	-0.23	.82
	Total	1.88 (0.62)	2.01 (0.44)	-0.98	.33	2.04 (0.52)	1.85 (0.45)	1.43	.16
STAI	Trait anxiety	2.26 (0.47)	2.25 (0.49)	0.16	.87	2.31 (0.48)	2.16 (0.47)	1.16	.25

Note. ECR-R = Experiences in Close Relationships – Revised Scale (Fraley et al., 2000); Heym's r-RST = Heym et al.'s (2016) r-RST scales; CW = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule-III (Wolpe & Lang, 1964); STAI = State Trait Anxiety Inventory (Spielberger et al., 1983). *p < .05; ***p < .001.

Table 8.4

Means, Standard Deviations and Independent T-Tests for Gender and Relationship Status Groups on the EEG Indices of Interest

	Sex				Relationship status			
	Male (n = 19)	Female (n = 44)			Not in a relationship (n = 41)	In a relationship (n = 22)		
Asymmetry index	Mean (SD)	Mean (SD)	t	*P* value	Mean (SD)	Mean (SD)	t	*P* value
F4/F3	-.32 (1.54)	-.15 (0.96)	-.56	.58	-.18 (1.16)	-.25 (1.20)	.23	.82
F6/F5	.03 (1.02)	.01 (1.02)	.08	.94	-.02 (1.06)	.08 (0.92)	-.40	.69
F8/F7	-.25 (1.31)	-.18 (0.77)	-.29	.77	-.20 (0.93)	-.19 (1.06)	-.05	.96
C4/C3	-.02 (1.29)	-.10 (1.19)	.25	.81	.11 (1.11)	-.44 (1.33)	1.80	.08
C6/C5	0.25 (1.18)	-.04 (0.72)	1.25	.22	.14 (0.94)	-.11 (0.78)	1.11	.27
T8/T7	0.09 (1.06)	-.04 (1.14)	.47	.64	-.07 (1.21)	.13 (0.88)	-.70	.49
P4/P3	-.16 (0.63)	.14 (0.60)	-1.87	.07	.09 (0.63)	-.03 (0.61)	.72	.47
P6/P5	0.16 (0.61)	.12 (0.74)	.19	.85	.24 (0.62)	-.09 (0.80)	1.90	.06
P8/P7	0.22 (0.70)	0.31 (0.71)	-.44	.66	.31 (0.77)	.22 (0.54)	.49	.63
Pz/Fz theta	-.42 (0.86)	-.24 (0.45)	-1.13	.26	-.28 (0.61)	-.33 (0.61)	.31	.75
Pz/Fz delta	-.11 (1.12)	.02 (0.75)	-.60	.55	.01 (0.95)	-.08 (0.74)	.37	.71

Table 8.5

Correlations between Age and Self-reported Measures and EEG Asymmetry Indices of Interest (N = 63)

Self-report measures	*r*	*p* value	Asymmetry indices	*r*	*p* value
Attachment anxiety	.06	.62	F4/F3	-.07	.61
Attachment avoidance	-.17	.19	F6/F5	.00	.98
BAS reward reactivity	-.03	.79	F8F7	-.15	.23
BAS drive	-.18	.16	C4C3	.10	.43
FFFS flight	-.03	.81	C6/C5	.10	.43
FFFS freeze	-.08	.52	T8/T7	-.05	.69
FFFS fight	-.06	.67	P4/P3	-.13	.30
BIS anxiety	-.24	.06	P6/P5	.05	.71
BIS appraisal	-.31*	.01	P8/P7	-.09	.47
CW-BAS fun seeking	.01	.95	Pz/Fz theta	-.14	.29
CW-BAS reward responsiveness	-.13	.32	Pz/Fz delta	-.10	.41
FSS social anxiety	.05	.72			
FSS agoraphobia	.01	.96			
FSS bodily harm	.17	.18			
FSS sex/aggression	.13	.30			
FSS animals	.01	.93			
FSS overall scale mean	.05	.69			
STAI trait anxiety	.07	.59			

Note. *$p < .05$. ECR-R = Experiences in Close Relationships – Revised Scale (Fraley et al., 2000); CW = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule-III (Wolpe & Lang, 1964); STAI = State Trait Anxiety Inventory (Spielberger et al., 1983).

generally not significantly associated with the EEG indices, to maximise statistical power and model parsimony, these variables were not entered as covariates in the final reported regression analyses. Where the variables are entered as covariates for comparison, the results are noted in the footnotes and detailed in the appendices.

Correlations

Correlations between the Self-Report Measures

Table 8.6 displays the Pearson's correlations between the self-report measures. The

correlations between the measures of attachment and reinforcement sensitivity showed a similar pattern to that found in Studies 1 and 2. Attachment anxiety was positively and modestly correlated with FFFS sensitivity as indexed by FFFS freeze and FSS overall mean. Both attachment anxiety and avoidance were also correlated with higher levels of social anxiety fears, with no significant difference in the magnitude of the correlations, Hotelling's t (63) = 0.62, $p > .05$. However, neither attachment dimensions were significantly correlated with bodily harm, which is argued to best index FFFS sensitivity compared to the other types of fear (Perkins et al., 2007). Also contrary to Study 1, there were no significant correlations between attachment avoidance and BAS sensitivity, although all of the correlations (except between attachment avoidance and BAS drive) were in the expected inverse direction (r = -.14 to -.19). Furthermore, STAI trait anxiety was positively correlated with both attachment dimensions. Hotelling's t-test revealed that the correlation between STAI trait anxiety and attachment anxiety was significantly stronger than with attachment avoidance, t (63) = 2.97, $p < .01$. Additionally, attachment anxiety was positively correlated with Heym et al.'s (2016) BIS anxiety scale. The intercorrelation between the attachment dimensions was moderate-large (r = 58, $p < .001$), which is higher than generally reported (e.g., Study 1: r = .35, $p <$ .001).

Among the measures of reinforcement sensitivity, a manifold of significant positive correlations was observed among the BAS scales (r = .34 to .81, $p < .01$), with the exception of a non-significant positive correlation between BAS drive and BAS fun seeking. BAS drive also had relatively smaller correlations with the other BAS scales. Conversely, Heym et al.'s (2016) BAS reward scale exhibited large correlations with Carver and White's (1994) fun seeking and reward responsiveness scales. Heym et al.'s (2016) FFFS Flight and Freeze scales exhibited moderate-large positive intercorrelations, and weaker non-significant

Table 8.6

Pearson's Correlations between the Self-Reported Measures of Adult Attachment and Reinforcement Sensitivity (N = 63)

Measure	Scale	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ECR-R	1 Anxiety	1																	
	2 Avoidance	.58***	1																
Heym's r-RST	3 BAS Reward	-.05	-.14	1															
	4 BAS Drive	-.08	.02	.41***	1														
	5 FFFS Flight	.20	.09	.11	.10	1													
	6 FFFS Freeze	.30*	.13	.01	.13	.60***	1												
	7 FFFS Fight	.14	.18	.07	.22†	.13	.16	1											
	8 BIS Anxiety	.38**	.16	-.09	-.23†	.19	.15	.13	1										
	9 BIS Appraisal	.17	.20	-.06	.22†	.10	.09	.02	.05	1									
CW	10 BAS-FS	-.07	-.16	.78***	.17	.04	-.14	-.09	-.11	-.29*	1								
	11 BAS-RR	-.08	-.19	.81***	.34**	.16	.10	.16	.15	.01	.43***	1							
FSS fears	12 Social anxiety	.39**	.32**	-.24†	-.15	.00	.23†	.08	.52**	.00	-.34**	-.09	1						
	13 Agoraphobia	.24†	.18	-.07	.05	.20	.26*	.21†	.17	.06	-.20*	-.02	.60***	1					
	14 Bodily harm	.15	-.03	.02	.10	.27*	.15	-.04	-.07	.00	-.04	-.01	.25*	.40**	1				
	15 Sex/aggression	.14	.09	-.06	.17	.32**	.34**	.04	-.05	-.04	-.16	-.12	.41***	.50***	.61***	1			
	16 Animals	.00	.10	.08	.14	.33**	.33**	-.05	-.05	-.02	-.04	-.17	.31*	.41***	.47***	.54***	1		
	17 Total	.26*	.24†	-.11	.06	.27*	.36**	.11	.16	.01	-.21†	-.09	.71***	.76***	.70***	.81***	.69***	1	
STAI	18 Trait anxiety	.61***	.34*	-.16	-.15	.14	.28*	.22†	.50***	.03	-.13	-.20	.54***	.29*	.25†	.31*	-.06	.41***	1

Note. †$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

correlations with Heym et al.'s (2016) FFFS fight scale. FFFS flight and freeze also had generally significant though modest positive correlations with the FSS scales and overall mean fear ratings, while FFFS fight was not significantly correlated with the FSS scale means or overall mean. Aside from a significant and modest correlation between FFFS freeze and STAI trait anxiety, there were no significant correlations between Heym et al.'s (2016) FFFS scales and the measures of BIS sensitivity. Finally, there was a positive manifold of significant correlations between the FSS scales (r = .25 to .81, p < .05). The FSS scales, with the exception of animal fear (non-significant) and bodily harm (marginally significant), also had significant and positive correlations with trait anxiety, but not with Heym et al.'s (2016) BIS anxiety or BIS appraisal scales.

Summary of correlational patterns between the self-report measures

Similar to Study 1 and 2, at the self-report level, attachment anxiety was positively correlated with FFFS sensitivity, while both attachment anxiety and attachment avoidance were more notably linked to measures of BIS sensitivity. However, contrary to the results of Study 1, attachment avoidance was unrelated to BAS sensitivity.

Correlations between the EEG Indices

Table 8.7 displays the correlations between the EEG asymmetry indices of interest. Firstly, it may be noted that the alpha asymmetry scores at the frontal electrode sites (F4/F3, F6/F5, and F8/F7) were not significantly correlated. This suggests a lack of convergence in electrical signal between these sites (which is reflected in the previously reported low internal reliability of the composite frontal alpha asymmetry score). In contrast, alpha asymmetry

Table 8.7

Pearson's Correlations between the EEG indices of Interest (Alpha Asymmetry Scores and Parietal versus Frontal Theta and Delta Activities) (N = 60 to 63)

		1	2	3	4	5	6	7	8	9	10	11
Alpha asymmetry												
1	F4/F3	1.00										
2	F6/F5	.17	1.00									
3	F8/F7	.05	.03	1.00								
4	C4/C3	.17	.00	.18	1.00							
5	C6/C5	.35**	.17	-.18	.55***	1.00						
6	T8/T7	-.01	.17	-.07	.19	.23†	1.00					
7	P4/P3	.24	.12	-.10	.00	.05	.02	1.00				
8	P6/P5	.30*	.01	-.37**	.32*	.44***	-.22	.24	1.00			
9	P8/P7	-.08	.10	.24	.27*	.01	-.28*	.23	.54***	1.00		
Parietal versus frontal theta and delta activity												
10	Pz/Fz theta	-.25*	.14	.26*	-.22	-.26*	-.07	-.04	-.21	-.04	1.00	
11	Pz/Fz delta	-.31*	.06	.25*	-.07	-.21	.02	-.26*	-.21	-.06	.75***	1.00

Note. *$p < .05$; **$p < .01$; ***$p < .001$.

score at the C6/C5 site was positively correlated with alpha asymmetry scores at the neighbouring electrode sites of C4/C3 and T8/T7 respectively. Likewise, alpha asymmetry scores at P6/P5 and P8/P7 exhibited a significant positive intercorrelation, while P4/P3 had positive correlations with both P6/P5 and P8/P7 that trended towards significance ($p = .07$ and $p = .08$ respectively). The alpha asymmetry score at C4/C3 also had small but consistent correlations with parietal alpha asymmetry (P6/P5 and P8/P7).

Furthermore, as reported in Table 8.7, parietal versus frontal theta and delta activities were highly correlated ($r = .75$, $p < .001$). Both indices were also positively correlated with alpha asymmetry at F8/F7, which is in line with the proposal that all three indices tap approach motivation. However, both indices, contrary to theoretical expectations were negatively correlated with alpha asymmetry at F4/F3. Parietal versus frontal theta activity

was also negatively correlated with alpha asymmetry at C6/C5, while parietal versus frontal delta activity had a significant negative correlation with alpha asymmetry at P4/P3.

Correlations between the Self-Report Measures and EEG Indices

Alpha asymmetry

The correlations between the measures of attachment and reinforcement sensitivity and alpha asymmetry scores are displayed in Table 8.8.[17] Attachment anxiety was significantly and negatively correlated with alpha asymmetry at F8/F7. The correlations at the other two frontal sites, F4/F3 and F6/F5, were negative in direction but not significant. Attachment anxiety was also significantly and positively correlated with alpha asymmetry at P6/P5. The correlations between attachment avoidance and FAA scores were negligible and non-significant, although the dimension was positively correlated with alpha asymmetry at C4/C3 and P6/P5. There were no other significant associations between the attachment dimensions and the alpha asymmetry scores.

Heym et al.'s (2016) BAS drive scale was significantly and positively correlated with alpha asymmetry at F4/F3. However, there were no other significant correlations between the measures of BAS sensitivity and FAA. With respect to the other brain regions, both Heym et al.'s (2016) BAS reward scale and CW-BAS fun seeking were positively correlated with alpha asymmetry at T8/T7, while CW-BAS fun seeking was also negatively correlated with alpha asymmetry scores at P6/P5. There were no other significant correlations between the

[17] Some papers have suggested that low alpha frequency (8-10 Hz) is more strongly associated with approach motivation than high alpha frequency (10-13 Hz) (Davidson, Marshall, Tomarken, & Henriques, 2000; Goncharova & Davidson, 1995; Wacker, Heldmann, & Stemmler, 2003). Given this possibility, the broad alpha frequency was divided into low and high alpha frequency, and alpha asymmetry scores were calculated. There were fewer significant correlations between the self-report measures and both low and high alpha asymmetry, compared with broad alpha asymmetry scores. As the significant correlations with low and high alpha asymmetry scores were not more meaningful, analyses were conducted on broad alpha frequency asymmetry scores. The correlation tables for the low and high alpha asymmetry scores can be found in Appendix E.

Table 8.8

Pearson's Correlations between Self-Reported Measures of Adult Attachment and Reinforcement Sensitivity and EEG Indices of Interest (Alpha Asymmetry Scores and Parietal versus Frontal Theta and Delta Scores)

Measure	Scale	F4/F3	F6/F5	F8/F7	C4/C3	C6/C5	T8/T7	P4/P3	P6/P5	P8/P7	Pz/Fz theta	Pz/Fz delta
ECR-R	1 Attachment anxiety	-.12	-.22	-.30*	.21	.11	-.11	.13	.28*	.07	.00	-.08
	2 Attachment avoidance	-.07	-.05	-.12	.26*	.12	-.11	.18	.30*	.11	.06	-.08
Heym's r-RST	3 BAS reward reactivity	-.04	.24	.03	-.03	.00	.29*	.07	-.18	-.12	.12	.16
	4 BAS drive	.28*	.12	.00	-.05	.01	.07	.24	.05	-.10	.18	.07
	5 FFFS flight	-.24	.09	-.24	-.15	-.32*	-.06	.12	-.10	.05	.00	.06
	6 FFFS freeze	-.09	-.02	-.24	-.21	-.27*	-.13	.15	-.06	-.09	.22	.13
	7 FFFS fight	.06	.16	-.17	.04	.04	-.02	.06	.04	-.09	.02	-.02
	8 BIS anxiety	-.07	-.24	-.04	-.08	-.11	-.06	.11	.02	.09	.09	-.01
	9 BIS appraisal	-.07	-.03	-.01	.05	.12	-.04	.12	.15	.06	.15	.07
CW	10 BAS fun seeking	-.05	.12	-.07	-.03	.01	.35**	-.01	-.26*	-.24	-.12	-.06
	11 BAS reward responsiveness	-.07	.22	.00	-.14	-.01	.13	.03	-.06	.00	.22	.23
FSS fears	12 Social anxiety	.08	-.22	-.04	-.06	-.02	-.11	.07	.09	.07	.19	.03
	13 Agoraphobia	.19	.03	-.02	-.04	-.04	-.16	.03	.09	.18	.15	.04
	14 Bodily damage	-.06	-.06	-.03	-.15	-.16	-.08	.02	-.02	-.09	.16	.26*
	15 Sex/aggression	.17	.01	.08	-.04	-.12	-.14	.04	-.13	-.12	.30*	.19
	16 Animals	.19	.17	.02	-.02	-.09	-.05	-.02	-.06	-.02	.16	.13
	17 Total	.15	-.05	-.01	-.09	-.12	-.15	.04	.01	-.01	.25*	.16
STAI	18 Trait anxiety	-.18	-.29*	-.11	-.03	-.19	-.09	.09	-.07	-.05	.20	.19

Note. ECR-R = Experiences in Close Relationships – Revised Scale (Fraley et al., 2000); Heym's r-RST = Heym et al.'s (2016) r-RST scales; CW = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule-III (Wolpe & Lang, 1964); STAI = State Trait Anxiety Inventory (Spielberger et al., 1983). *$p < .05$; **$p < .01$.

measures of BAS sensitivity and alpha asymmetry.

Heym et al.'s (2016) FFFS flight and FFFS freeze scales displayed a pattern of negative correlations with alpha asymmetry scores at almost all frontal and central-temporal sites, but this was significant only at C6/C5. Heym et al.'s (2016) FFFS fight scale, FSS specific fear scores, and FSS overall fear score were not significantly correlated with any of the alpha asymmetry indices.

With regards to the measures of BIS sensitivity, STAI trait anxiety was significantly and negatively correlated with alpha asymmetry at F6/F5. There were no other significant correlations between the measures of BIS sensitivity and alpha asymmetry scores.

Parietal versus frontal theta and delta activities

Contrary to hypotheses, the approach-related constructs (i.e., BAS sensitivity and attachment avoidance) did not show significant correlations with parietal versus frontal theta and delta activity (see also Table 8.8). However, there were significant positive correlations between sex/aggression fear and FSS overall mean and parietal versus frontal theta activity, as well as between fear of bodily damage and parietal versus frontal delta activity. Posterior versus frontal theta and delta activity was not significantly associated with any of the other self-report measures.

Summary of the correlational patterns between the self-report measures and EEG indices

In general, there were few significant correlations between the self-report measures and frontal alpha asymmetry. Attachment anxiety, FFFS sensitivity and BIS sensitivity were, to a small degree, inversely related to FAA scores, indicative of greater relative right frontal activity and withdrawal tendencies. However, the

association was often only significant at one electrode site (and trending towards significance for FFFS sensitivity), and was not consistent across the three pairs of frontal electrode sites and different measures of FFFS and BIS sensitivity. Similarly, among the measures of BAS sensitivity, only Carver and White's (1994) BAS drive scale exhibited a significant, positive correlation with FAA scores at F4/F3, weakly indicative of greater relative left frontal activity and approach motivation. Furthermore, there was a lack of significant associations between the self-report measures and parietal versus frontal delta and theta activities.

Hierarchical Multiple Regressions

Since both attachment dimensions and reinforcement sensitivity can be conceptualised within an approach-withdrawal framework, we tested a hierarchical multiple regression model in which the general motivational tendencies of reinforcement sensitivity were entered in Step 1 (with Heym et al.'s purpose-built RST scales and the proxy RST indices in separate models) and the more domain-specific attachment patterns were entered in Step 2. Heym et al.'s (2016) purpose-built RST scales were entered in Step 1 in the first set of regression models, and Carver and White's (1994) BAS scales along with the proxy measures of BIS and FFFS sensitivities were entered in Step 1 in a second set of regression models. The independent variables were regressed onto the alpha asymmetry scores at each of the nine homologous sites, as well as parietal versus frontal, theta and delta activities.

Multivariate Outliers

As part of post-hoc regression diagnostics, the data were screened for multivariate outliers. Outliers are defined as extreme or atypical data points of dubious origin and/or disproportionate influence, which are recognised to have harmful effects on error variance,

statistical power, type I/II error rates, and the accuracy of parameter estimates (Osborne, 2010; Cohen, Cohen, West, & Aiken, 2003). With regards to multivariate outliers, these cases are observed to have atypical or extreme scores on two or more variables (Cohen et al., 2003). In the present study, a number of tests were used to identify multivariate outliers including leverage, discrepancy, and global and specific influence.

Leverage refers to how far away is an observation's standing with respect to the mean values on the set of independent (predictor) variables (Cohen et al., 2003). In the present study, Centered Leverage Values (CLV) were obtained via SPSS. Outlying cases that had substantially higher CLVs than other cases were identified using both visual inspection (by creating an index plot of the CLV) and a rule of thumb cut-off of $2 \times [(k+1)/n]$ (where k refers to the number of predictors in the regression model, and n refers to the sample size) (Belsky, Kuh, & Welsch, 1980). For the set of regression models containing Heym's r-RST scales, there was only one case identified as having a very high leverage value (.369) using visual inspection and the cut-off (.323). For the set of regression models containing Carver and White's (1994) BAS scales and the proxy r-RST measures, there were three cases with leverage values (.325, .305, and .296) above the cut-off (.258) and observed to be substantially higher on the index plot.

Discrepancy (or *distance*) refers to the difference between the predicted and observed values on the criterion variable (Cohen et al., 2003). Whilst raw residuals can provide an indication of discrepancy, outliers can pull the regression line toward them to improve the overall fit, and thereby diminish the deviation (raw residual value). Given this issue, Cohen et al. (2003) recommended examining the externally studentised residuals, which estimates the residual with the influential observation deleted. Externally studentised residuals were once again obtained via SPSS, and extreme observations were identified using visual inspection of an index plot of the residuals. As externally studentised residual values follow a t-distribution

and so 5% of cases are expected to be greater than 2.0 in magnitude, a cut-off of ± 2.0, as recommended by Cohen et al. (2003), was also implemented. The identified cases for the series of regressions using Heym's r-RST scales as predictors and for the series of regressions using Carver and White's (1994) BAS scales and the proxy r-RST measures are presented in Tables 8.9 and 8.10 respectively. The tables show that for each criterion, there were two to six identified cases above the cutoff, as expected for the t-distribution of residuals.

Finally, measures of *influence* combine leverage and discrepancy information to provide an estimate of how the regression equation would change if an observation is removed from the data set (Cohen et al., 2003). There are two types of influence: *global influence*, which refers to how an observation affects the overall characteristics of the regression equation; and *specific influence*, which refers to an observation affects the estimate of specific regression coefficients. To assess global influence, we used Cook's D (Cook, 1977), which compares the predicted values of the criterion with a case included and deleted, for all cases in the data set. An index plot of Cook's D values, obtained via SPSS, was visually inspected for potentially influential cases, and then a rule of thumb cut-off value of 1.0 was applied (Cohen et al., 2003). The diagnostic test results for global influence are summarised in Table 8.10 for the regression models using Heym's r-RST scales, and in Table 8.11 for the regression models using Carver and White's (1994) BAS scales and proxy r-RST measures. Although visual inspection of the T plot suggests some observations with higher Cook's D, none of these values exceeded the diagnostic cut-off. Therefore, the data did not contain observations with notably strong global influence. In terms of specific influence, DFBETAS were obtained via SPSS, which indicates both the direction and magnitude that the regression coefficients would change with the inclusion of a case (Cohen et al., 2003). A cut-off of > ±1 is recommended by Cohen et al. (2003) for small to moderate sample sizes, and so was adopted in the present study. The diagnostic results for specific influence are also

Table 8.9

Minimum and Maximum Values for Studentised Deleted Residuals, Along with the Number of Extreme Cases and their Values for Each Asymmetry Score Criterion Using Heym's r-RST Measures and Adult Attachment as Predictors

Criterion	Min	Max	No. of cases exceed cutoff (±2.0)	Case values
F4/F3	-3.186	2.302	6	-3.19*, -2.91*, 2.88*, -2.23, -2.09, 2.30
F6/F5	-4.010	2.616	6	-4.01, -2.11, -2.09, 2.12, 2.44, 2.62
F8/F7	-3.356	4.242	5	-3.36, -2.53, -2.25, 2.27, 4.24*
C4/C3	-3.552	2.475	5	-3.55*, -3.10*, -2.97*, 2.34, 2.47
C6/C5	-2.509	4.438	5	-2.51, -2.03, 3.30*, 3.55*, 4.44*
T8/T7	-2.253	4.269	5	-2.25, -2.13, -2.04, 3.70*, 4.27*
P4/P3	-3.701	3.508	4	-3.70)*, -3.45*, 2.02, 3.51*
P6/P5	-3.306	3.160	4	-3.31*, -3.03*, -2.42, 3.16*
P8/P7	-2.98	4.086	2	-2.99*, 4.37*
Pz/Fz theta	-2.455	2.816	4	-2.45, 2.82*, 2.29, 2.78*
Pz/Fz delta	-2.456	3.242	6	-2.46, -2.31, -2.04, 2.19, 3.00*, 3.24*

*Deviating cases as observed from t-plot

Table 8.10

Minimum and Maximum Values for Studentised Deleted Residuals, Along with the Number of Extreme Cases and their Values for Each Asymmetry Score Criterion Using Carver and White's (1994) BAS Scales, Proxy r-RST Measures and Adult Attachment as Predictors

Criterion	Min	Max	No. of cases exceed cutoff? (±2.0)	Case values
F4/F3	-3.279	2.481	3	-3.28, -3.12, 2.48*
F6/F5	-4.209	2.390	6	-4.21*, -2.15, 2.04, 2.06, 2.24, 2.39
F8/F7	-3.814	4.602	4	-3.81, -2.39, -2.27, 4.60*
C4/C3	-3.515	2.719	5	-3.51*, -2.99*, -2.92*, 2.15, 2.72*
C6/C5	-2.135	5.263	4	-2.13, 2.82, 3.81, 5.26*
T8/T7	-2.097	4.092	4	-2.10, 2.09, 3.41*, 4.09*
P4/P3	-3.602	3.597	4	-3.60*, -3.52*, 2.00, 3.60*
P6/P5	-2.776	3.215	5	-2.78, -2.70, -2.69, -2.06, 3.21*
P8/P7	-2.979	4.235	2	-2.98, 4.23*
Pz/Fz theta	-1.779	3.286	3	3.29*, 2.22, 3.21*
Pz/Fz delta	-1.956	3.579	4	2.08, 2.66*, 2.81*, 3.25*

*Deviating cases as observed from t-plot

Table 8.11

Summary of Global and Specific Influence Diagnostic Tests for the Regression Models Containing Heym's r-RST Scales and Adult Attachment as Predictors

Criterion	Cook's D				DFBETAS
	Min	Max	Cases above cutoff (1.0)	Cases identified from T plot	Cases exceeding cutoff (± 1)
F4/F3	.000	.145	none	none	none
F6/F5	.000	.443	none	.443, .121	none
F8/F7	.000	.297	none	.297, .231	none
C4/C3	.000	.359	none	.359	3.16 (DFB0)
C6/C5	.000	.646	none	.646, .360	3.00 (DFB0), 1.15 (DFB5)
T8/T7	.000	.331	none	.331	1.18 (DFB0), -1.05 (DFB0)
P4/P3	.000	.167	none	none	None
P6/P5	.000	.154	none	none	None
P8/P7	.000	.210	none	.210, .192	None
PzFz theta	.000	.138	none	none	None
PzFz delta	.000	.133	none	none	None

Table 8.12

Summary of Global and Specific Influence Diagnostic Tests for the Regression Models Containing Carver and White's (1994) BAS Scales, Proxy r-RST Measures, and Adult Attachment as Predictors

Criterion	Cook's D				DFBETAS
	Min	Max	Cases above cutoff (1.0)	Cases identified from T plot	Cases exceeding cutoff (± 1)
F4/F3	.000	.220	None	.220, .182	-1.06 (DFB0)
F6/F5	.000	.549	None	.549	None
F8/F7	.000	.359	None	.359, .155	None
C4/C3	.000	.247	None	.248, .210	2.27 (DFB0), -1.14 (DFB0)
C6/C5	.000	.398	None	.398, .279	2.19 (DFB0)
T8/T7	.000	.131	None	none	none
P4/P3	.000	.246	None	.246, .151	none
P6/P5	.000	.170	None	.170, .159	none
P8/P7	.000	.117	None	none	none
PzFz theta	.000	.456	None	.456, .244	none
PzFz delta	.000	.456	None	.456, .244	none

displayed in Tables 8.11 and 8.12. Across the models, there were nine instances (some instances could be attributed to the same participant for different dependent variables) where the DFBETAS exceeded the cut-off, and, most commonly, the specific influence was on the constant of the regression equation. Therefore, there were negligible effects on most of the regression coefficient estimates, with only a few cases of notable specific influence.

Although the study did not identify many cases with high leverage, discrepancy and/or influenced, to ensure data quality, cases that violated the diagnostic criteria for two or more of these tests were deleted list-wise. For the series of regression models containing Heym et al.'s r-RST scales as predictors, there were only three such cases. For the series of regression models containing Carver and White's (1994) BAS scales and proxy measures of r-RST, again there were only three cases (although these were not identical to the previous). Deleting these multivariate outliers from the respective regression models produced results that were largely similar to the results obtained from the full data set (see Appendix F, although associations with posterior versus frontal delta and theta asymmetry were strengthened and standard errors were lower in some models within the current data set. Therefore, because of the slight improvement to data quality, regression results based on the data with the multivariate outliers removed are reported in this chapter.

Multicollinearity

Before detailing the results of the regression analyses, checks on multicollinearity were also performed. Multicollinearity refers to the problem when one or more independent (criterion) variables are highly correlated with other independent (criterion) variable(s) within the regression model (Cohen et al., 2003). In such a case, there would be very little unique information contained in the highly correlated predictor from which to derive an estimate of the regression coefficient β for that predictor. The estimated regression coefficient would be

very unreliable and have a large standard error. Two indices were used to assess multicollinearity. The first index, *tolerance*, is a measure of the degree to which each variable is independent of other predictors in the model. Values range from 0 to 1, with small numbers below .10 indicative of extremely high degrees of overlap (Cohen et al., 2003). [18] In the current study, tolerance values ranged from .45 to .90, which does not fall below the cut-off and indicates a moderate to high degree of independence among the predictors. The second index is the *variance inflation factor* (VIF), and is the reciprocal of the tolerance index. It measures the degree to which the variance of each regression coefficient is inflated, compared to when the predictors are uncorrelated (Cohen et al., 2003). Cohen et al. (2003) recommended that VIF values of 10 and above are indicative of highly correlated variables.[19] In the present study, the VIF values ranged from 1.11 to 2.22, which suggest that the predictors share negligible correlations. Therefore, both the tolerance and VIF values were acceptable, implicating no issues of multicollinearity in the present data.

Alpha Asymmetry

Regressing Heym's r-RST Measure and Adult Attachment on Alpha Asymmetry Scores

Table 8.13 presents the first set of regressions in which Heym's RST scales were used in the first step to predict alpha asymmetry scores. Estimates reported in the table were based on the regression model including both Steps 1 and 2. None of the overall regression models were statistically significant (p = .16 to .75).

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[18] Both Keith (2006) and Cohen et al. (2003) warns that a tolerance cut-off of < .10 and VIF cut-off of > 10 are too low and high respectively, and would require extremely high intercorrelations between predictors to be identified as problematic. Therefore, Keith (2006) recommends alternative cut-offs of < .14 or < .17 for tolerance, and > 6 or 7 for VIF, as more stringent criteria. If these criteria are adopted, the range of tolerance and VIF values in the present data still fall comfortable within the acceptable range, and suggest no issues of multicollinearity.

[19] See previous footnote.

Table 8.13

Hierarchical Regressions Predicting Alpha Asymmetry Scores from Heym's r-RST scales and Adult Attachment (N = 56)

Index	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
	F4F3				**F6F5**				**F8F7**			
Step 1				.17				.17				.12
BAS reward	-.41	.34	-.19		.61	.37	.26		.11	.30	.06	
BAS drive	.50	.30	.28		-.38	.32	-.19		.18	.26	.12	
FFFS flight	-.46	.26	-.30		.27	.28	.16		-.31	.22	-.25	
FFFS freeze	.14	.27	.09		.03	.29	.02		-.07	.23	-.05	
FFFS fight	-.04	.22	-.03		.33	.24	.19		-.09	.19	-.07	
BIS anxiety	.09	.22	.06		-.37	.25	-.22		.16	.19	.13	
BIS appraisal	-.31	.22	-.20		.10	.24	.06		.15	.19	.12	
Step 2				.02				.04				.04
Att. anxiety	-.14	.13	-.19		-.21	.14	-.25		-.16	.11	-.24	
Att. avoidance	.09	.14	.10		.16	.15	.17		.03	.12	.05	
Model statistics	*F (9, 47) = 1.26, p = .28*				*F (9, 47) = 1.38, p = .22*				*F (9, 47) = 1.00, p = .45*			
	C4C3				**C6C5**				**T8T7**			
Step 1				.05				.15				.11
BAS reward	.36	.42	.14		.25	.24	.17		.58	.39	.25	
BAS drive	.05	.37	.02		.13	.21	.10		.03	.33	.02	
FFFS flight	-.10	.31	-.05		-.31	.18	-.29		.10	.29	.06	
FFFS freeze	-.46	.33	-.23		-.18	.19	-.16		-.12	.30	-.07	
FFFS fight	.10	.27	.05		-.07	.16	-.06		-.22	.25	-.13	
BIS anxiety	-.08	.28	-.04		.08	.16	.07		.13	.25	.08	
BIS appraisal	.22	.27	.11		.18	.16	.16		.00	.25	.00	
Step 2				.18*				.07				.01
Att. anxiety	.33	.16	.34*		.09	.09	.16		-.06	.15	-.07	
Att. avoidance	.20	.17	.18		.10	.10	.16		-.05	.16	-.06	
Model statistics	*F (9, 47) = 1.55, p = .16*				*F (9, 47) = 1.41, p = .21*				*F (9, 47) = .70, p = .71*			
	P4P3				**P6P5**				**P8P7**			
Step 1				.05				.06				.07
BAS reward	.23	.23	.17		-.07	.25	-.05		.07	.26	.05	
BAS drive	.02	.20	.02		-.07	.22	-.05		-.19	.22	-.14	
FFFS flight	.01	.17	.01		-.07	.19	-.06		.13	.19	.12	
FFFS freeze	.11	.18	.11		-.16	.19	-.13		-.26	.20	-.23	
FFFS fight	-.06	.15	-.06		.00	.16	.00		.00	.16	.00	
BIS anxiety	.14	.15	.15		-.05	.16	-.05		.03	.17	.03	
BIS appraisal	.05	.15	.05		.08	.16	.07		.11	.17	.10	
Step 2				.08				.17**				.05
Att. anxiety	-.04	.09	-.07		.13	.09	.23		.05	.10	.10	
Att. avoidance	.18	.09	.34		.17	.10	.28		.10	.11	.16	
Model statistics	*F (9, 47) = .77, p = .64*				*F (9, 47) = 1.49, p = .18*				*F (9, 47) = .65, p = .75*			

Note. *$p < .05$; **$p < .01$.

Contrary to hypotheses (1a-1c, 2a-2b), neither the measures of reinforcement sensitivity nor adult attachment were significantly associated with alpha asymmetry scores at any of the frontal electrode sites. Furthermore, neither the incremental steps nor the overall regression models were significant at the frontal electrode sites. Therefore, neither reinforcement sensitivity nor adult attachment evidenced links with FAA scores, contrary to predictions based on the approach-withdrawal model of FAA.

Although no hypotheses were made regarding alpha asymmetry scores in the central-temporal region, the attachment variables in Step 2 accounted for a significant amount of incremental variance at electrode site C4/C3. Attachment anxiety was found to be a significant positive predictor to alpha asymmetry scores at this electrode site. However, the overall regression model was not significant. None of the incremental steps, overall regression models, and predictors were significant at the other two pairs of electrode sites, C6/C5 and T8/T7.

Finally, Contrary to hypothesis 1b, none of the measures of FFFS sensitivity were significantly related to alpha asymmetry scores at the parietal electrode sites. Attachment variables did predict a significant incremental amount of variance in alpha asymmetry scores at P6/P5, although neither attachment dimensions were significant unique predictors. The overall regression model fit statistics were not significant at any of the pairs of parietal electrode sites, including P6/P5.

Regressing Carver and White's (1994) BAS scales, FSS, STAI and Adult Attachment on Alpha Asymmetry Scores

A second set of hierarchical multiple regressions was conducted with Carver and White's (1994) BAS scales and the proxy indices of reinforcement sensitivity (FSS and

STAI-trait anxiety) as predictors in the first step, adult attachment dimensions as predictors in the second step, and the alpha asymmetry scores as the criterion variables. Due to the moderate to high correlations between the FSS fear scales that might implicate problems of multicollinearity, the FSS overall scale means were included in the model. The estimates for the final model containing both steps are shown in Table 8.14.

In the frontal region, none of the regression steps and overall models reached statistical significance. In terms of the independent predictors, contrary to hypothesis 1a, the measures of BAS sensitivity were not significantly associated with FAA scores. Furthermore, contrary to hypotheses 1b and 1c, FFFS sensitivity (as indexed by the proxy measure FSS) and BIS sensitivity (as indexed by trait anxiety) did not have significant associations with FAA scores. Finally, contrary to hypotheses 2a and 2b, neither attachment dimensions were predictive of FAA scores. Therefore, the data did not provide evidence of any associations between FAA and reinforcement sensitivity and adult attachment, contrary to the approach-withdrawal model of FAA.

No hypotheses were made regarding alpha asymmetry scores in the central region. Although none of the overall regression models were significant for the three pairs of electrode sites, Step 2 containing the attachment dimensions accounted for significant incremental amounts of variance for both electrode pairs C4/C3 and C6/C5. For C4/C3, attachment anxiety had a significant, unique, and positive prediction to alpha asymmetry scores. Neither attachment dimensions were significant unique predictors at C6/C5.

Additionally, BAS fun seeking was a significant positive predictor to alpha asymmetry scores at the electrode sites T8/T7, although the incremental steps and overall regression model was not significant. Therefore, the attachment variables, but not the measures of reinforcement sensitivity, appear to have some predictive validity to alpha asymmetry scores in the central region that warrants further investigation.

Table 8.14

Hierarchical Regressions Predicting Alpha Asymmetry Scores from CW-BAS Scales, FSS, STAI-Trait Anxiety, and Adult Attachment (N = 55)

Index	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
	F4F3				**F6F5**				**F8F7**			
Step 1				.16				.15				.06
BAS drive	.31	.29	.16		-.15	.31	-.07		.07	.25	.04	
BAS fun	.01	.25	.01		-.06	.27	-.03		-.27	.22	-.19	
BAS reward	-.66	.39	-.28		.79	.42	.31		-.07	.34	-.03	
FSS	.42	.32	.20		-.14	.34	-.06		.19	.28	.10	
STAI	-.77	.38	-.36		-.56	.40	-.24		-.13	.32	-.07	
Step 2				.00				.03				.06
Att. anxiety	.00	.15	.00		-.08	.16	-.09		-.19	.13	-.27	
Att. avoidance	.03	.15	.04		.22	.16	.22		-.07	.13	-.09	
Model statistics	*F (7, 48) = 1.32, p = .26*				*F (7, 48) = 1.49, p = .19*				*F (7, 48) = 1.14, p = .36*			
	C4C3				**C6C5**				**T8T7**			
Step 1				.02				.03				.16
BAS drive	-.07	.31	-.03		.11	.24	.07		-.12	.33	-.05	
BAS fun	.10	.27	.05		.05	.21	.04		.69	.29	.37*	
BAS reward	-.21	.43	-.08		-.02	.33	-.01		.03	.45	.01	
FSS	-.25	.35	-.10		-.03	.27	-.02		-.25	.37	-.10	
STAI	-.61	.41	-.26		-.56	.32	-.31		.08	.43	.03	
Step 2				.20**				.14*				.00
Att. anxiety	.39	.16	.43*		.20	.13	.30		-.02	.17	-.02	
Att. avoidance	.16	.16	.15		.15	.13	.20		-.03	.17	-.03	
Model statistics	*F (7, 48) = 1.88, p = .09*				*F (7, 48) = 1.31, p = .26*				*F (7, 48) = 1.33, p = .26*			
	P4P3				**P6P5**				**P8P7**			
Step 1				.04				.07				.10
BAS drive	.12	.18	.10		-.15	.18	-.10		-.28	.21	-.20	
BAS fun	.07	.16	.07		-.28	.16	-.24		-.32	.18	-.27	
BAS reward	.00	.24	.00		.16	.25	.09		.19	.29	.11	
FSS	-.15	.20	-.11		-.21	.20	-.14		-.06	.23	-.04	
STAI	.19	.23	.15		-.52	.24	-.35*		-.35	.27	-.23	
Step 2				.08				.26***				.03
Att. anxiety	-.02	.09	-.04		.22	.09	.38*		.09	.11	.16	
Att. avoidance	.18	.09	.32		.20	.10	.31*		.05	.11	.07	
Model statistics	*F (7, 48) = 0.94, p = .49*				*F (7, 48) = 3.47, p = .004*				*F (7, 48) = 1.05, p = .41*			

Note. *$p < .05$; **$p < .01$.

In the parietal region, contrary to hypothesis 1b, FFFS sensitivity as indexed by phobic ratings on the FSS was not significantly related to alpha asymmetry scores at any of the parietal sites. Alpha asymmetry scores at P6/P5 were associated with a number of significant unique predictors: a significant negative association was observed with trait anxiety, and significant positive associations were observed with both attachment anxiety and attachment avoidance. Furthermore, the two attachment dimensions accounted for a significant amount of incremental variance in alpha asymmetry scores at P6/P5, although this was not the case for Step 1 containing the measures of reinforcement sensitivity.

Summary of regression results predicting alpha asymmetry

Contrary to hypotheses 1a-c and 2a-b, both measures of reinforcement sensitivity and adult attachment were not significantly associated with alpha asymmetry scores in the frontal region. This lack of associations suggests that individual differences in reinforcement sensitivity and adult attachment do not map neatly onto the approach-withdrawal model of FAA.

Furthermore, contrary to hypothesis 1b and 1c, neither FFFS sensitivity nor BIS sensitivity were associated with greater relative right parietal activation nor greater relative left frontal activation respectively, providing no empirical support for the anxious arousal versus anxious apprehension model of alpha asymmetry.

Unexpectedly, the attachment dimensions did have some predictions to alpha asymmetry scores in the central (and to some degree, parietal) regions across both sets of regression models, thereby showing a different pattern of associations to reinforcement sensitivity. However, further research is needed to elucidate the meaning of these associations.

Therefore, adult attachment and reinforcement sensitivity appear to be generally unrelated to frontal alpha asymmetry. A few associations were found in the central and parietal region, especially for the attachment dimensions, but these are not easily interpretable.

Parietal versus Frontal Delta and Theta Activity

The hierarchical multiple regression models with parietal versus frontal delta and theta activity as the criterion outcome are also presented in Tables 8.15 and 8.16.

As seen in Table 8.15, the regression models predicting parietal versus frontal theta and delta activities from Heym et al.'s (2016) r-RST scales and adult attachment were not significant. Contrary to hypothesis 1d, the measures of BAS sensitivity were not significantly associated with relatively greater parietal theta and delta activities. There was one significant, unique prediction of FFFS freeze to relative greater parietal theta activity, although the step containing the r-RST variables and the overall regression model did not account for significant amounts of variance. Heym et al.'s (2016) r-RST scales and the measures of adult attachment were generally not predictive of parietal versus frontal theta and delta activities.

In contrast, as shown in Table 8.16, there were a number of significant predictors of parietal versus frontal theta and delta activities in the regression models containing Carver and White's (1994) BAS scales and the proxy FFFS and BIS measures, along with the adult attachment scales. In both models, the first step containing the measures of reinforcement sensitivity accounted for a significant amount of variance in parietal versus frontal theta and delta activity. The overall regression models were also significant in both instances. The pattern of significant standardised betas was similar across both models. In particular, in support of hypothesis 1d, BAS reward responsiveness exhibited significant, positive, and

Table 8.15

Hierarchical Regressions Predicting Parietal versus Frontal Theta and Delta Activity from Heym's r-RST scales and Adult Attachment (N = 58)

Index	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
	Pz/Fz theta				**Pz/Fz delta**			
Step 1				.17				.08
BAS reward	.06	.19	.05		.18	.28	.10	
BAS drive	.26	.19	.22		.10	.28	.06	
FFFS flight	-.17	.16	-.17		.08	.23	.06	
FFFS freeze	.40	.17	.39*		.31	.25	.21	
FFFS fight	-.10	.14	-.10		-.11	.20	-.08	
BIS anxiety	.17	.14	.19		.03	.20	.03	
BIS appraisal	.06	.14	.06		.04	.20	.03	
Step 2				.01				.02
Att. anxiety	-.08	.08	-.16		-.05	.12	-.08	
Att. avoidance	.04	.09	.07		-.06	.13	-.08	
Model statistics	*F (9, 49) = 1.23, p = .30*				*F (9, 49) = .58, p = .81*			

Note. *$p < .05$

Table 8.16

Hierarchical Regressions Predicting Parietal versus Frontal Theta and Delta Activity from Carver and White's (1994) BAS Scales, FSS, STAI and Adult Attachment (N = 58)

Index	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
	Pz/Fz theta				**Pz/Fz delta**			
Step 1				.26**				.18
BAS drive	.26	.15	.22		.18	.21	.11	
BAS fun	-.26	.14	-.26		-.29	.20	-.21	
BAS reward	.40	.19	.31*		.60	.27	.33*	
FSS	.27	.16	.23		.28	.23	.17	
STAI	.38	.20	.31		.68	.28	.40*	
Step 2				.03				.08
Att. anxiety	-.11	.08	-.23		-.17	.12	-.26	
Att. avoidance	.00	.08	.01		-.09	.12	-.12	
Model statistics	*F (7, 51) = 2.98, p = .01*				*F (7, 51) = 2.58, p = .02*			

Note. *$p < .05$, **$p < .01$.

moderately sized predictions to parietal versus frontal theta and delta asymmetry scores. That is, individuals with higher levels of BAS reward responsiveness tended to have greater relative parietal theta and delta activities, indicative of greater approach motivation.

However, contrary to hypothesis 1d, BAS fun seeking exhibited associations in the opposite direction, such that the construct predicted lower levels of parietal theta and delta activity (the association was significant for theta activity, but only trended towards significance for delta activity, $p = .09$). This suggests that BAS fun-seeking is related to lower levels of approach motivation. Finally, although not hypothesised, BIS sensitivity as indexed by trait anxiety had a significant and marginally significant ($p = .07$) positive prediction to greater relative parietal delta and theta activities respectively. In this case, BIS sensitivity appears to be related to greater approach motivation, which is the proposed defensive direction of BIS activation according to the r-RST. The attachment dimensions were not significant unique predictors, and did not contribute to explaining significant incremental amounts of variance in parietal versus frontal theta and delta activities.

Summary of regression results predicting parietal versus frontal theta and delta activities

In partial support of hypothesis 1d, BAS reward responsiveness was significantly associated with greater parietal theta and delta activities, which is proposed to be a neurobiological index of approach motivation. However, BAS fun seeking was associated with relatively less parietal (versus) frontal theta and delta activities, which suggests that the construct has a less strong component of approach motivation compared with BAS reward responsiveness. No other measures of BAS sensitivity were significantly associated with parietal versus frontal theta and delta

Unexpectedly, BIS sensitivity (as indexed by trait anxiety) was also related to relatively greater parietal (versus frontal) theta and delta activities. This suggests that the construct may involve approach tendencies, in line with the revised conceptualisation of BIS. However, Heym's BIS anxiety and BIS appraisal scales were unrelated to parietal versus frontal theta and delta activities.

Chapter Summary

This chapter detailed the results of in-depth exploratory and confirmatory data analyses for Study 3. Firstly, descriptives and internal reliabilities for the self-report measures and EEG indices were provided. The descriptives were acceptable, but the internal reliabilities for the EEG composite indices were low and so subsequent analyses focused on EEG activity at individual homologous pairs of electrode sites. Secondly, background analyses (e.g., t-tests and correlations) were conducted to examine whether there were any significant differences on the study measures as a function of sex, age and relationship status. While there were a few differences on the self-report measures, there were no differences on the EEG indices as a function of sex, age and relationship status. Therefore, to conserve statistical power, the sociodemographic variables were not included as covariates in subsequent regression analyses. Thirdly, the correlational analyses showed similar patterns of associations between adult attachment and reinforcement sensitivity as found in Studies 1 and 2, with both attachment dimensions notably linked to BIS sensitivity. The correlations between the EEG indices showed low convergence between alpha asymmetry scores at different electrode sites (especially for the frontal region), although parietal versus frontal theta and delta activities were highly intercorrelated. Therefore, subsequent analyses focused on alpha asymmetry scores for individual homologous pairs of electrodes. There were also very few significant correlations between the self-report measures and EEG indices of frontal

alpha asymmetry, parietal alpha asymmetry, and parietal versus frontal delta and theta activities. Finally, converging with the correlational results, neither self-reported measures of adult attachment nor reinforcement sensitivity were predictive of alpha asymmetry scores in the multiple hierarchical regression models. However, BAS reward responsiveness and BIS sensitivity were predictive of greater relative parietal theta and delta activity, while BAS fun seeking was predictive of greater relative frontal theta and delta activity. Together, the results of the current study suggest that adult attachment and reinforcement sensitivity are not related to frontal or parietal alpha asymmetry, contrary to predictions based on both Davidson's (1984, 1992, 1993, 1995) approach-withdrawal model of FAA and Heller's (Heller et al., 1995; Heller et al., 1997) distinction between anxious arousal and anxious apprehension. The results do attest to some limited associations between BAS sensitivity and greater relative parietal theta and delta activity, indicative of greater approach motivation in accordance with Wacker et al.'s (2003) BIS-BAS model of anterior asymmetry, although even here, the associations were inconsistent. The results and their implications will be discussed further in the next chapter.

Chapter 9: Study 3 - Discussion

Chapter Overview

A considerable number of statistical analyses were conducted for Study 3, and the specific results were detailed in the previous chapter. In this chapter, the more general findings will be synthesised and highlighted, and then discussed with respect to the hypotheses and empirical and theoretical literature for Study 3 (which were provided in Chapter 5). The theoretical implications of the general findings for the nature of the relations between individual differences in adult attachment and reinforcement sensitivity will also be discussed. Finally, the chapter will review some limitations of the study, as well as provide suggestions for future research.

Study 3 Aim and Summary of Results

The central aim of Study 3 was to examine the links between individual differences in self-reported adult attachment and reinforcement sensitivity and EEG-derived neurological correlates of approach and avoidance disposition. At the bivariate correlational level, there were a number of weak and isolated associations between adult attachment and reinforcement sensitivity and frontal alpha asymmetry (FAA) scores. However, at the multivariate level, hierarchical multiple regressions revealed that neither adult attachment nor reinforcement sensitivity were significantly associated with FAA scores. The study also did not find any meaningful associations between adult attachment and reinforcement sensitivity and alpha asymmetry scores in the central and parietal regions. In contrast to these null associations, the regression analyses did reveal a number of significant predictors of parietal versus frontal theta and delta activities: BAS reward responsiveness and BIS sensitivity positively predicted

greater relative parietal theta and delta activities, while BAS fun seeking was associated with greater relative frontal theta and delta activities. In sum, the present data attest to a general lack of meaningful associations between adult attachment and reinforcement sensitivity and alpha asymmetry scores. However, there were some links between BAS and BIS sensitivities and parietal versus frontal theta and delta activities. In the next section, these findings are discussed in more detail with respect to the study's hypotheses and the extant empirical and theoretical literature.

Reinforcement Sensitivity and EEG Correlates

Contrary to Hypothesis 1a, BAS sensitivity was generally unrelated to FAA scores. There was a sole significant positive correlation between BAS drive, as assessed by Heym's measure, and FAA scores at the F4/F3 electrode sites, but no significant associations emerged in the regression analyses. This null result was somewhat surprising as the link between approach tendencies and greater relative LFA is one of the more robust associations established in the resting FAA literature and forms the basis of Davidson's (1984, 1992, 1993, 1995) approach-withdrawal model of FAA. The literature review conducted in Chapter 5 found that BAS sensitivity had small to medium correlations with relative LFA across 11 out of 17 studies, and this was found most often for the frontal F4/F3 channels. In this respect, the sole significant positive correlation found in the present study between BAS drive and FAA scores at the F4/F3 channels is consistent with the reviewed research. However, the absence of significant associations in the regression analyses suggests that the link between BAS sensitivity and relative LFA is tenuous. This is in line with the results of Wacker et al.'s (2010) meta-analysis, which found that the mean weighted correlation between trait BAS or agentic extraversion and FAA scores was small and non-significant, with a high degree of

variability due to factors such as experimenter, reference schemes, and sample sizes. This may explain the null findings of the present study, despite a significant positive association between BAS sensitivity and FAA scores reported in some previous studies. Therefore, the evidence from the present study suggests that BAS sensitivity is not robustly related to greater relative LFA, which, although contrary to Davidson's approach-withdrawal model of FAA, is in line with Wacker et al.'s (2010) meta-analytic conclusion.

Also contrary to hypothesis 1b, FFFS sensitivity was not significantly related to FAA, and in particular, to greater relative RFA. Although there were a number of modest, negative correlations between Heym et al.'s (2016) FFFS scales and FAA scores, none was statistically significant. Furthermore, there were no significant associations between any of the FSS fear-proneness scales and FAA scores, nor were there any significant predictions of FFFS sensitivity to FAA scores in the regression analyses. The absence of a meaningful association between FFFS sensitivity and FAA is again contrary to Davidson's (1984, 1992, 1993, 1995) approach-withdrawal model of FAA, which proposes that withdrawal tendencies are linked to greater relative RFA. However, as acknowledged in Chapter 5, the evidence base for this theorised association is mixed. The literature review detailed in Chapter 5 found significant associations between aversive motivation and greater relative RFA in only 6 out of 16 studies, while the majority of studies found non-significant associations. However, it should be noted that all of these previous studies used Carver and White's (1994) BIS scale, which confounds FFFS and BIS sensitivities as defined by the r-RST (Heym et al., 2008). Given the heterogeneity of the measure, researchers have argued that Carver and White's (1994) BIS scale does not fit neatly within the approach-withdrawal model of FAA. Instead, more homogeneous measures of withdrawal tendencies should map onto greater relative RFA (Coan & Allen, 2003; Harmon-Jones, & Allen, 1997). Circumventing the measurement issues

inherent to Carver and White's (1994) BIS scale, the present study employed both purpose-built and proxy measures of FFFS sensitivity as defined by the r-RST, which are intended to assess pure avoidance, and thereby is the first study to examine the link between the revised conceptualisation of FFFS sensitivity and FAA. Even so, the study found no associations between withdrawal-oriented FFFS sensitivity and greater relative RFA, contrary to the approach-withdrawal model of FAA. Although FFFS activation is presumed to manifest as pure avoidance, the various measures of FFFS sensitivity used in the present study were also operationally heterogeneous (e.g., measures assessing flight, freeze, fight, and specific fears), and this may have contributed to the lack of associations. For example, Heym et al.'s (2016) FFFS fight scale, which assesses approach-oriented aggression (e.g., "If someone attacks me, I hit out"), had small correlations of mixed directions with the FAA indices. In any case, the absence of associations with FAA scores across the different measures of FFFS sensitivity suggests that the link between the latter construct and greater relative RFA is tenuous.

Furthermore, contrary to hypothesis 1c, BIS sensitivity was generally unrelated to FAA. Although FAA scores for the electrode pair F6/F5 did exhibit an isolated significant correlation with trait anxiety, there were no other significant correlations or associations identified in the regression analyses. The significant correlation between trait anxiety and FAA scores at F6/F5 was also negative in direction, implicating greater relative RFA. This is contrary to the anxious apprehension model of alpha asymmetry proposed by Heller and her colleagues which posits that BIS-mediated anxious apprehension has an approach component and should be related to greater relative left hemispheric activity (Heller, Etienne, and Miller, 1995; Heller, Nitschke, Etienne, & Miller, 1997). However, the direction of the association found in the present study is partly consistent with some previous studies that have found Carver and White's (1994) BIS measure to be negatively related to FAA scores, in

accordance with the approach-avoidance model of FAA whereby aversive-withdrawal tendencies, which in part characterises BIS sensitivity, is related to greater relative RFA. Nonetheless, as mentioned, the reported association between BIS sensitivity and greater relative RFA is rather tenuous, and the one significant association found in this study do not provide compelling evidence in support of this link. Rather, the general lack of pervasive and significant correlations, as well as null associations in the regression analyses, more strongly suggests that BIS sensitivity is not related to either greater relative LFA or RFA. It is likely that measures of the revised conceptualisation of BIS are conceptually and operationally heterogeneous [e.g., Heym et al. (2016) operationalises BIS sensitivity in terms of two dimensions – appraisal and anxiety], and do not embody purely approach or withdrawal tendencies. Although the behavioural manifestation of BIS sensitivity may involve cautious approach, Gray and McNaughton (2000) centrally characterised the system as related to motivational conflict, involving the activation of both the FFFS and BAS. Additionally, BIS activation may involve a unique range of behaviours, including behavioural inhibition and risk assessment, as well as cautious approach (which may also be qualitatively different to appetitive approach). Therefore, as BIS sensitivity may involve the co-activation of FFFS and BAS and a complex range of behaviours, it may not map onto either greater relative RFA, as per the anxious apprehension model, or LFA, as per the approach-withdrawal model of FAA, but is unrelated to FAA.

Although no hypotheses were made based on Wacker et al.'s (2003) BIS-BAS model of anterior asymmetry (BBMAA), a brief comment will be made here with regards to implications of the study's findings for this model. The BBMAA proposes that goal-directed BAS and FFFS behavioural activation (irrespective of motivational direction) are related to greater relative LFA, while BIS induced goal-conflict is related to greater relative RFA.

Although the study found isolated and weak associations between BAS sensitivity and greater relative LFA, and between BIS sensitivity and greater relative RFA, there were no evidence in support of a link between FFFS sensitivity and greater relative LFA. Therefore, the data do not provide dissociative evidence in support of the BBMAA over the approach-withdrawal model of FAA. Generally, this study found weak evidence of any associations between reinforcement sensitivity and FAA.

However, there were some interesting findings with regards to parietal versus frontal theta and delta activity, both that were hypothesised and not hypothesised. At the correlational level, no significant associations were observed between reinforcement sensitivity and parietal versus frontal theta and delta activity, although there was a trend towards greater parietal theta and delta activity for individuals with higher levels of BAS reward responsiveness. Stronger associations were found in the regression analyses such that, in partial support of Hypothesis 1d, BAS reward responsiveness was significantly linked to greater parietal activity across both theta and delta frequencies. This supports Wacker et al.'s (2010) proposition that greater parietal slow wave activity is related to approach orientation underpinned by dopaminergic functioning. However, neither BAS drive nor Heym's BAS reward reactivity were related to greater parietal delta or theta activities, suggesting that the link is restricted to BAS reward responsiveness and not pervasive across the measures of BAS sensitivity.

Unexpectedly, BIS sensitivity, as assessed by the proxy measure of trait anxiety, had a significant association with greater relative parietal delta activity in the regression analyses. To the extent that relatively more slow wave activity in the parietal regions correspond to greater approach motivation, as proposed by Wacker et al. (2010), this suggests that BIS sensitivity is related to approach tendencies. This would concur with Gray and

McNaughton's (2000) revised conceptualisation of BIS sensitivity, which involves cautious approach. However, as previously mentioned, BIS sensitivity was unrelated to greater relative LFA, which is assumed to index greater approach motivation according to the approach-avoidance model of FAA. The lack of convergence between BIS sensitivity and the two different EEG markers of approach suggests that the former construct is not robustly related to approach motivation. This is further substantiated by the lack of significant links between trait anxiety and greater relative parietal theta activity, and between Heym et al.'s (2016) BIS anxiety and BIS appraisal scales and parietal versus frontal delta and theta activities. Once again, this could be attributed to the fact that BIS sensitivity involves sensitivity to goal-conflict that may manifest as motivational and behavioural ambivalence, and not simply pure approach or avoidance. Alternatively, that BIS-trait anxiety was related to greater relative parietal slow wave activity and not greater relative LFA could be because the latter is not a robust EEG-derived marker of approach motivation. As mentioned, Wacker et al.'s (2010) meta-analysis found that the mean weighted correlation between trait approach constructs and FAA scores was small and non-significant, as well as liable to experimental parameters. Despite these qualifications, it may be concluded that BIS-trait anxiety appears to be related to greater approach motivation as indexed by greater relative parietal delta activity, although this association does not generalise to parietal versus frontal theta activity, other measures of BIS sensitivity, and resting FAA.

In summary, there is a lack of compelling evidence for any associations between reinforcement sensitivity and FAA. Contrary to Davidson's approach-withdrawal model of FAA, neither BAS sensitivity nor FFFS sensitivity were related to greater relative LFA and RFA respectively. This calls into question the reliability and validity of the FAA scores as an index of approach and avoidance. Furthermore, BIS sensitivity was not associated with either

greater relative LFA or RFA, contrary to both the approach-withdrawal model of FAA and the anxious apprehension model respectively. In this case, BIS sensitivity is more likely to involve the co-activation of FFFS and BAS and a complex range of behaviours, rather than map onto EEG-derived markers assumed to index pure approach or avoidance. In contrast, there were significant associations between BAS sensitivity and BIS sensitivity and parietal versus frontal activities across both theta and delta frequencies. Specifically, BAS reward responsiveness was associated with greater relative parietal slow wave activities, which suggests that it has a more notable approach component, compared with BAS fun seeking which exhibited an inverse association. Furthermore, BIS sensitivity also appeared to be related to greater approach motivation as indexed by greater relative parietal delta activity. Although the associations did not generalise across measures of BAS and BIS sensitivity, there are some links with the neural correlates of approach and avoidance motivation.

Adult Attachment and EEG Correlates

With regards to adult attachment, contrary to Hypotheses 2a, attachment anxiety was not substantially related to withdrawal tendencies as indexed by greater relative RFA and lower FAA scores. Attachment anxiety did exhibit a pattern of negative correlations with FAA scores but this was significant for only one pair of electrodes (F8/F7). Additionally, attachment anxiety had negative predictions to FAA scores across all but one of the regression models, but none of these were statistically significant and the step containing the attachment variables did not explain a significant incremental amount of variance in FAA scores. Thus, although the isolated significant correlation between attachment anxiety and greater relative RFA may be interpreted as weak evidence in support of Hypothesis 2a, the non-significant correlations and regression results on the whole suggest otherwise. That is,

there appears to be no robust and consistent evidence of a link between attachment anxiety and greater relative RFA, which is assumed to index withdrawal motivation according to Davidson's approach-withdrawal model of FAA.

Likewise, contrary to Hypothesis 2b, attachment avoidance was unrelated to lower levels of approach motivation as indexed by reduced relative LFA and lower FAA scores. The correlations between attachment avoidance and FAA scores, while negative in direction, were negligible and non-significant, and there were no significant associations in the regression analyses. Therefore, to the degree that resting FAA scores index approach-withdrawal in accord with Davidson's model, the study provides no evidence that attachment avoidance is inversely associated with approach/appetitive motivation.

Although three previous studies have linked insecure attachment to greater relative RFA, and secure attachment to greater relative LFA, on closer examination, these associations with resting FAA are not robust. Some studies have found only trend or modest associations. For example, Rognoni et al. (2008) found that secure adult attachment was related to generally symmetrical frontal activity in both hemispheres, although trending towards relative LFA. Fraedrich et al. (2010) similarly reported a trend association between secure attachment and greater relative LFA. Furthermore, Rognoni et al. (2008) reported near zero resting FAA scores for fearful-avoidant individuals, as opposed to greater relative RFA. Thus, given these three studies and their modest findings, the literature offers inconclusive evidence of any associations. These findings coupled with the null results of the present study suggest that adult attachment has weak and inconsistent associations with resting FAA scores. To the degree that resting FAA scores index approach and withdrawal tendencies in accordance with Davidson's model, this suggests that the trait motivational tendencies do not have clear cut and strong associations with adult attachment dimensions.

Moreover, the correlational and regression analyses revealed that both adult attachment dimensions were unrelated to parietal versus frontal theta and delta activities, providing further evidence that the dimensions do not map onto neural markers of approach motivation. This was despite the positive association between BAS reward responsiveness and greater relative parietal theta and delta activities, providing predictive validity evidence in support of the neural correlate as a marker of approach motivation. Although no other studies have examined adult attachment in relation to greater parietal slow frequency activities, the finding is consistent with the lack of associations found in the present study between the attachment dimension and resting FAA scores. Therefore, the null result provides further evidence of the lack of clear-cut and robust links between adult attachment and approach tendencies. Overall, it appears that the attachment dimensions are unrelated to neurophysiological markers of approach and avoidance derived from resting EEG examined in the present study.

The absence of any links between the adult attachment and the EEG-derived neural indices of approach and avoidance may be because the attachments dimensions cannot be simply reduced to approach or avoidance, but rather involve motivational ambivalence and behavioural heterogeneity. The correlational data from the three studies reported in this thesis suggest that the attachment dimensions are more strongly linked to BIS sensitivity, while a number of other studies have shown that insecure attachment involves conflicting approach-avoidance behaviour and threat and reward appraisals toward the attachment figure (e.g., MacDonald et al., 2013; Mikulincer et al., 2010). Furthermore, the attachment dimensions exhibit only modest associations with BAS-approach and FFFS-withdrawal (Carnelley & Story, 2008; Jiang & Tiliopoulos, 2014; Karantzas et al., 2010; Meyer et al., 2005; Mikulincer & Shaver, 2007). As such, neither attachment anxiety nor attachment avoidance

appear to be strongly characterised by pure approach or avoidance motivation, but are likely to involve a mixture of both.

This was the first study to examine the association between the adult dimensions of attachment anxiety and attachment avoidance and EEG-derived neural correlates of trait approach and avoidance. The consistent null associations between adult attachment and both FAA and parietal versus frontal theta and delta activities overwhelmingly suggests that adult attachment is not related to neural markers of approach and avoidance. This could point to the fact that adult attachment does not correspond with clear-cut approach or avoidance motivation, but rather involve motivational ambivalence.

Adult Attachment and Reinforcement Sensitivity

This was the first study to simultaneously compare individual differences in adult attachment and reinforcement sensitivity in relations to neural correlates of approach and avoidance. The results suggest that adult attachment and reinforcement sensitivity do not share overlapping associations with the EEG-derived neural markers of approach and avoidance tendencies. On the one hand, the attachment dimensions exhibited no relations with the resting EEG indices. On the other hand, while reinforcement sensitivity was unrelated to FAA, BAS and BIS sensitivities did exhibit some associations with greater relative parietal theta and delta activities, indicative of varying degrees of approach orientation. Therefore, the two domains are dissimilarly related to EEG-derived neural correlates of approach and avoidance.

As the attachment dimensions do not correspond with neural signatures of approach and avoidance, the indirect implication is that individual differences in adult attachment and

reinforcement sensitivity are neurologically unrelated. It was hypothesised that attachment avoidance, to the degree that it is inversely related to BAS sensitivity, would be negatively related to neural markers of dispositional approach; while attachment anxiety, to the degree that it is linked to FFFS sensitivity, would be positively related to neural markers of dispositional withdrawal. However, the attachment dimensions were consistently unrelated to the resting EEG indices of approach and withdrawal, despite BAS and BIS sensitivities being linked to greater relative parietal theta and delta activities. This suggests that the attachment dimensions are not reducible to approach and avoidance tendencies, which centrally characterise BAS and FFFS sensitivities respectively. Therefore, the results suggest that adult attachment is neurologically unrelated to reinforcement sensitivity, to the degree that they do not share overlapping links to neural markers of dispositional approach and avoidance.

However, the study does not eliminate the possibility that the attachment dimensions may be related to BIS sensitivity. As already discussed, both attachment anxiety and attachment avoidance are likely to involve simultaneous approach and avoidance tendencies, but the neural markers examined in the present study do not lend themselves to providing valid assessments of motivational ambivalence [although Wacker et al. (2003) did theorise that BIS sensitivity is related to greater relative RFA]. Furthermore, BIS sensitivity also did not map clearly onto the resting EEG indices of approach and avoidance, aside from the unexpected link between the proxy measure of trait anxiety and greater relative parietal delta activity. Thus, although the EEG correlates examined in the present study were the most relevant in the existing literature to reinforcement sensitivity, the measures may not have provided the best assessment of motivational ambivalence, which appears to be inherent to both the attachment dimensions and BIS sensitivity. Therefore, the present data do not allow for a conclusion regarding the nature of the relations between individual differences in adult

attachment and BIS sensitivity, and in particular, the extent to which both involves motivational ambivalence.

Moreover, the lack of pervasive and strong associations between both adult attachment and reinforcement sensitivity and the EEG indices of approach and avoidance calls into question the degree to which the study's data can reliably inform upon the nature of the relations between adult attachment and reinforcement sensitivity. Not only were the EEG indices unrelated to adult attachment, the study also failed to find consistent and strong links with reinforcement sensitivity, contrary to some previous findings. Therefore, it may be concluded from the study's data that both domains are not strongly related to resting EEG neural correlates of approach and avoidance. This does not necessarily rule out relations between individual differences in adult attachment and reinforcement sensitivity, as the domains may overlap in other respects such as cognitive-affective processes and/or behaviour. Alternatively, the lack of robust associations may point to measurement issues. For example, Wacker et al. (2010) questioned the validity of resting FAA as an index of approach and avoidance tendencies, as their review of studies found small to non-significant associations (notably, the reviewed studies also included ones on agentic extraversion, and not focally on BAS sensitivity). However, there is substantial evidence to support Davidson's (1984, 1992, 1993, 1995) longstanding approach-withdrawal model of FAA, including data from Harmon-Jones' research group and the review provided in Chapter 5. Nonetheless, measurement issues will be detailed in the next section. Keeping possible validity and reliability issues in mind, conclusions regarding the neurological nature of the relations between adult attachment and reinforcement sensitivity need to be made cautiously.

Methodological Limitations

The interpretation of the results needs to be qualified with a number of limitations pertaining to the EEG methodology, as well as the study's general design. These include technical difficulties, low internal reliabilities of EEG indices, state fluctuations during resting EEG measurement, and inflation of type 1 errors that potentially impact on the validity of conclusions drawn from the study's data. Furthermore, the nature of the EEG-derived indices as difference scores and the poor spatial precision of the EEG data limit the scope of interpretations that can be made. Some of these issues were noted in Chapter 5 (e.g., use of a difference score and poor spatial precision), along with the advantages of the EEG methodology. In this section, each of these issues will be discussed in further detail, focusing on their impact on the interpretation of results.

Firstly, some unforeseen technical difficulties were experienced during EEG data acquisition, which may have reduced the reliability of the data. Specifically, there were some intermittently dysfunctional electrodes that resulted in missing EEG recording for a number of electrode channels across most participants. Although cases with EEG recording missing for six or more electrode channels were excluded, most of the remaining cases still had one to five electrode channels where the EEG data had to be interpolated. As interpolation provides only an estimate of the EEG activity based on the available recording from the surrounding electrode channels, this potentially reduces the reliability of the EEG data (Luck, 2005). Therefore, given the technical difficulties that may have adversely impacted on the EEG data quality, it is worthwhile to replicate the present research, as well as extend the study design to incorporate additional measures such as fMRI and/or heart rate variability to triangulate the data.

Secondly, and perhaps critically, the internal reliabilities for the EEG asymmetry scores were lower than desirable. Cronbach's alpha internal reliabilities ranged from .54 to

.79 for the alpha asymmetry scores, while the values for the alpha asymmetry scores averaged across three homologous pairs of electrodes for each region (frontal, central-temporal and parietal) were exceedingly low (.22 to .56). These less than robust internal reliabilities for the EEG asymmetry scores may be in part due to the fact that the indices are derived difference scores (i.e., alpha power at the left electrode site minus alpha power at the right homologous site). Any errors of measurement inherent to each constituent site are compounded in the calculation of the difference score. However, Allen and Coan (2004) argued that this is not a major issue, as the internal reliability for each constituent score (i.e., the alpha frequency at each electrode site) has usually been shown to be above > .90, resulting in generally highly reliable alpha asymmetry difference scores. The less than desirable lower internal reliabilities found in the present study could once again be attributed to the technical issues experienced during EEG data acquisition.

Thirdly, state fluctuations could have additionally contributed to the lower internal reliabilities. While resting alpha asymmetry is assumed to measure a stable latent trait, in actuality, it is also considerably influenced by situation-specific and moment-to-moment changes in cortical brain activity. Hagemann et al. (2002) determined that almost 40% of the variance could be attributed to situation-specific fluctuations, while Tomarken et al. (1992) found test-retest reliabilities of .41 to .71. It is widely acknowledged that EEG recordings are sensitive to slight variations in experimental procedure including the experimenter's gender and demeanour, experimental instructions, and time of day (Allen & Coan, 2004; Harmon-Jones, & Peterson, 2012). Additionally, the resting state itself is uncontrolled, and liable to the participant's mood (both their state prior to testing, as well as moment-by-moment fluctuations during the experimental session) and free-form mentation (Allen & Coan, 2004). Some researchers have recommended examining EEG activity contingent upon an event (for example, event-related potential), which is arguably a more controlled experimental situation

that is designed to evoke particular emotional and/or cognitive states (Coan, Allen, & McKnight, 2006). For example, Rognoni et al. (2008) found that the fearful-avoidant attachment style was related to near zero resting FAA scores, while the same individuals showed significantly greater relative RFA when viewing fearful film clips. However, the present study focally examined resting EEG as it is proposed to more relevantly capture dispositional approach and avoidance motivation. Future studies could examine EEG activity in response to state activations of the attachment or reinforcement sensitivity systems, such as via the viewing of film clips of separation and appetitive, aversive and ambivalent scenes. This would allow for comparing the predictions of individual differences in reinforcement sensitivity and adult attachment to dynamic neural activity during response to situations known to activate the motivational and attachment systems. Nonetheless, the current study provides a useful starting point in examining links between adult attachment and reinforcement sensitivity and recognised neurophysiological markers of dispositional approach and avoidance derived from resting EEG activity.

Fourthly, in the present study, significant associations were often isolated to specific measures, electrode sites and EEG indices. For example, Heym et al.'s (2016) BAS drive was associated with greater relative LFA at F4/F3 only (and not F8/F7 or F6/F5), implicating higher levels of approach motivation, but was unrelated to parietal versus frontal theta and delta asymmetry, which is also proposed as an index of approach motivation. These isolated associations could reflect the propensity for alpha asymmetry research specifically, and EEG studies generally, to suffer from the inflation of Type 1 errors (Allen et al., 2004). This is due to the multiple comparisons and permutations of parameters (such as recording from multiple sites, under multiple reference montages, and examining difference frequency bands, along with multiple self-report measures) inherent to EEG studies. While similar findings across

comparative measures would provide reassuring convergent validity, this was not observed in the present study. Therefore, the isolated associations in the present study could potentially represent Type 1 errors. Alternatively, as Allen et al. (2004) suggests, it is possible that the isolated associations do reflect systematic relationships between specific measures and asymmetry at specific sites. For example, BAS reward responsiveness is meaningfully related to greater relative parietal theta and delta activities but not greater relative LFA at any of the frontal electrode sites, as the former may be a more reliable indicator of approach motivation compared to the latter (Wacker et al., 2010). As it is difficult to confidently conclude whether the isolated associations in the present study reflect systematic relationships or Type 1 errors, further replication studies are needed.

Fifthly, the EEG-derived indices of left versus right FAA and parietal versus frontal theta and delta activities are difference scores that represent relative levels of cortical activity, and do not indicate absolute activity in specific regions. Difference scores necessarily correct for large individual differences in overall alpha power and skull thicknesses, which may greatly impact on the magnitude of the asymmetry (Eshel et al., 1995; Leissner et al., 1970). However, as a simple unidimensional measure, the difference scores do not allow for the deduction of meaningful absolute levels of EEG activity in the regions of interest (i.e., left and right frontal hemispheres, and general parietal and frontal regions). That is, it is not possible to meaningfully deduce whether greater relative LFA is due to greater absolute LFA and/or reduced absolute RFA, while simultaneously taking into account individual differences in overall alpha power and skull thickness. Similarly, greater relative parietal activity as indexed by the asymmetry score could be due to either higher absolute levels of parietal activity or reduced absolute levels of frontal activity. This limits the scope of the interpretations. For example, while BAS drive was associated with greater relative LFA, it is

unclear whether this is due to more absolute LFA (corresponding to greater approach motivation), and/or reduced absolute RFA (corresponding to reduced avoidance motivation). Indeed, the literature has revealed mixed findings, with studies attributing the greater relative LFA associated with BAS-related approach constructs to bilateral frontal activation (e.g., Harmon-Jones & Allen, 1997; Hewig et al., 2004, 2006), greater left frontal activity (Diego et al., 2001), and reduced right frontal activity (Coan & Allen, 2003). These divergent claims point to the difficulty of ascertaining absolute levels of cortical activity. The ambiguity in interpreting EEG asymmetry scores similarly applies in association with adult attachment. Higher levels of either/both attachment dimensions (indicative of attachment insecurity) were hypothesised in the present study to be related to lower FAA scores, but it is not possible to differentiate between lower FAA scores arising from reduced LFA and/or increased RFA. Therefore, there is an inherent degree of ambiguity with regards to the interpretation of the EEG-derived difference scores examined in the present study that does not allow one to infer absolute levels of cortical activity.

Finally, although the EEG methodology possesses high temporal precision in assessing changes in neural activity, it has low spatial resolution with respect to locating the source of neural activity, which further limits the scope of interpretations. Indeed, Allen and Coan (2004) stated that alpha asymmetry is a very coarse measure that, at most, locates the cortical activity to the broad frontal region, and not at the level of specific electrode sites, which is similarly the case for parietal versus frontal theta and delta activities. This is because the EEG data only capture the cortical surface electrical activity, which arises from cumulative electrical activity within the brain of unknown origins and configurations. In contrast, hemodynamic measures such as fMRI and PET have much more superior spatial resolutions, and are more able to address research questions concerning underlying neural

structures and processes, although they lack the temporal precision of EEG. It may be beneficial in future studies to supplement the temporally precise EEG measure with the spatially accurate hemodynamic measures of fMRI and/or PET, in order to compare both the degree and location of brain activation associated with individual differences in reinforcement sensitivity and adult attachment.

Conclusion

The present study aimed to comparatively examine adult attachment and reinforcement sensitivity and their links with resting EEG correlates of dispositional approach and avoidance. Neither adult attachment nor reinforcement sensitivity exhibited strong and robust associations with the resting EEG indices, contrary to a number of theoretical models (Davidson, 1984, 1992, 1993, 1995; Heller et al., 1995, 1997; Wacker et al., 2003). This may be due to the construct heterogeneity of the attachment dimensions and reinforcement sensitivity, such that they do not neatly map onto neural correlates of approach and avoidance. Indeed, the attachment dimensions and BIS sensitivity are likely to be characterised by motivational ambivalence, which is not indexed by the resting EEG measures adopted in the present study. Furthermore, along with a number of methodological issues, the reliability of the resting EEG indices (especially FAA) was low. As such, the lack of associations could also potentially be attributed to measurement issues. Therefore, although the data revealed that adult attachment and reinforcement sensitivity do not share overlaps with resting EEG correlates of approach and avoidance tendencies, the study does not rule out any relations between adult attachment and reinforcement sensitivity.

Chapter 10: General Discussion

Chapter Overview

This chapter aims to synthesise the key findings from the three empirical studies detailed in the previous chapters, and draw out the major implications and conclusions in the light of the thesis aim and research question. After revisiting the thesis aim and summarising the results across the three studies, the chapter will discuss the key implications of the results for the nature of the relations between individual differences in adult attachment and reinforcement sensitivity. Following this, some general limitations and caveats to the conclusions made in this thesis will be outlined. Finally, the chapter will propose some future directions and summarise the contribution of this research programme.

Thesis Aims and Hypotheses Revisited

The overarching aim of this thesis was to examine the nature of the relations between individual differences in adult attachment and reinforcement sensitivity. Specifically, the thesis examined whether stable patterns of relating in close relationships as captured by the dimensions of attachment anxiety and attachment avoidance were related to individual differences in the sensitivity of Behavioural Approach System (BAS), Fight-Flight-Freeze System (FFFS), and Behavioural Inhibition System (BIS), as described by the revised Reinforcement Sensitivity Theory (r-RST; Gray & McNaughton, 2000). Both attachment theory and r-RST propose biobehavioural motivational systems that underpin survival, are evolutionary-based, involve approach-avoidance dynamics, and threat and reward appraisals. Therefore, it is of interest to see whether individual differences in the functioning of these systems overlap. To address this research question, three studies were devised to collate

psychometric, behavioural, and neurophysiological data. It was hypothesised that attachment avoidance and attachment anxiety would be differentially linked to BAS and FFFS sensitivities respectively, while both attachment dimensions would be related to motivational ambivalence.

Summary of Results

The first study aimed to provide preliminary data on the links between self-reported adult attachment and reinforcement sensitivity at the psychometric level. There were modest associations between attachment avoidance and BAS sensitivity, and between attachment anxiety and FFFS sensitivity. More notably, both attachment dimensions were significantly linked to BIS sensitivity, which suggests that attachment insecurity (higher levels of attachment anxiety and/or attachment avoidance) is more strongly characterised by sensitivity to motivational ambivalence.

Building upon psychometric evidence of the first study, the second study aimed to compare the prediction of adult attachment and reinforcement sensitivity to behavioural response to a critical attachment-relevant situation – that is, separation from, and subsequent reunion with, an attachment figure in a simulated virtual scenario. Specifically, attachment anxiety was associated with more negative affect, generally and during separation; and attachment avoidance was associated with more spouse-directed negativity overall, and less of a rebound in positive affect during reunion. In contrast, reinforcement sensitivity had negligible predictions, aside from an association between BAS sensitivity and greater likelihood of engaging in proximity-seeking during separation. This study showed that adult attachment orientations have greater predictive power to responses to the attachment-relevant scenario, compared with the more domain-general reinforcement sensitivity constructs.

Finally, to add to the self-report and behavioural data, the third study aimed to compare whether adult attachment and reinforcement sensitivity are related to resting EEG neural correlates of approach and avoidance. Although there were a few associations between BAS and BIS sensitivities and parietal versus frontal theta and delta activities, indexing approach motivation, neither adult attachment nor reinforcement sensitivity had robust and strong links with the neural markers. It appears that the two domains do not easily map onto simple approach and avoidance, and thus do not share overlapping links with the associated resting EEG neural correlates.

Attachment Insecurity is characterised by BIS Sensitivity

One of the most intriguing findings of the present research is that both adult attachment dimensions appear to be related to BIS sensitivity. Across all three studies, in accordance with hypotheses, both attachment anxiety and attachment avoidance were consistently linked to the self-reported proxy and purpose-built measures of BIS sensitivity. Furthermore, these links were observed to be stronger for attachment anxiety than attachment avoidance. This converges with the few extant self-report studies on adult attachment and reinforcement sensitivity that have found the same pattern of associations when using Carver and White's (1992) BIS scale, which measures a confluence of BIS and FFFS sensitivity (Carnelley & Story, 2008; Meyer et al., 2005; Mikulincer & Shaver, 2007). Moreover, the results add to a large existing evidence base that attest to substantial overlaps between attachment anxiety (and, to a smaller degree, attachment avoidance) and BIS-related constructs including trait anxiety (see Mikulincer & Shaver, 2007, for a review) and neuroticism (see Shaver & Brennan, 1992, for a review). Extending these previous studies, the present research uniquely contributes evidence of a direct link between the attachment

dimensions and measures of BIS sensitivity as defined by the r-RST, as opposed to the outdated conceptualisation of BIS sensitivity and BIS-related constructs.

This observed primary association with BIS sensitivity suggests that attachment insecurity, in the form of higher levels of attachment anxiety and/or attachment avoidance, critically involves sensitivity to motivational ambivalence. That is, insecure individuals may be more disposed to experiencing motivational conflict between threats and rewards, of both a general and relational nature. A number of studies have found that both attachment dimensions are related to relational ambivalence in the form of conflicting interpersonal approach-avoidance behaviour, appraisals, and motives (e.g., MacDonald et al., 2012; McClure, Bartz, & Lydon, 2012; Mikulincer et al., 2010; Nikitin & Freund, 2010). This is likely to reflect the conflict between two basic motivations: the instinctive desire to approach the attachment figure as a source of security, and simultaneous withdrawal in reaction to relational threat arising from cues of unavailability and/or rejection from the attachment figure. Moreover, insecurely attached individuals may be disposed to experiencing greater motivational ambivalence in general. Feelings of insecurity arising from the attachment figure's unavailability place an individual in a state of hypervigilance toward threats in the environment. When exposed to a situational threat, the individual experiences compounded distress due to the attachment figure's unavailability (Mikulincer & Shaver, 2007). The vicious cycle of attachment figure's unavailability, heightened sensitivity and responsivity to threats, and strong activation of the attachment needs results in an intensified state of motivational conflict. In these ways, attachment insecurity is critically characterised by inherent motivational ambivalence.

The potential role of BIS sensitivity for insecurely attached individuals can also be traced back to early observations of ambivalent attachment patterns in infants. Using the

Strange Situation Paradigm (SSP), Ainsworth et al. (1967, 1978) observed a behavioural pattern which she called 'anxiously attached to mother and resistant.' Infants who displayed this pattern would appear to be distressed by separation from his or her caregiver, but upon reunion, they would exhibit an ambivalent response, oscillating between proximity seeking and angrily resisting contact. This response pattern is attributed to inconsistent caregiving, and both Bowlby (1973) and Ainsworth et al. (1978) acknowledged that the attachment figure in these instances arouse both positive feelings of love and negative feelings of anger and anxiety, inevitably resulting in "painful conflicts" (Bowlby, 1973, p. 253). The language used to describe anxious-ambivalent infant attachment is reminiscent of that describing BIS activity, that is, approach-avoidance behaviour, inconsistent reinforcement history, and conflicting appraisals. Therefore, the idea of motivational conflict is inherent to classical attachment theory, and specifically, in relations to the anxious-ambivalent infant attachment style.

Moreover, the behavioural outputs of the BIS hold parallels with behavioural patterns associated with attachment anxiety and attachment avoidance. Attachment anxiety is positively associated with hypervigilance, state and trait anxiety, reduced exploratory behaviour and increased cautious approach, which are the typical behavioural outputs associated with BIS (Gray & McNaughton, 2000). This close correspondence may account for the stronger associations between attachment anxiety and BIS sensitivity. With regards to attachment avoidance, behavioural manifestations of the BIS may be less obvious, but instead take the form of strong inhibition of prepotent behaviours. Attachment avoidance has been associated with preconscious activation of the attachment system in the form of increased accessibility to attachment figure representations (Mikulincer, Gillath, & Shaver, 2002) and heightened physiological reactivity to distress (Diamond & Fagundes, 2010), countered by

subsequent conscious denial of attachment needs and distress. As Mikulincer et al. (2002) described, individuals with high levels of attachment avoidance "have learned to inhibit the natural tendency to seek proximity, which at a fundamental level they possess, as indicated by their performance in nonattachment-related threat contexts" (p. 893). This strong inhibitory response to fundamental attachment needs is likely to involve the BIS, such that the avoidant individual experiences and successfully inhibits the behavioural manifestation of unconscious motivational conflict. However, the absence of manifest hypervigilant behaviour, anxiety and cautious approach may account for the smaller (but still robust) associations between attachment avoidance and BIS sensitivity. Therefore, both attachment dimensions are, in different ways, related to behaviours that are typically associated with BIS sensitivity.

The results of the present research importantly point to the involvement of the sensitivity of an underlying biobehavioural system, the BIS, which is responsible for resolving ambivalence. In doing so, this thesis makes a significant contribution to the current state of knowledge regarding the basic neurobiological mechanisms that underpin attachment behaviour. While Bowlby (1969/1982) originally theorised that attachment behaviour is the output of neurobiolocially-based system(s) that serve to promote survival, attachment research has instead tended to focus on cognitive and behavioural processes and outcomes. The studies reported in this thesis is among a handful that have attempted to examine whether individual differences in attachment behaviour is related to the sensitivities of the basic, biobehavioural motivational systems proposed by Gray and McNaughton (2000). In this way, this thesis importantly contributes to the understanding of the functioning of the attachment system in relations to the sensitivity of fundamental, evolutionary-based, neurobiological motivational systems. In particular, the three studies evidenced links between both

attachment dimensions and BIS sensitivity, which substantiates Bowlby's (1969/1982) claim that attachment behaviour is underpinned by fundamental, biobehavioural systems. Appropriately, the BIS is responsible for resolving conflict between basic survival motivations, such as avoidance of threat and approach to safety. The interplay between BIS sensitivity and functioning and attachment behaviour warrants attention in future research. This thesis provides important preliminary evidence that point to the BIS as one biologically-based basic motivational system that potentially mediates insecure attachment behaviour.

While the adult attachment dimensions exhibited robust associations with self-reported BIS sensitivity, the present research failed to replicate the associations at the behavioural and neurological levels. In Study 2, self-reported BIS sensitivity did not predict ambivalent behaviour within the virtual attachment-related separation scenario, while in Study 3, self-reported adult attachment and BIS sensitivity did not share overlap with any of the resting EEG neural correlates. However, both studies provided limited assessments of motivational ambivalence. In the virtual separation scenario, ambivalent behaviour was operationalised as engaging in both positive and negative spouse-directed actions, but motivational conflict may have manifest in other forms that were not measured (such as mixed affective states). Furthermore, while Wacker et al. (2003) proposed that greater relative RFA indexes BIS sensitivity, this was not substantiated by Study 3's results. It should also be noted that the lack of convergence in findings between self-report and non-self-report measures is not unusual in research and may reflect differences in operationalisation. These measurement issues will be discussed in further detail later in this chapter. It is suffice to note here that although BIS sensitivity and adult attachment did not overlap in their predictions to response to separation and resting EEG neural correlates specifically, this does not negate the meaningfulness of the consistent associations found at

the self-report level. Rather, the data suggest that individual differences in adult attachment and reinforcement sensitivity do not overlap in relations behavioural response to separation and neural correlates, but BIS sensitivity still importantly characterises attachment insecurity at the self-reported phenomenological level.

Attachment Anxiety is Modestly Linked to FFFS Sensitivity

The present research further suggests that attachment anxiety has modest but consistent links with FFFS sensitivity at the self-report level. Across all three studies, attachment anxiety exhibited a correlation of around .30 with at least one measure of FFFS sensitivity. Specifically, in Study 1 and 2, attachment anxiety was associated with higher levels of fear-proneness, which is a proxy measure of FFFS sensitivity. Furthermore, Study 3 found that attachment anxiety was correlated with Heym et al.'s (2016) FFFS freeze scale and FSS ratings of social anxiety fears. These results are consistent with previous studies that have also found attachment anxiety to be correlated with self-reported FFFS sensitivity (Harnett & Penn, 2012; Karantzas et al., 2010), as well as Carver and White's (1992) BIS scale, which represents a conflation of FFFS and BIS sensitivities (Carnelley & Story, 2008; Meyer et al, 2005; Mikulincer & Shaver, 2007). Additionally, the data are consistent with a number of studies have linked attachment anxiety to greater threat sensitivity, including greater pain affect (MacDonald & Kingsbury, 2006), frequent expressions of fear (e.g., Consedine & Fiori, 2009), heightened response to threatening stimuli in a dot-probe task (Karantzas et al., 2010), stronger defensive motivation (e.g., Ein-Dor et al., 2011a, 2011b), increased threat perception (e.g., MacDonald et al., 2012), and aversive relationship goals (Carnelley & Story, 2008). Given the shared feature of FFFS-mediated activity, the

accumulated evidence converge to suggest that attachment anxiety is modestly but consistently related to FFFS sensitivity.

Theoretically, this link is not unexpected as Bowlby (1973) proposed that attachment anxiety and the regulation of fear responses share important and intimate links. Fear prompts attachment behaviour, while the attachment figure serves as a safe haven to alleviate fear. Thus, attachment security is associated with reduced susceptibility to fear, while attachment insecurity leads to a dysregulated and intensified fear response. The data from the present research, together with evidence from previous studies, attest to this link between the two survival motivational systems. Even at the self-report level, it appears that individuals who worry more about their attachment figure's availability indicate greater fearfulness to threatening stimuli in general, suggestive of a more sensitive FFFS, and vice versa. Therefore, the present data suggest some overlap between attachment anxiety and FFFS sensitivity.

The extent to which the two behavioural systems are linked is unclear, and require further investigation. The modest correlations at the self-report level would suggest that the two systems are related but not completely overlapping and redundant. That is, fear of aversive stimuli and situations such as spiders, heights, and surgery do not necessarily translate to fear of rejection from the attachment figure. Similarly, worry about the attachment figure's availability may heighten one's sensitivity to threats in the environment, but not necessarily implicate the person would be more fearful of different types of stimuli. Rather, the data suggest a modest degree of overlap between attachment anxiety and FFFS sensitivity, as opposed to strong and "intimate" links as proposed by Bowlby (1973). Relatedly, the nature of the relations between attachment anxiety and FFFS sensitivity and the direction of causality remains to be investigated. It is possible that the anxious person is

more hypersensitive to threat because of the uncertainty of the secure base, or alternatively, greater sensitivity to threats leads to more frequent and intense activation of attachment concerns that characterise the anxious individual. The two explanations are not mutually exclusive, and it would not be surprising to find bi-directional causality. These questions regarding the degree and nature of the overlap between attachment anxiety and FFFS sensitivity are directions for future research.

Although measures of attachment anxiety and FFFS sensitivity exhibited overlaps at the self-report level, the link was once again not evidenced at the behavioural and neurophysiological levels. In Study 2, FFFS sensitivity had no significant predictions to attachment behaviour in the virtual separation scenario. Moreover, in Study 3, attachment anxiety and FFFS sensitivity did not share overlaps with resting EEG correlates of withdrawal motivation. This could be attributed to the aforementioned generally weak correspondence between self-report and non-self-report measures due to the differences in operationalisation. For example, Leau and Beauducel (2008) found small effect sizes between psychometric and behavioural parameters of the one construct of BIS-anxiety. Moreover, attachment anxiety and FFFS sensitivity were only modestly related at the self-report level, and so it is unsurprising that they lack overlapping predictions to behaviour and neurophysiology. It appears that, from Study 2, the domain-specific construct of attachment anxiety has greater predictive power to response to the attachment-related separation event than the more domain-general construct of FFFS sensitivity. Furthermore, Study 3 suggests that attachment anxiety is not strongly defined by withdrawal motivation as measured by resting EEG. Together, these results suggest that attachment anxiety is only weakly related to FFFS sensitivity at the self-report level.

Attachment Avoidance is Unrelated to FFFS Sensitivity

No evidence of a link was found between attachment avoidance and FFFS sensitivity across the three studies, at the self-report, behavioural and neurophysiological levels. In Study 1, attachment avoidance exhibited near-zero correlations with both proxy and purpose-built measures of FFFS sensitivity. In Study 2, although attachment avoidance did predict more negative spouse-directed behaviours overall during the virtual separation scenario, these behaviours may not necessarily be mediated by the FFFS, but rather constitute offensive (as opposed to defensive) aggression. Indeed, FFFS sensitivity did not predict higher levels of negativity toward the spouse nor other responses to separation. Moreover, in Study 3, attachment avoidance was not related to any of the resting EEG indices of aversive-withdrawal motivation. Therefore, the data converge to suggest that attachment avoidance is unrelated to the sensitivity of the FFFS.

The results from the present research are largely consistent with findings from previous studies. Attachment avoidance has not been found to be related to stronger aversive motivation, as measured by Carver and White's (1994) BIS scale (Carnelley & Story, 2008; Meyer et al., 2005; Mikulincer & Shaver, 2003), pain affect (MacDonald & Kingsbury, 2006), and aversive romantic relationship goals (Carnelley & Story, 2008). However, Ure's (2011) doctoral thesis, which proposed that attachment avoidance is related to a hypersensitive FFFS, did find that the dimension was related to FFFS fight and attentional bias away from threatening stimuli in one study. Yet, attachment anxiety was more consistently correlated with FFFS responses across all three studies reported in her thesis. Therefore, there is a lack of strong and consistent evidence to support Ure's thesis that attachment avoidance is related to a hypersensitive FFFS. Instead, it appears that the present

data, along with previous research, suggest no relations between attachment avoidance and FFFS sensitivity.

The theoretical implication of this finding is that attachment avoidance is not directly related to the sensitivity of the FFFS that is responsible for mediating defensive behaviour towards aversive stimuli. Discomfort with intimacy and the tendency to avoid the attachment figure is not associated with greater sensitivity to situational threats and a tendency to exhibit defensive behaviour such as withdrawal more generally. This may appear to be at odds with the aforementioned research that attachment avoidance involves preconscious heightened physiological reactivity to distress (Diamond & Fagundes, 2010) and detection of non-attachment related threats (Mikulincer et al., 2002; Ure, 2011), as well as the reported modest but consistent links with BIS sensitivity in the present research. Furthermore, attachment avoidance is regarded as a defensive behavioural pattern driven by fear of the attachment figure's unavailability and involving deactivation (i.e., inhibition of proximity-seeking behaviour and attachment needs) to protect oneself from further rejection (Bowlby, 1960; Shaver & Mikulincer, 2002). Therefore, attachment avoidance clearly involves some degree of aversive motivation. It may be that the manifestation of attachment avoidance is a domain-specific activation of the FFFS, prompting fear toward and withdrawal from the attachment figure, but this does not generalise to a more sensitive FFFS response to aversive stimuli in general. The role of the FFFS in mediating situation-specific aversive behavioural patterns such as attachment avoidance is an important topic for future research. However, the present research shows that attachment avoidance is not related to a generally more sensitive FFFS.

Attachment Avoidance is Weakly Related to BAS Sensitivity

Finally, in the present research, attachment avoidance was found to be weakly and

inconsistently related to BAS sensitivity. In Study 1, attachment avoidance had small, negative and significant correlations with almost all measures of BAS sensitivity, with the exception of RST-PQ-BAS Impulsivity. However, none of these associations were replicated in Studies 2 and 3. In Study 2, BAS sensitivity did predict greater likelihood of engaging in proximity-seeking during separation from the attachment figure. However, unexpectedly, neither attachment dimensions were actually associated with proximity-seeking during separation. Therefore, it was unclear whether the link between BAS sensitivity and proximity-seeking reflected engagement in a novel action or appetitive-approach towards the attachment figure. Furthermore, attachment avoidance and BAS sensitivity did not share overlapping (and divergent) links with the resting EEG correlates of approach motivation. While BAS sensitivity was associated with greater relative parietal theta and delta activities, attachment avoidance was unrelated to any of the EEG indices of dispositional approach. Thus, the results of Study 3 suggest that attachment avoidance does not have straightforward (inverse) links with neurophysiological markers of approach motivation. Together, the data do not provide strong evidence in support of an inverse link between attachment avoidance and BAS sensitivity: at most, the link appears to be tenuous.

The present findings are contrary to a number of previous studies that have found attachment avoidance to be related to lower levels of appetitive motivation. Past studies have found inverse associations between attachment avoidance and BAS sensitivity, similar to what was found in Study 1 (Carnelley & Story, 2008; Meyer et al., 2005; Mikulincer & Shaver, 2010). However, these associations were modest and all of these studies used Carver and White's (1994) BAS scales and tended to calculate an overall index of BAS sensitivity. The studies reported in the present thesis employed different purpose-built measures of BAS (including different facets of BAS sensitivity) that were consistent with the r-RST, as well as

examined links with behavioural approach and neurophysiological correlates of approach. In doing so, this thesis provides more comprehensive evidence that attachment avoidance is weakly and inconsistently related to BAS sensitivity.

Although the present research does not provide evidence of a direct link between attachment avoidance and reduced BAS-mediated sensitivity to appetitive stimuli in general, this does not eliminate the possibility that the dimension may be related to reduced appetitive motivation in social/attachment contexts. For example, aside from the three studies cited in the previous paragraph that have found a direct, modest association between attachment avoidance and BAS sensitivity, a number studies have found links with reduced social approach motivation, in the form of social anhedonia (Berry et al., 2006; Troisi et al., 2010), lower levels of the interpersonal facets of extraversion (i.e., warmth, gregariousness and positive emotions; Mikulincer & Shaver, 2010; Noftle & Shaver, 2006), and reduced sensitivity to social reward (Vrticka et al., 2008). Troisi et al. (2000) speculate that this may reflect the avoidant individual's reduced capacity to experience social rewards. In future, research, it may be worthwhile to examine the hypoactive role of the BAS in mediating reduced appetitive behaviour in attachment relationships for individuals with higher levels of attachment avoidance. For example, studies can include more focal questionnaires on perceived social reward in relationships, as well use EEG or fMRI to examine neural response to images of positive social interactions. The present research nonetheless contributes to our understanding of the nature of the relations between attachment avoidance and global BAS sensitivity.

Attachment Anxiety is Unrelated to BAS Sensitivity

Across the three studies reported in this thesis, attachment anxiety was unrelated to BAS sensitivity. Apart from a few isolated significant correlations between attachment

anxiety and a few indices of BAS sensitivity in Study 1 (which became non-significant in the regression analyses), no significant associations were found in Studies 2 and 3, nor did the two constructs overlap in their predictions to responses to separation or resting EEG correlates of approach (and avoidance) motivation. Therefore, there is scant evidence to suggest that attachment anxiety is related to BAS sensitivity, but rather, the two are largely independent constructs.

This absence of relations is consistent with the literature. The few studies that have directly examined the relations between adult attachment and reinforcement sensitivity found near-zero correlations between attachment anxiety and BAS sensitivity (Carnelley & Story, 2008; Meyer et al., 2005; Mikulincer & Shaver, 2010). Furthermore, in this instance, there is no evidence to suggest that attachment anxiety might be related to reduced appetitive social motivation. In contrast to attachment avoidance, attachment anxiety is not associated with reduced appetitive relationship goals (Carnelley & Story, 2008) and social anhedonia (Berry et al., 2006; Troisi et al., 2010), and exhibits inconsistent links with extraversion (Mikulincer & Shaver, 2010; Noftle & Shaver, 2006). Instead, it appears that the evidence (both in the present research and existing literature) more strongly suggests that attachment anxiety is related to the sensitivity of the aversive motivational systems of FFFS and BIS, as opposed to BAS sensitivity. That is, the two attachment dimensions capture different motivational components, with attachment anxiety oriented towards threat appraisals such as fear of rejection, worry over attachment figure's availability, and hypervigilance to threats in general; rather than oriented towards social and general rewards. Therefore, the present research found that the dimension of attachment anxiety is consistently unrelated to BAS sensitivity.

General implications for the nature of the relations between adult attachment and reinforcement sensitivity

The data from the three studies paint an overall picture of modest overlaps between individual differences in adult attachment and reinforcement sensitivity. Across all three studies, the self-reported associations were modest and restricted to that between both attachment dimensions and BIS sensitivity and attachment anxiety and FFFS sensitivity. Moreover, adult attachment and reinforcement sensitivity exhibited no overlaps in their predictions to attachment behaviour and resting EEG correlates: reinforcement sensitivity had no significant predictions to differential responses to the attachment-relevant separation scenario in Study 2, while adult attachment was not associated with the neural correlates of dispositional approach and avoidance in Study 3. The lack of convergence between the two domains, especially at the behavioural and neurophysiological levels, suggests an absence of robust, direct relations between adult attachment and reinforcement sensitivity, although there are modest links at the self-report level.

The divergence between the self-report, behavioural and neurophysiological data is not unusual, but rather typical when employing different methodologies. The minimal shared variance and relationships of very small effect sizes between different assessment methods (especially self-report versus non-self-report) have been reported for a number of constructs, including impulsivity (Cyders & Coskunpinar, 2011), distress intolerance (McHugh et al., 2011), pain experience (Beyer, McGrath, & Berde, 1990), creativity (Ng & Feldman, 2012), and subjective well-being (Sandvik, Diener, & Seiditz, 2006). More pertinently, Leue and Beauducel (2008) in their meta-analysis found associations of very small effect sizes between psychometric measures and experimental task performance parameters of reinforcement sensitivity. This gap between self-report, behavioural and neurophysiological data could

reflect operationalisational differences that measure disparate aspects of the same phenomenon. For example, the item content of the self-reported measures of reinforcement sensitivity pertain to typical responses to a range of specific situations (e.g., "It would excite me to win a contest"), based on the participant's conscious reflection; while, quite divergently, frontal alpha asymmetry measures the level of activity at the cortical surface of the brain at rest, which is assumed to provide some indication of brain activation corresponding to approach motivation. Likewise, the adult attachment questionnaire measures self-assessed behavioural tendencies in close relationships (e.g., "I prefer not to show a partner how I feel deep down"), which sets in contrast to the Simoland behavioural paradigm that records state-specific behavioural responses to a separation scenario. Accordingly, in the present research, self-reported reinforcement sensitivity had some links to self-reported attachment behaviour in close relationships more generally, but not state behavioural response to the separation scenario specifically. Given the dissimilar operationalisations that potentially tap unique aspects of the latent construct of interest, it is unsurprising that the self-reported associations between reinforcement sensitivity and adult attachment were not replicated at the behavioural and neurophysiological levels.

Although the present research did not find strong and direct associations between reinforcement sensitivity and adult attachment, this does not necessarily implicate that the two domains are completely unrelated. One possibility may be that the two domains are related in an *indirect*, hierarchical manner. Compared to attachment theory, r-RST is a much more broad and domain-general theory. As Corr (2008, p. 30) wrote, r-RST "attempts to provide explanatory constructs that work at the general level" and was not intended to explain every basic, situation-specific need or motive. In contrast, attachment theory is a much more circumscribed theory concerning appraisals and behaviour toward the attachment figure,

often in situations of distress. Accordingly, as proposed by Ure (2011), "the attachment system may operate as a sub-system of RST that is calibrated specifically to regulate appetitive and aversive processes in close relationships" (p. 31). Therefore, although the r-RST may describe basic approach, avoidance, and conflict resolution processes that are generally relevant to attachment behaviour, the sensitivities of the underlying motivational systems may not directly translate to specific behaviours (and behavioural patterns) in close relationships. Rather, reinforcement sensitivity may predict sensitivity to relational rewards, threats, and ambivalence, which, in turn, has been related to adult attachment patterns (e.g., Gere et al., 2013; MacDonald et al., 2013; Nikitin & Freund, 2010). In this way, r-RST as a broad and domain-general theory may not have strong, direct links with adult attachment, but rather the relation may be indirectly mediated by relational motives. Future research could include an explicit self-report or behavioural (e.g., attentional dot-probe task) measure of sensitivity to rewards, threats, and ambivalence in close relationships, and assess whether this is a potential intermediary between global reinforcement sensitivity and adult attachment. For the present findings, the gap in domain-specificity may account for the weak direct associations between reinforcement sensitivity and adult attachment.

Moreover, r-RST may have limited explanatory scope with respect to accounting for individual differences in attachment behaviour insofar as it provides insufficient consideration of cognitive and social processes. Given that r-RST focuses on biobehavioural systems that promote survival, some researchers have argued that the theory neglects higher-level 'reflective' processes, such as executive control over behaviour and metacognitive processes, as well as social factors (Carver, 2008; Smillie, 2008a). In this way, r-RST may provide an insufficient account of the cognitive and social processes that importantly characterise attachment behavioural patterns. For example, one key concept proposed in

attachment theory is that of Internal Working Models (IWMs), which are cognitive representations of the lovability of oneself and trustworthiness and responsiveness of others. Although such cognitions are undeniably mediated by brain functions, they are at least one level removed from the basic stimulus-contingent responses mediated by the r-RST systems. Furthermore, as Carver (2008) noted, the higher level of 'reflective' cognitive processes may exert executive control over reinforcement sensitivity. For example, insight into one's own IWMs, as well as social influences such as a new relationship or therapeutic intervention, can modify one's attachment behaviour. Therefore, attachment behavioural patterns cannot be simply reduced to a domain-specific manifestation of BAS-, FFFS-, and BIS-mediated stimuli-contingent approach-avoidance responses. In this way, as Smillie (2008a; Smillie et al., 2011) argued, r-RST provides a necessary but insufficient and partial explanation of personality, and the challenge for future research is to determine how basic motivation interfaces with higher-order processes.

Further to the limited explanatory scope of r-RST, it needs to be remembered that few psychological phenomenon, including attachment anxiety and avoidance, can be accounted by a single brain-behavioural system or circulatory. Indeed, researchers have only managed to find single (and separate) brain circulatories for freezing and fighting behaviours, while most states are complex, whole-brain constructions (e.g., Barrett, in press). With regards to the attachment 'system', Bowlby (1969/1982) himself originally described the diverse range of attachment behaviour as arising from multiple hierarchically organised behavioural systems, with some systems being more "reflexive" and simple in nature, while other systems are more sophisticated and goal-corrected. Therefore, unsurprisingly, the present research did not find straightforward and strong one-to-one mappings between the attachment dimensions and the r-RST systems. Instead, attachment behaviour may be underpinned by all three r-RST

systems, as well as other brain-behavioural systems. It is not difficult to imagine that attachment insecurity may involve, to varying degrees, BAS-mediated approach in desiring proximity to the attachment figure, FFFS-mediated withdrawal associated with fear of rejection, and BIS-mediated conflict resolution as arising from the motivational ambivalence. The important point is that attachment patterns are not likely to be reducible to one or two brain-behavioural systems, such as those described by r-RST, but rather are complex phenomena that involve the interaction of multiple social, biological, and behavioural systems. It is of interest in future research to identify other brain-behavioural systems that might mediate attachment behaviour. The present research provides a starting point for examining whether adult attachment is related to the three biobehavioural systems defined by r-RST.

The present research also contributes important insights into the nature of the relations between adult attachment and personality more generally. The results converge with the plethora of research on attachment dimensions and personality dimensions such as the Big 5, which conclude modest overlaps (see Noftle & Shaver, 2006, for a review). While the attachment dimensions do map onto some personality traits, they are not redundant and provide unique explanatory power in the context of close relationships (Noftle & Shaver, 2006). This appears to be similarly the case for the nature of the relations between adult attachment and reinforcement sensitivity. The constructs may share overlapping phenotypic features (e.g., BIS anxiety and attachment anxiety; FFFS flight and attachment avoidance), but they offer different levels and scopes of explanation. In particularly, the r-RST is a neurobiologically-based theory of personality and motivation, and so it is unsurprising that links with attachment are not straightforward. Therefore, while the attachment dimensions

evidence modest links with personality (including reinforcement sensitivity), they have unique explanatory roles in the context of close relationships.

The r-RST can still offer a powerful explanatory framework for motivational dynamics underlying attachment behaviour. The theory is concerned with the sensitivities of motivational systems to basic reinforcers, and, as noted by Gray (1970), "people are the most important dispensers of both rewards and punishments for other people" (p. 257). The attachment relationship in both childhood and adulthood is one of the most primary sources of reinforcers in the form of fear, safety, and love (Bowlby, 1969/1982, 1973). Consequently, the r-RST motivational systems are likely to play a central role in mediating attachment behaviour. An interesting research question regarding the r-RST foundations of attachment behaviour is how attachment patterns and reinforcement sensitivity emerge developmentally – whether the sensitivity of the motivational systems influence attachment behaviour and/or attachment experiences affect the sensitivity of the motivational systems. While these remain as outstanding research questions, the r-RST still has great potential to contribute to the understanding of the motivational foundations of attachment behaviour.

General Limitations

There are a number of limitations that apply to all three studies. Firstly, the correlational design of all three studies does not permit conclusions regarding causality to be advanced with respect to the nature of the relations between adult attachment and reinforcement sensitivity. Study 1 examined links between self-reported measures of adult attachment and reinforcement sensitivity, while studies 2 and 3 extended this by looking at links to behavioural and neurophysiological correlates. These studies are unable to inform upon the causal mechanism by which the two adult attachment and reinforcement sensitivity

are related. For example, higher levels of attachment insecurity may prompt more survival concerns, resulting in a more sensitive FFFS, and higher levels of attachment security may promote BAS-mediated exploratory behaviour. Conversely, an individual with a more sensitive FFFS or BIS may be more predisposed to developing attachment insecurity. Furthermore, it remains to be explored whether the two domains are related in ways (e.g., indirectly or in association with other behaviours) that were not examined in the present study. All these questions remain for future research. It would be useful for future studies to include an experimental manipulation. For example, researchers can manipulate state attachment security such as via priming techniques, and assess whether this changes reported sensitivities of the BAS, FFFS and BIS, and vice versa. The studies reported in this thesis were able to inform upon the degree to which the two domains are related at the self-report level, and whether these two domains are similarly associated with attachment behaviour and neural correlates of approach and avoidance.

A second limitation common across the three studies is the reliance on self-report and proxy measures of reinforcement sensitivity. As Smillie et al. (2006) argued, self-report measures are not ideal for the assessment of r-RST as it is difficult for participants to accurately introspect and report on the sensitivity of their biologically-based motivational systems. As such, the self-report measures could conceal or attenuate links between adult attachment and reinforcement sensitivity. In an attempt to circumvent this issue, Study 3 included EEG-derived neurophysiological indices of dispositional approach and avoidance motivation. Even so, these indices serve as proxy measures of the sensitivity of the r-RST systems, with debatable validity given tenuous associations found in both Study 3 and previous research. This issue of validity does not only apply to the self-report measures and EEG indices used in the present study, but rather, reflects the more general issue of

operationalising r-RST and the lack of a gold standard measure (Smillie et al., 2006). Future studies may benefit from the development of newer and more valid measures of reinforcement sensitivity, as well as employ other existing (proxy) measures such as behavioural learning tasks that assess sensitivity to threats and rewards. The present study attempted to make use of the best available purpose-built and proxy measures of reinforcement sensitivity that are faithful to the revised theory, and supplemented the self-report measures with relevant neurophysiological indices.

Thirdly, all three studies assessed self-reported adult romantic attachment. Although adult romantic attachment was the focus of this thesis, it is possible that assessing global attachment tendencies may yield different results. Global measures of attachment – as derived from assessing attachment behaviour across multiple relationships (e.g., parent, romantic partner, sibling, and friend) – are recently argued to provide a more trait-like assessment of attachment behaviour (Fraley et al., 2011). Furthermore, according to Overall et al.'s (2003) hierarchical model of multiple attachment relationships, global attachment can be regarded as a broad higher-order representation, while romantic attachment is more domain-specific. In these ways, global attachment as a broader construct may have closer links with the sensitivity of the general motivational systems, given the aforementioned issue of mismatch in domain-specificity for adult romantic attachment and reinforcement sensitivity. Nonetheless, romantic attachment is likely to be the primary and most important attachment relationship in adulthood, and so was examined in the present thesis. Future studies would additionally benefit from the inclusion of global adult attachment measures. Relatedly, future studies could also examine links between reinforcement sensitivity and other operationalisations of attachment such as the Adult Attachment Inverview (AAI; George et a., 1985). As noted in Chapter 1, the AAI assesses the ability to provide a coherent

narrative of early caregiving experiences, and shows empirical divergence from self-reported adult attachment dimensions (e.g., r = .07 between AAI security and self-reported attachment dimensions) (Roisman et al., 2007a). Therefore, as concluded by Roisman (2009), attachment is not a single monolithic construct, and so there is potential for future studies to investigate links between reinforcement sensitivity and more diverse operationalisations of attachment.

Fourthly, all three studies used non-representative participant samples, which limit the generalisability of the findings. Studies 1 and 2 recruited first year undergraduate psychology students, while Study 3 recruited paid volunteers mostly from the university community. All three samples were predominantly female, university educated, and self-elected to participate in the research, as is typical in psychological research. Given the homogeneity across the samples, the generalisability of the results to other populations might be questionable. However, the functioning of the attachment and reinforcement sensitivity systems are not theorised to vary for different sociodemographic backgrounds, but rather, these are basic evolutionary-based motivational systems intrinsic to all humans. Indeed, informative research on both sets of biobehavioural systems have been conducted on even non-human animals, and, more pertinently, individual differences in adult attachment and reinforcement sensitivity have been established in university student populations (e.g., Corr, 2008; Mikulincer & Shaver, 2007).

Implications

The findings of this thesis offer a number of applied implications. In the relationship counselling setting, the evidenced link between attachment insecurity and BIS sensitivity suggest that it may be important to consider an individual's sensitivity to motivational ambivalence. While further research is required to determine whether attachment insecurity

causes sensitivity to motivational ambivalence or vice versa, it is potentially of therapeutic value to help a client understand and reduce their level of motivational ambivalence, along with trying to increase their levels of attachment security. This may be achieved through some form of cognitive-behavioural therapy, such as training clients to attend to and pursue general and relational rewards, and to be less overly-sensitive to general and relational threats. In clinical settings, the present research offers potential insight into how reinforcement sensitivity and attachment orientation may interact to contribute to psychopathology. For example, given the positive association between attachment insecurity and BIS sensitivity, an insecurely attached person with greater BIS sensitivity may be particularly vulnerable to anxiety disorders. Conversely, the absence of associations between attachment insecurity and BAS sensitivity suggest that the two constructs independently contribute to disorders such as addictions. While further research is required, understanding the nature of the relations between the attachment and reinforcement sensitivity motivational systems can have useful applications including in relationship counselling and clinical settings.

Research Summary and Contribution

In summary, this thesis presented three research studies that were designed to examine the nature of the relations between individual differences in adult attachment and reinforcement sensitivity. A summary of the findings are presented in box below. The three studies found modest associations between adult attachment and BIS sensitivity (and, to a lesser degree, FFFS sensitivity), but did not find robust associations at the behavioural and neuropsychological levels. Whilst Bowlby (1969/1982) theorised that attachment behaviour arises from fundamental, survival-based motivational systems, the present data do not

provide evidence of strong overlap between attachment behaviour and r-RST motivational systems. It appears that the two domains are largely independent: the attachment system is concerned with dyadic stress-regulation, while r-RST describes more general motivations. However, there were consistent links between attachment anxiety and avoidance and self-reported BIS sensitivity. These links provide a better understanding of attachment insecurity as characterised by sensitivity to motivational ambivalence. Greater BIS sensitivity may explain the anxious person's worry over rejection and, at the same time, desire for closeness with the attachment figure, and the avoidant individual's surface discomfort with intimacy juxtaposed with deeper, unmet attachment needs. The relationship between attachment insecurity and BIS sensitivity is an important direction for future research. It may be concluded from the present research that adult attachment does not share strong and direct links with reinforcement sensitivity, but there are some relations with BIS sensitivity. In this way, this thesis contributes to understanding how differential attachment patterns are related to more general motivational systems, which in turn, provides insight to attachment system functioning.

Summary of Findings

1. Neither attachment anxiety nor attachment avoidance has robust associations with BAS sensitivity.

2. Attachment anxiety has modest associations with FFFS sensitivity at the self-report level.

3. Attachment avoidance is unrelated to FFFS sensitivity.

4. Both attachment dimensions evidence links with BIS sensitivity.

Conclusion

This thesis provides an important and unique attempt to examine the nature of the relations between individual differences in adult attachment and reinforcement sensitivity. In doing so, it contributes to the limited understanding of how the differential functioning of the attachment system is related to the more biologically-based fundamental motivational systems. Extending the small number of existing studies that have directly examined links between adult attachment and reinforcement sensitivity, the three studies reported in this thesis provides a more comprehensive assessment of the relations between the attachment dimensions and the sensitivity of all three motivational systems – the BAS, FFFS, and BIS. Previous studies tended to focus on the sensitivity of one or two motivational systems, and, in their operationalisation of the constructs, neglect the substantial theoretical revisions by Gray and McNaughton (2000). The present research used a careful selection of both purpose-built and self-report measures of reinforcement sensitivity that takes into account these theoretical revisions. Moreover, the present thesis made use of self-report, behavioural and neurophysiological data to address the research question.

Across the three studies, both attachment anxiety and attachment avoidance were consistently related to BIS sensitivity, while attachment anxiety additionally exhibited modest links with FFFS sensitivity at the self-report level. No notable associations were found with BAS sensitivity. It appears that attachment insecurity is centrally characterised by motivational ambivalence, and the sensitivity of the BIS potentially plays a critical role in resolving both relational and general ambivalence. This is an important direction for future research.

Despite these links at the self-report level, neither adult attachment nor reinforcement sensitivity shared any overlaps in their predictions to behavioural response to attachment-

related separation or neurophysiological correlates of approach and avoidance. In Study 2, reinforcement sensitivity did not meaningfully predict responses to separation from, and subsequent reunion with, the attachment figure. Instead, the attachment dimensions displayed more powerful, unique and direct predictions to behavioural responses to the attachment-relevant situation. In Study 3, neither attachment dimensions were associated with the resting EEG-derived neurophysiological correlates of dispositional approach and avoidance. This suggests that the attachment anxiety and attachment avoidance do not map simply onto withdrawal and approach tendencies respectively, and insofar as these tendencies are mediated by reinforcement sensitivity, the data do not provide evidence of robust and direct relations between adult attachment and reinforcement sensitivity.

Together, the self-report, behavioural, and neurophysiological data suggests that there are not strong, direct links between adult attachment and reinforcement sensitivity, but rather, the relations are modest. However, this does not mean that the two domains are completely unrelated. It may be that the general motivational systems and the more circumscribed attachment behaviour are related in an indirect, hierarchical manner. This possibility provides an interesting direction for future research to examine whether domain-specific and perhaps even state activations of the BAS, FFFS and BIS mediate individual differences in adult attachment.

This thesis provides an important first step in establishing the nature of the relations between adult attachment patterns and the global sensitivities of the r-RST motivational systems. Although much more research is needed to understand the motivational mechanisms that underpin attachment behaviour, the spirit of this research follows Bowlby's (1969/1982) proposal that attachment behaviour involves basic, biobehavioural motivational systems.

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APPENDIX A

Study 1 Questionnaires

The Experiences in Close Relationships-Revised (ECR-R) Questionnaire

Reference: Fraley, R. C., Waller, N. G., & Brennan, K. A. (2000). An item-response theory analysis of self-report measures of adult attachment. *Journal of Personality and Social Psychology*, *78*, 350-365.

Instructions: 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 clicking a circle to indicate how much you agree or disagree with the statement.

(Each item below is rated on a 7-point Likert scale: **1 = Strongly disagree, 2 = Disagree, 3 = More disagree than agree, 4 = Neutral, 5 = More agree than disagree, 6 = Agree,** and **7 = Strongly agree**.)

(This questionnaire takes 5-10 minutes to complete.)

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.

End of questionnaire.

The Behavioural Activation Scale (BAS) from the BIS/BAS scales

Reference: Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS scales. *Journal of Personality and Social Psychology*, *67*, 319-333.

Instructions: Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

(Each item below is rated on a 4-point Likert scale: **1 = very true for me, 2 = somewhat true for me, 3 = somewhat false for me,** and **4 = very false for me**.)

(This questionnaire takes 5 minutes to complete.)

1. I go out of my way to get things I want.
2. When I'm doing well at something I love to keep at it.
3. I'm always willing to try something new if I think it will be fun.
4. When I get something I want, I feel excited and energized.
5. When I want something I usually go all-out to get it.
6. I will often do things for no other reason than that they might be fun.
7. If I see a chance to get something I want I move on it right away.
8. When I see an opportunity for something I like I get excited right away.
9. I often act on the spur of the moment.
10. When good things happen to me, it affects me strongly.
11. I crave excitement and new sensations.
12. When I go after something I use a "no holds barred" approach.
13. It would excite me to win a contest.

End of questionnaire.

The Y2 (trait) scale from the State Trait Anxiety Inventory (STAI)

Reference: Spielberger, C. D., Gorsuch, R. L., Lushene, R. E., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the state-trait anxiety inventory: STAI (Form Y2)*. Palo Alto, CA: Consulting Psychologists Press.

As the STAI-Y2 is a copyrighted questionnaire, it is not reproduced here.

Fear Survey Schedule (FFS-II)

Reference: Geer, J. H. (1965). The development of a scale to measure fear. *Behaviour Research and Therapy*, *3*, 45-53.

Instructions: Listed below are fifty-one objects and situations. Using the scale below, rate each on the intensity of your fear associated with that specific object or event.

(Each item below is rated on a 7-point Likert scale: **1 = None, 2 = Very little, 3 = A little, 4 = Some, 5 = Much, 6 = Very much**, and **7 = Terror**.)

(This questionnaire takes 5 minutes to complete.)

1. Sharp objects
2. Being a passenger in a car
3. Dead bodies
4. Suffocating
5. Failing a test
6. Looking foolish
7. Being a passenger in an airplane
8. Worms
9. Arguing with parents
10. Rats and mice
11. Life after death
12. Hypodermic needles
13. Being criticized
14. Meeting someone for the first time
15. Roller coasters
16. Being alone
17. Making mistakes
18. Being misunderstood
19. Death
20. Being in a fight
21. Crowded places
22. Blood
23. Heights
24. Being a leader
25. Swimming alone
26. Illness
27. Being with drunks
28. Illness or injury to loved one
29. Being self-conscious
30. Driving a car
31. Meeting authority
32. Mental illness
33. Closed places
34. Boating
35. Spiders
36. Thunderstorms
37. Not being a success
38. God
39. Snakes
40. Cemeteries
41. Speaking before a group
42. Seeing a fight
43. Death of a loved one
44. Dark places
45. Strange dogs
46. Deep water
47. Being with a member of the opposite sex
48. Stinging insects
49. Untimely or early death
50. Losing a job
51. Auto accidents

End of questionnaire.

Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ)

Reference: Corr, P. J., & Cooper, A. (in prep). The Corr-Cooper Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ): Development and validation.

Instructions: Below are a list of statements about everyday feelings and behaviours. Please rate how accurately each statement describes *you in general*. Circle only one response. Do not spend too much time thinking about the questions and please answer honestly.

(Each item below is rated on a 4-point Likert scale: **1 = Not at all, 2 = Slightly, 3 = Moderately,** and **4 = Highly**.)

(This questionnaire takes 10-15 minutes to complete.)

1. I feel sad when I suffer even minor setbacks.
2. I am often preoccupied with unpleasant thoughts.
3. Sometimes even little things in life can give me great pleasure.
4. I am especially sensitive to reward.
5. I put in a big effort to accomplish important goals in my life.
6. I have found myself fighting back when provoked.
7. I sometimes feel 'blue' for no good reason.
8. When feeling 'down', I tend to stay away from people.
9. I often experience a surge of pleasure running through my body.
10. I would be frozen to the spot by the sight of a snake or spider.
11. I have often spent a lot of time on my own to "get away from it all".
12. I am a very active person.
13. I'm motivated to be successful in my personal life.
14. I think retaliation is often the best form of defence.
15. I am always 'on the go'.
16. My hearts starts to pump strongly when I am getting upset.
17. I regularly try new activities just to see if I enjoy them.
18. I get carried away by new projects.
19. Good news makes me feel over-joyed.
20. I think you have to stand up to bullies in the workplace.
21. The thought of mistakes in my work worries me.
22. I have experienced the feeling of overwhelming dread.
23. When nervous, I sometimes find my thoughts are interrupted.
24. I would run quickly if fire alarms in a shopping mall started ringing.
25. I often overcome hurdles to achieve my ambitions.
26. I sometimes wake up in a state of terror.
27. If I feel threatened I will fight back.
28. I often feel depressed.
29. I think I should 'stop and think' more instead of jumping into things too quickly.
30. I often feel that I am on an emotional 'high'.
31. I love winning competitions.
32. I get a special thrill when I am praised for something I've done well.
33. I take a great deal of interest in hobbies.
34. I would not tolerate bullying behaviour towards me.

35. I sometimes cannot stop myself talking when I know I should keep my mouth closed.
36. I often do risky things without thinking of the consequences.
37. My mind is sometimes dominated by thoughts of the bad things I've done.
38. I get very excited when I get what I want.
39. I feel driven to succeed in my chosen career.
40. I'm always finding new and interesting things to do.
41. I'm always weighing-up the risk of bad things happening in my life.
42. People are often telling me not to worry.
43. I can be an aggressive person when I need to be.
44. I am very open to new experiences in life.
45. I always celebrate when I accomplish something important.
46. I am a panicky sort of person.
47. I find myself reacting strongly to pleasurable things in life.
48. I find myself doing things on the spur of the moment.
49. I usually react immediately if I am criticized at work.
50. I would defend myself if I was falsely accused of something.
51. I would instantly freeze if I opened the door to find a stranger in the house.
52. I'm always buying things on impulse.
53. I am very persistent in achieving my goals.
54. When trying to make a decision, I find myself constantly chewing it over.
55. I often worry about letting down other people.
56. I would go on a holiday at the last minute.
57. I physically shake when I am very upset.
58. I would run fast if I knew someone was following me late at night.
59. I would leave the park if I saw a group of dogs running around barking at people.
60. I worry a lot.
61. I would freeze if I was on a turbulent aircraft.
62. My behaviour is easily interrupted.
63. It's difficult to get some things out of my mind.
64. I think the best nights out are unplanned.
65. There are some things that I simply cannot go near.
66. If I see something I want, I act straight away.
67. I think it is necessary to make plans in order to get what you want in life.
68. I tend to panic a lot.
69. When nervous, I find it hard to say the right words.
70. I find myself thinking about the same thing over and over again.
71. I often wake up with many thoughts running through my mind.
72. I would not hold a snake or spider.
73. Looking down from a great height makes me freeze.
74. I often find myself 'going into my shell'.
75. My mind is dominated by recurring thoughts.
76. I am the sort of person who easily freezes-up when scared.
77. I take a long time to make decisions.
78. I often find myself lost for words.
79. I will actively put plans in place to accomplish goals in my life.

End of questionnaire.

Demographic Questions

(This section takes 5 minutes to complete.)

1. What is your gender? (male/female)
2. What is your age? (years)
3. Are you currently involved in an exclusive romantic relationship (i.e., dating, engaged, or married)? (yes/no)
4. Please select the option that best describes your relationship status. (Single, Dating, Engaged, Married or Cohabitating, Divorced, Widowed)
5. If you are in a relationship, how long have you been involved with this person? (years, months)
6. Are your biological parents (or the caretakers who raised you) divorced?
7. If your parents are divorced, how old were you when they separated or divorced? (age in years)
8. What is your country of residence? (specify)
9. Please select the option that best describes your ethnicity. (Caucasian, African American/Black, Hispanic/Latino, Asian, Middle Eastern, Pacific Islander, Other [specify])

End of questionnaire.

APPENDIX B

Study 2 - Identification with Protagonist and Game Presence Scale

In the following pages we will ask you some questions about how you experienced the game. There is no “right” or “wrong” for these questions, just answer as you feel.

Response scale: **1 = not at all, 2 = rather not, 3 = undecided, 4 = somewhat,** and **5 = very much**.

(The following items assess identification with the protagonist and game presence.)

1. I identified myself with my Simo.
2. I liked the characters.
3. The game was silly to me.
4. The behavior of the other Simos influenced by mown behaviour.
5. I cared about the characters.
6. I was always aware that the other characters were controlled by the computer.
7. The other Simos seemed to me to be sensitive.
8. I got completely involved into the game.
9. I often had the thought that the Simos are only virtual characters.
10. During the game I consciously thought about current or past relationships of mine.

End of questionnaire.

APPENDIX C

Study 3 Questionnaires

Fear Survey Schedule (FFS-III)

Reference: Wolpe, J., & Lang, P. J. (1964). A fear survey schedule for use in behaviour therapy. *Behaviour Research and Therapy*, *2*, 27–30.

Instructions: The items in this questionnaire refer to things and experiences that may cause fear or other unpleasant feelings. Write the number of each item in the column that describes how much you are disturbed by it nowadays.

(Each item below is rated on a 5-point Likert scale: **1 = Not at all, 2 = A little, 3 = A fair amount, 4 = much, 5 = Very much**)

Classifications: A = Animal; S = Social or interpersonal; T = Tissue damage, illness and death, and their associations; N = Noises; C = Other classical phobias; M = Miscellaneous

1. Noise of vacuum cleaners (N)
2. Open wounds (T)
3. Being alone (C)
4. Being in a strange place (M)
5. Loud voices (N)
6. Dead people (T)
7. Speaking in public (S)
8. Crossing streets (C)
9. People who seem insane (T)
10. Falling (M)
11. Automobiles (C)
12. Being teased (S)
13. Dentists (T)
14. Thunder (C)
15. Sirens (N)
16. Failure (M)
17. Entering a room where other people are already seated (S)
18. High places on land (C)
19. People with deformities (T)
20. Worms (A)
21. Imaginary creatures (M)
22. Receiving injections (T)
23. Strangers (S)
24. Bats (A)
25. Journeys (C)

a-Train
b-Bus
c-Car

26. Feeling angry (M)
27. People in authority (S)
28. Flying insects (A)
29. Seeing other people injected (T)
30. Sudden noises (N)
31. Dull weather (M)
32. Crowds (S)
33. Large open spaces (C)
34. Cats (A)
35. One person bullying another (T)
36. Tough looking people (S)
37. Birds (A)
38. Sight of deep water (C)
39. Being watched working (S)
40. Dead animals (T)
41. Weapons (M)
42. Dirt (C)

43. Crawling insects (A)
44. Sight of fighting (T)
45. Ugly people (S)
46. Fire (C)
47. Sick people (T)
48. Dogs (A)
49. Being criticized (S)
50. Strange shapes (M)
5 I. Being in an elevator (C)
52. Witnessing surgical operations (T)
53. Angry people (S)
54. Mice (A)
55. Blood (T)
a-Human
b-Animal
56. Parting from friends (S)
57. Enclosed places (C)
58. Prospect of a surgical operation (T)
59. Feeling rejected by others (S)
60. Airplanes (C)
61. Medical odors (T)
62. Feeling disapproved of (S)
63. Harmless snakes (A)
64. Cemeteries (T)
65. Being ignored (S)
66. Darkness (C)
67. Premature heart beats (missing a beat) (T)
68. a-Nude men (S)
b-Nude women (S)
69. Lightning (C)
70. Doctors (T)
71. Making mistakes (M)
72. Looking foolish (S)

End of questionnaire.

Heym et al.'s Revised Reinforcement Sensitivity Theory Measure

Reference: Heym, N., Skatova, A., Ferguson, E., & Lawrence, C. (2016). The development and psychometric evaluation of the BIS/BAS/FFFS subsystems scales for measurement of approach and avoidance motivation. *Manuscript submitted for publication.*

Instructions: For each item of this questionnaire, indicate how much you agree or disagree with what the item says by circling the appropriate number. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very false for me, 2 = somewhat false for me, 3 = somewhat true for me, 4 = very true for me

BIS Anxiety items
1. I worry about making mistakes.
2. The thought of failure makes me very anxious.
3. I feel worried when I think I have done poorly at something important.
4. I generally worry a lot.

BIS Appraisal items
5. I always like to carefully appraise any situation before making a decision.
6. When an opportunity arises I tend to weigh up all the pros and cons.
7. I tend to collect lots of information before making final decisions.

BAS Reward items
8. I'm always willing to try something new if I think it will be fun.
9. When I get something I want, I feel excited and energized.
10. I will often do things for no other reason than that they might be fun.
11. When I see an opportunity for something I like I get excited right away.
12. When good things happen to me, it affects me strongly.

BAS Drive items
13. When I want something I usually go all-out to get it.
14. I go out of my way to get things I want.
15. If I see a chance to get something I want I move on it right away.
16. When I go after something I use a "no holds barred" approach.

FFFS Flight items
17. In dangerous situations I sometimes just run away.
18. My first response in threatening situations is to get away as soon as possible.
19. When in danger (i.e. fire alarm, fight etc.), I'm one of the first to get out.
20. When I get startled, I often start to run.

FFFS Freeze items
21. I often freeze/tense up in extremely threatening situations.
22. When I feel I'm in danger I sometime feel myself unable to act or move.
23. When I'm scared I usually pretend not to be there (i.e. closing my eyes) or that it is all over.
24. When I encounter things I am extremely frightened off, I can't do anything but tremble and shake.

FFFS Fight items
25. I sometimes react in an irrationally aggressive way in threatening situations.
26. I have been known to lash out without thinking when I've been scared.
27. When threatened, I can't control the urge to strike someone.
28. If someone attacks me, I hit out.
29. I have hit someone when I've been extremely frightened.
30. When I have been physically trapped (e.g. by another person), I have tried to punch and kick my way out.

End of questionnaire.

APPENDIX D

Study 1 Supplementary Analyses: Multiple Hierarchical Linear Regressions Predicting Attachment Dimensions from R-RST Variables, Controlling for the Non-Criteron Attachment Dimension as a Covariate

Hierarchical Regressions Predicting Attachment Dimensions from CW-BAS, FSS and STAI (N = 225)

Predictors	Attachment Anxiety			
	B	SE B	β	ΔR^2
Step 1				.13***
Gender	-.09	.14	-.04	
Age	.01	.02	.01	
Relationship status	-.55	.13	-.24***	
Step 2				.05***
Attachment avoidance	.11	.06	.11	
Step 3				.24***
CW-BAS Drive	.01	.03	.03	
CW-BAS-FS	.06	.03	.13*	
CW-BAS RR	.02	.03	.03	
FSS	.00	.00	.11†	
STAI	.06	.01	.54***	
Model statistics	R^2 = .48, F (9, 215) = 21.84***			

Predictors	Attachment Avoidance			
	B	SE B	β	ΔR^2
Step 1				.17***
Gender	-.03	.15	-.01	
Age	.01	.02	.03	
Relationship status	-.64	.15	-.29***	
Step 2				.05***
Attachment anxiety	.14	.08	.15	
Step 3				.06**
CW-BAS Drive	.03	.03	.06†	
CW-BAS-FS	-.07	.03	.15*	
CW-BAS RR	-.05	.04	-.10	
FSS	.00	.00	-.10	
STAI	.02	.01	.19*	
Model statistics	R^2 = .28, F (9, 215) = 9.08***			

Note. CW-BAS = Carver & White's (1994) BAS measure; FS = Fun-Seeking; RR = Reward Responsiveness; FSS = Fear Survey Schedule; STAI = State-Trait Anxiety Inventory. †$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Hierarchical Regressions Predicting Attachment Dimensions from RST-PQ Measures (N = 225)

Predictors		Attachment Avoidance			
		B	SE B	β	ΔR^2
Step 1					.17***
	Gender	-.11	.15	-.05	
	Age	.02	.02	.06	
	Relationship status	-.67	.15	-.31***	
Step 2					.05***
	Attachment Anxiety	.21	.07	.22***	
Step 3					.04
	BAS Reward Interest	-.01	.02	-.03	
	BAS Goal-Drive Persistence	.00	.02	-.02	
	BAS Reward Reactivity	-.04	.02	-.17*	
	BAS Impulsivity	.00	.02	.02	
	FFFS	.02	.01	.10	
	BIS	.00	.01	.02	
	Panic	-.03	.03	-.09	
	Defensive Fight	.01	.02	.03	
Model statistics		R^2 = .26, F (12, 212) = 6.08***			

Predictors		Attachment Anxiety			
		B	SE B	β	ΔR^2
Step 1					.13***
	Gender	-.06	.14	-.02	
	Age	.03	.02	.08	
	Relationship status	-.43	.14	-.19**	
Step 2					.05***
	Attachment Avoidance	.18	.06	.17**	
Step 3					.26***
	BAS Reward Interest	-.03	.02	-.10	
	BAS Goal-Drive Persistence	-.02	.02	-.08	
	BAS Reward Reactivity	.00	.02	-.01	
	BAS Impulsivity	.04	.02	.18*	
	FFFS	-.01	.01	-.07	
	BIS	.04	.01	.43***	
	Panic	.01	.02	.02	
	Defensive Fight	-.01	.02	-.03	
Model statistics		R^2 = .44, F (12, 212) = 13.71***			

Note. *p < .05; **p < .01; ***p < .001.

APPENDIX E

Correlations between Self-reported Measures and Low and High Alpha Frequency

Pearson's Correlations between Self-reported Measures of Adult Attachment and Reinforcement Sensitivity and Low Alpha Frequency (8-10 Hz) Asymmetry Scores

Measure	Scale	F4/F3	F6/F5	F8/F7	C4/C3	C6/C5	T8/T7	P4/P3	P6/P5	P8/P7
ECR-R	1 Attachment anxiety	-.04	-.27*	-.12	.12	-.01	-.03	.14	.15	.14
	2 Attachment avoidance	.09	.05	-.03	.31*	-.09	-.07	.14	.21	.06
Heym's r-RST	3 BAS reward reactivity	.00	.09	-.15	.02	-.03	.11	.15	-.14	.01
	4 BAS drive	.26*	.12	-.17	-.08	-.07	-.11	.15	-.19	-.04
	5 FFFS flight	-.10	-.07	-.21	-.03	.06	.09	.21	-.02	.20
	6 FFFS freeze	.01	-.11	-.18	-.02	-.06	-.06	.14	-.02	.05
	7 FFFS fight	.26*	.06	-.22	.09	.03	-.05	.08	.04	-.17
	8 BIS anxiety	-.14	-.22	.09	-.01	-.06	.18	.08	.12	.05
	9 BIS appraisal	-.04	.09	.17	-.01	-.05	.02	.10	-.01	-.13
CW	10 BAS fun seeking	-.03	.11	-.10	.01	-.03	.15	.02	-.13	-.03
	11 BAS reward responsiveness	-.02	.05	-.12	-.07	.11	.06	.14	-.11	.03
FSS fears	12 Social anxiety	-.03	-.15	.03	.03	-.20	.06	-.02	.14	.18
	13 Agoraphobia	.22	.03	.01	.02	-.21	-.03	.03	.05	.21
	14 Bodily damage	-.11	-.19	-.09	.04	-.17	-.07	.00	-.04	-.02
	15 Sex/aggression	.03	.05	.00	.10	-.25	-.09	.01	-.12	-.07
	16 Animals	.10	.17	.02	.05	-.32*	-.05	.00	-.08	.13
	17 Total	.08	-.04	-.01	.09	-.33**	-.04	-.04	.01	.07
STAI	18 Trait anxiety	-.19	-.26*	-.06	.12	-.16	-.05	.14	.16	.00

Note. ECR-R = Experiences in Close Relationships – Revised Scale (Fraley et al., 2000); Heym's r-RST = Heym et al.'s (in prep) r-RST scales; CW = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule-III (Wolpe & Lang, 1964); STAI = State Trait Anxiety Inventory (Spielberger et al., 1983). *$p < .05$; **$p < .01$.

Pearson's Correlations between Self-reported Measures of Adult Attachment and Reinforcement Sensitivity and High Alpha Frequency (10-13 Hz) Asymmetry Scores

Measure	Scale	F4/F3	F6/F5	F8/F7	C4/C3	C6/C5	T8/T7	P4/P3	P6/P5	P8/P7
ECR-R	1 Attachment anxiety	.08	-.20	-.10	.23	.11	-.29*	.09	.15	-.03
	2 Attachment avoidance	-.07	-.04	-.14	.18	.18	-.12	.18	.29*	.16
Heym's r-RST	3 BAS reward reactivity	-.01	.05	-.04	-.13	.01	.23	.17	-.05	-.09
	4 BAS drive	.20	.11	-.22	-.11	.11	.04	.05	.16	-.02
	5 FFFS flight	-.18	-.01	-.03	-.24	-.14	.06	.14	.02	.17
	6 FFFS freeze	-.04	-.04	-.07	-.23	-.14	-.04	.13	.00	-.04
	7 FFFS fight	.04	.09	-.12	.00	-.06	-.23	.00	.11	-.02
	8 BIS anxiety	.06	-.15	.07	.03	-.28*	-.07	.17	.01	.05
	9 BIS appraisal	-.02	.08	.09	.07	.08	-.15	.09	.13	.00
CW	10 BAS fun seeking	.06	.04	.04	-.12	.12	.26*	.16	-.18	-.21
	11 BAS reward responsiveness	-.06	.04	-.07	-.14	-.14	.13	.08	.05	.01
FSS fears	12 Social anxiety	.01	-.03	-.14	.03	.04	-.14	.13	.06	.06
	13 Agoraphobia	-.06	-.03	-.14	.03	.07	-.10	.12	.13	.28*
	14 Bodily damage	-.20	.01	-.22	-.23	.07	-.01	.02	-.04	-.12
	15 Sex/aggression	-.02	-.01	-.17	-.10	.05	-.05	-.10	-.04	.02
	16 Animals	.01	.12	-.17	-.04	.10	.07	-.04	.04	-.02
	17 Total	-.06	.03	-.23	-.08	.07	-.09	.06	.04	.05
STAI	18 Trait anxiety	-.07	-.10	-.02	-.04	.01	-.28*	.12	-.14	-.11

Note. ECR-R = Experiences in Close Relationships – Revised Scale (Fraley et al., 2000); Heym's r-RST = Heym et al.'s (in prep) r-RST scales; CW = Carver & White's (1994) BAS scales; FSS = Fear Survey Schedule-III (Wolpe & Lang, 1964); STAI = State Trait Anxiety Inventory (Spielberger et al., 1983). *$p < .05$.

APPENDIX F

Hierarchical Regressions Predicting Alpha Asymmetry and Pz vs Fz Delta/Theta Activities Based on Full Data Set without Removal of Outliers

Hierarchical Regressions Predicting Alpha Asymmetry Scores from Heym's r-RST scales and Adult Attachment (N = 58)

Index	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
	F4F3				**F6F5**				**F8F7**			
Step 1				.17				.19				.09
BAS reward	-.11	.30	-.06		.69	.32	.32*		-.07	.27	-.04	
BAS drive	.42	.30	.23		-.44	.32	-.22		.27	.27	.17	
FFFS flight	-.61	.25	-.40*		.20	.27	.12		-.18	.22	-.13	
FFFS freeze	.16	.27	.10		.02	.29	.01		-.06	.24	-.04	
FFFS fight	.11	.22	.07		.42	.23	.25†		-.24	.19	-.18	
BIS anxiety	.12	.22	.08		-.40	.23	-.25†		.20	.19	.16	
BIS appraisal	-.18	.22	-.11		.15	.23	.09		.06	.19	.04	
Step 2				.02				.03				.06
Att. anxiety	-.11	.13	-.15		-.20	.14	-.24		-.18	.12	-.28	
Att. avoidance	.12	.14	.15		.17	.15	.18		.01	.13	.02	
Model statistics	*F (9, 49) = 1.26, p = .28*				*F (9, 49) = 1.59, p = .15*				*F (9, 49) = .93, p = .51*			
	C4C3				**C6C5**				**T8T7**			
Step 1				.07				.18				.11
BAS reward	-.05	.38	-.02		.12	.28	.06		.80	.38	.34*	
BAS drive	-.02	.38	-.01		-.04	.28	-.02		-.15	.37	-.07	
FFFS flight	-.06	.32	-.03		-.43	.23	-.30		-.14	.31	-.07	
FFFS freeze	-.56	.35	-.27		-.27	.25	-.18		-.16	.34	-.08	
FFFS fight	.15	.27	.08		.14	.20	.10		.05	.27	.03	
BIS anxiety	-.35	.27	-.19		-.18	.20	-.13		.00	.27	.00	
BIS appraisal	.13	.28	.07		.21	.20	.14		.15	.27	.08	
Step 2				.13*				.03				.00
Att. anxiety	.32	.17	.33†		.11	.12	.15		-.01	.17	-.01	
Att. avoidance	.12	.18	.11		.06	.13	.07		-.04	.18	-.04	
Model statistics	*F (9, 49) = 1.33, p = .24*				*F (9, 49) = 1.47, p = .19*				*F (9, 49) = .72, p = .69*			
	P4P3				**P6P5**				**P8P7**			
Step 1				.06				.06				.08
BAS reward	.19	.19	.16		-.14	.21	-.10		-.13	.24	-.09	
BAS drive	.02	.19	.02		-.07	.21	-.06		-.10	.23	-.08	
FFFS flight	.02	.16	.02		-.05	.18	-.05		.27	.20	.24	
FFFS freeze	.10	.17	.10		-.17	.19	-.15		-.26	.21	-.21	
FFFS fight	-.06	.14	-.06		-.01	.15	-.01		-.14	.17	-.12	
BIS anxiety	.12	.14	.13		-.09	.15	-.08		.05	.17	.04	
BIS appraisal	.04	.14	.04		.07	.15	.06		.01	.17	.01	
Step 2				.08				.16**				.02
Att. anxiety	-.04	.08	-.08		.12	.09	.23		.03	.10	.05	
Att. avoidance	.18	.09	.34†		.16	.10	.27		.07	.11	.12	
Model statistics	*F (9, 49) = .92, p = .52*				*F (9, 49) = 1.55, p = .16*				*F (9, 49) = .59, p = .80*			
	PzFz theta				**PzFz delta**							
Step 1				.17				.08				
BAS reward	.06	.19	.05		.18	.28	.10					
BAS drive	.26	.19	.22		.10	.28	.06					
FFFS flight	-.17	.16	-.17		.08	.23	.06					
FFFS freeze	.40	.17	.39*		.31	.25	.21					
FFFS fight	-.10	.14	-.10		-.11	.20	-.08					
BIS anxiety	.17	.14	.19		.03	.20	.03					
BIS appraisal	.06	.14	.06		.04	.20	.03					
Step 2				.01				.02				
Att. anxiety	-.08	.08	-.16		-.05	.12	-.08					
Att. avoidance	.04	.09	.07		-.06	.13	-.08					
Model statistics	*F (9, 49) = 1.23, p = .30*				*F (9, 49) = .58, p = .81*							

Hierarchical Regressions Predicting Alpha Asymmetry Scores from CW-BAS Scales, FSS, STAI-Trait Anxiety, and Adult Attachment (N=58)

Index	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2	B	SE B	β	ΔR^2
	F4F3				**F6F5**				**F8F7**			
Step 1				.12				.13				.06
BAS drive	.29	.27	.16		-.08	.28	-.04		.16	.23	.10	
BAS fun	.01	.24	.00		-.01	.26	-.01		-.27	.21	-.19	
BAS reward	-.39	.33	-.19		.56	.35	.25		.06	.28	.03	
FSS	.28	.28	.15		.04	.30	.02		.15	.24	.09	
STAI	-.65	.35	-.33		-.57	.37	-.27		.01	.30	.00	
Step 2				.01				.03				.06
Att. anxiety	.01	.15	.01		-.09	.16	-.11		-.19	.13	-.29	
Att. avoidance	.07	.15	.08		.19	.15	.21		-.02	.12	-.03	
Model statistics	*F (7, 51) = 1.06, p = .40*				*F (7, 51) = 1.34, p = .25*				*F (7, 51) = 1.02, p = .43*			
	C4C3				**C6C5**				**T8T7**			
Step 1				.03				.07				.14
BAS drive	.05	.33	.02		-.04	.24	-.02		.02	.31	.01	
BAS fun	.00	.30	.00		-.06	.22	-.04		.67	.29	.35*	
BAS reward	-.38	.41	-.14		-.05	.30	-.02		-.06	.39	-.02	
FSS	-.26	.35	-.11		-.18	.26	-.10		-.20	.33	-.09	
STAI	-.69	.44	-.28		-.79	.32	-.43*		.12	.41	.05	
Step 2				.14*				.09				.00
Att. anxiety	.36	.18	.37		.20	.14	.28		-.04	.17	-.04	
Att. avoidance	.17	.18	.15		.11	.13	.14		-.01	.17	-.01	
Model statistics	*F (7, 51) = 1.48, p = .19*				*F (7, 51) = 1.37, p = .24*				*F (7, 51) = 1.17, p = .34*			
	P4P3				**P6P5**				**P8P7**			
Step 1				.05				.07				.09
BAS drive	.08	.16	.07		-.14	.16	-.10		-.21	.20	-.15	
BAS fun	.07	.15	.07		-.27	.15	-.24		-.33	.18	-.28	
BAS reward	.03	.20	.02		.08	.20	.05		.25	.24	.16	
FSS	-.18	.17	-.16		-.17	.17	-.12		-.08	.21	-.06	
STAI	.17	.22	.14		-.55	.22	-.40*		-.27	.26	-.18	
Step 2				.08				.27***				.04
Att. anxiety	-.02	.09	-.03		.22	.09	.40*		.08	.11	.15	
Att. avoidance	.17	.09	.33		.19	.09	.31*		.08	.11	.12	
Model statistics	*F (7, 51) = 1.06, p = .40*				*F (7, 51) = 3.63, p = .003*				*F (7, 51) = 1.04, p = .42*			
	PzFz theta				**PzFz delta**							
Step 1				.26**				.18†				
BAS drive	.26	.15	.22		.18	.21	.11					
BAS fun	-.26	.14	-.26		-.29	.20	-.21					
BAS reward	.40	.19	.31*		.60	.27	.33*					
FSS	.27	.16	.23		.28	.23	.17					
STAI	.38	.20	.31		.68	.28	.40*					
Step 2				.03				.08				
Att. anxiety	-.11	.08	-.23		-.17	.12	-.26					
Att. avoidance	.00	.08	.01		-.09	.12	-.12					
Model statistics	*F (7, 51) = 2.98, p = .01*				*F (7, 51) = 2.58, p = .02*							

Note. *$p < .05$; **$p < .01$.