Social Reward and Threat Processing

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A Thesis

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Cardiff University

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Summary

The aim of this project was to investigate the relationships between individual differences in social expectancies and motivation, and how these relate to broader personality traits and to social integration outcomes such as individuals' sense of belonging. A cognitive model of social motivation and reactivity to social feedback was proposed. In this model, generalised expectancies are considered to play a pivotal role in motivating human social behaviour.

Two novel measures were developed: the levels of dispositional expectancies of social threat and reward scale (the LODESTARS) and a task-based measure of social motivation and reactivity to social reward and punishment (the social and monetary incentive delay (SMID) task). Rigorous validation studies were employed to ensure the validity and utility of these measures.

The research reported in this thesis employed multiple methods: self-report, task-based measures, and structural and functional (blood oxygenation-level-dependent; BOLD) neuroimaging. The findings of all studies conducted supported the key proposal that dispositional biases in expectancies of social reward and punishment are critical for understanding individual differences in reactivity to social feedback and social outcomes such as loneliness. In the proposed model, expectancies exert their effects both by informing social approach and avoidance motivations and by directly influencing perceptions of and reactions to social cues. Convergent findings from the multiple modalities employed were consistent with both these proposed mechanisms.

Brief Contents

Declaration I
Acknowledgements II
Summary III
Brief Contents IV
Contents VI
Chapter 1 Introduction and conceptual overview 1
1.1 Conceptualising social reward and punishment 3
1.2 Outline of the thesis 4
Chapter 2 Literature Review 6
2.1 Introduction 6
2.2 Unifying principles 24
2.3 Research questions and outline of the empirical approach employed 25
Chapter 3 General Methods 27
3.1 Overview 27
3.2 Psychometric and Process-Based Measures 27
3.3 Magnetic resonance imaging (MRI) methods 52
Chapter 4 Development and validation of a measure of generalised social threat and reward expectancies 55
4.1 Introduction 55
4.2 LODESTARS development 60
4.3 Study 1A: Comparison of results with those of the original STARS study 61
4.4 Internal consistency and reliability of the LODESTARS 66
4.5 LODESTARS reward and threat correlations 86
4.6 Construct validity of the LODESTARS 87
4.7 Testing the predictions of the proposed model: links between social expectancies and social approach and avoidance motives 111
4.8 Testing the predictions of the proposed model: links between social expectancies and social integration outcomes 123
4.9 Conclusion 135
Chapter 5 Relating individual differences in social threat and reward expectancies to human brain structure 137

5.1 Introduction 137
5.2 Methods 150
5.3 Results 163
5.4 Discussion 182
5.5 Conclusion 223
Chapter 6 Development and validation of a task-based measure of social motivation and reactivity to social reward and punishment 224
6.1 Introduction 224
6.2 Task development 225
6.3 Task validation: Reaction time metrics 234
6.4 Task validation: Affective responses 241
6.5 Assessing predictions of the proposed model: links between motivation, behaviour and reactions to feedback 253
6.6 Conclusion 264
Chapter 7 General Discussion 265
7.1 Contributions 266
7.2 Implications 269
7.3 Limitations 273
7.4 Future directions 276
7.5 Conclusion 278
References 280
Appendix 1. Social Network Index adjusted for students – showing changes 330
Appendix 2. Post-Cyberball Need Threat Scale 333
Appendix 3. Full inter-correlation tables for all self-report variables in each study 334
Appendix 4. Pilot testing for SMID task 335
Appendix 5. Script for SMID task instructions 348
Appendix 6. Post-SMID task questions probing affective responses to the task 350
Appendix 7. Full correlations of post-SMID affect response questions with all other self-report variables and with SMID RT indices 351
Appendix 8. A preliminary study of the neural correlates of exposure to social and monetary incentives in the SMID task 352

Contents

Declaration I
Acknowledgements II
Summary III
Brief Contents IV
Contents VI
Chapter 1 Introduction and conceptual overview 1
1.1 Conceptualising social reward and punishment 3
1.2 Outline of the thesis 4
Chapter 2 Literature Review 6
2.1 Introduction 6
2.1.1 Attachment theory and adult attachment theory 8
2.1.2 Social motives and goals: The need to belong 14
2.1.3 Affect, behaviour and cognition (ABC) models of personality traits 20
2.1.3.1 The importance of expectancies 23
2.2 Unifying principles 24
2.3 Research questions and outline of the empirical approach employed 25
Chapter 3 General Methods 27
3.1 Overview 27
3.2 Psychometric and Process-Based Measures 27
3.2.1 Studies 29
3.2.2 Participants 30
3.2.3 Data collection 30
3.2.4 Psychometric measures 30
3.2.5 Procedures 47
3.2.5.1 Pre-tests 47
3.2.5.2 Study 1A 47
3.2.5.3 Study 1B 47
3.2.5.4 Brain structure data acquisition 48
3.2.5.5 Imaging study 48
3.2.5.6 Cyberball study 49

3.2.5.7 Autumn 2014 study 51
3.3 Magnetic resonance imaging (MRI) methods 52
3.3.1 MRI 52
3.3.2 Structural MRI 53
3.3.3 Functional MRI (fMRI) 53
Chapter 4 Development and validation of a measure of generalised social threat and reward expectancies 55
4.1 Introduction 55
4.1.1 Existing self-report measure of social reward and threat expectancies 56
4.1.2 Aims of the present research 59
4.2 LODESTARS development 60
4.3 Study 1A: Comparison of results with those of the original STARS study 61
4.3.1 Methods 62
4.3.2 Results 62
4.3.2.1 Gender differences in self-report measures (n = 23 males; 38 females) 63
4.3.3 Discussion: Comparison of results with those of the original STARS study 64
4.4 Internal consistency and reliability of the LODESTARS 66
4.4.1 Methods: Internal consistency 67
4.4.2 Results: Internal consistency 67
4.4.2.1 Factor analytic results 67
4.4.2.2 Cronbach's alphas 69
4.4.3 Methods: Test-retest reliability 73
4.4.3.1 Data screening 73
4.4.3.2 Reliability 74
4.4.4 Results: Test-retest reliability 75
4.4.4.1 Intraclass correlation coefficients (ICCs) 77
4.4.4.2 Coefficients of variation (CVs) 78
4.4.5 Discussion: Internal consistency and test-retest reliability of the LODESTARS 78
4.4.5.1 Limitations 85
4.5 LODESTARS reward and threat correlations 86
4.6 Construct validity of the LODESTARS 87
4.6.1 Methods 87

4.6.1.1 LODESTARS associations with measures of social motivation, affiliative traits and tendencies 88
4.6.1.2 LODESTARS associations with measures of self-concept, attachment and concerns about rejection 89
4.6.1.3 LODESTARS associations with the Big Five 90
4.6.1.4 LODESTARS associations with measures tapping affective dispositions 90
4.6.1.5 LODESTARS associations with measures of social integration and perceived belonging 91
4.6.1.6 LODESTARS associations with measures of interpersonal attitudes and impulsivity 92
4.6.2 Results 93
4.6.2.1 Measures of social motivation, affiliative traits and tendencies 93
4.6.2.2 Measures of self-concept, attachment and concerns about rejection 95
4.6.2.3 The Big Five 99
4.6.2.4 Measures tapping affective dispositions 101
4.6.2.5 Measures of social integration and perceived belonging 102
4.6.2.6 Measures of interpersonal attitudes and impulsivity 103
4.6.3 Summary and discussion of key findings 107
4.7 Testing the predictions of the proposed model: links between social expectancies and social approach and avoidance motives 111
4.7.1 Methods 116
4.7.2 Results 117
4.7.2.1 Prediction 1: That the observed positive association between extraversion and friendship approach goals is mediated by greater social reward expectancies 117
4.7.2.2 Prediction 2: That the observed negative association between BAP-aloof and friendship approach goals is mediated by lower social reward expectancies 118
4.7.2.3 Prediction 3: That the observed negative association between avoidant attachment and friendship approach goals is mediated by lower social reward expectancies 120
4.7.2.4 Prediction 4: That the observed positive association between anxious attachment and friendship avoidance goals is mediated by greater social threat expectancies 122
4.7.3 Discussion 122
4.8 Testing the predictions of the proposed model: links between social expectancies and social integration outcomes 123
4.8.1 Methods 127

4.8.2 Results 127

4.8.2.1 Prediction 1: That the observed positive association between extraversion and social integration is mediated by greater social reward expectancies 127

4.8.2.2 Prediction 2: That the observed negative association between neuroticism and social integration is mediated by greater social threat expectancies 129

4.8.2.3 Prediction 3: That the observed negative association between BIS and social integration is mediated by greater social threat expectancies 130

4.8.2.4 Prediction 4: That the observed negative association between BAP-aloof and social integration is mediated by lower social reward expectancies 132

4.8.2.5 Prediction 5: That the observed negative association between avoidant attachment and social integration is mediated by lower social reward expectancies 133

4.8.2.6 Prediction 6: That the observed negative association between anxious attachment and social integration is mediated by greater social threat expectancies 133

4.8.3 Discussion 134

4.9 Conclusion 135

Chapter 5 Relating individual differences in social threat and reward expectancies to human brain structure 137

5.1 Introduction 137

5.1.1 Brain regions involved in valuation. 140

5.1.2 Separate neural systems for reward and threat? 143

5.1.3 Modulation of valenced social expectations by dispositional affective biases and attachment style 146

5.1.4 Differential susceptibility and subjective salience 148

5.1.5 Summary of hypotheses 149

5.2 Methods 150

5.2.1 Participants 150

5.2.2 Voxel-based morphometry methods 150

5.2.2.1 Image acquisition 150

5.2.2.2 Image analysis 151

Segmentation 151

Spatial normalisation and smoothing 152

5.2.2.3 Statistical analyses 154

5.2.2.4 Correction for multiple comparisons 159

5.2.2.5 Mitigation of Type II errors 161

5.3 Results 163

5.3.1 Results that survived nonstationary cluster extent correction....164
5.3.2 Results that survived significance thresholding at $p < 0.005$, uncorrected for multiple comparisons, and a 10 voxel cluster-extent threshold....170
5.3.3 Brain regions in which GMvol is correlated with both reward and threat expectancies....181
5.4 Discussion....182
5.4.1.1 mPFC and social cognition....183
5.4.1.2 Greater GMvol in left dmPFC associated with higher expectations of social reward....186
5.4.1.3 Greater GMvol in right vmPFC associated with lower expectations of social threat....192
5.4.1.4 Greater GMvol in left lateral occipital cortex associated with lower expectations of social threat....195
5.4.1.5 Greater GMvol in right postcentral gyrus associated with lower expectations of social threat....199
5.4.1.6 Greater GMvol in right pMTG/STS associated with higher expectations of social threat....200
5.4.2 Neural networks supporting individual differences in social expectancies?....203
5.4.3 Social expectancies and the reward network....204
5.4.4 Social expectancies and the aversion network....205
5.4.5 Social expectancies and the social perception/attention network....206
5.4.6 Social expectancies and emotion regulation systems....208
5.4.7 Social expectancies and empathy....214
5.4.8 Summary of findings related to social threat expectancies....217
5.4.9 Summary of findings related to social reward expectancies....217
5.4.10 Overlap analyses....218
5.4.11 Limitations of the VBM study....221
5.5 Conclusion....223
Chapter 6 Development and validation of a task-based measure of social motivation and reactivity to social reward and punishment....224
6.1 Introduction....224
6.2 Task development....225
6.2.1 Conceptualising ‘non-social’ reward and punishment....225
6.2.2 Task design....226
6.2.3 Monetary stimuli....227

6.2.4 Social stimuli 228
6.2.5 'No outcome' stimuli 232
6.2.6 SMID task procedure 233
6.3 Task validation: Reaction time metrics 234
6.3.1 Interpretation of reaction time (RT) results 235
6.3.2 Discussion 241
6.4 Task validation: Affective responses 241
6.4.1 Method 241
6.4.2 Results 242
6.4.2.1 State self-esteem (SSE) responses to the SMID task 242
6.4.2.2 SSE and self-reported affective responses to the SMID task 245
6.4.2.3 Self-reported motivation for SMID task outcomes 248
6.4.2.4 Perception of facial expressions in the social reward and punishment outcomes 251
6.4.3 Discussion 252
6.5 Assessing predictions of the proposed model: links between motivation, behaviour and reactions to feedback 253
6.5.1 Methods 253
6.5.1.1 Associations between SMID RT metrics and self-reported approach and avoidance traits, tendencies and goals 254
6.5.1.2 Associations between SMID RT metrics and reactivity to feedback 254
6.5.1.3 Links between social expectancies and reactivity to feedback 255
6.5.2 Results 255
6.5.3 Discussion 260
6.5.3.1 Associations between SMID RT metrics and self-reported approach and avoidance traits, tendencies and goals 260
6.5.3.2 Associations between SMID RT metrics and reactivity to feedback 261
6.5.3.3 Links between social expectancies and reactivity to feedback 262
6.6 Conclusion 264
Chapter 7 General Discussion 265
7.1 Contributions 266
7.2 Implications 269
7.2.1 On the independence of social reward and threat processing 269

7.2.2 On the links between individual differences in social perception brain regions and biases in dispositional expectancies of social reward and threat 270
7.2.3 On the role of the posterior superior temporal sulcus and middle temporal gyrus in social cognition 272
7.3 Limitations 273
7.4 Future directions 276
7.5 Conclusion 278
References 280
Appendix 1. Social Network Index adjusted for students – showing changes 330
Appendix 2. Post-Cyberball Need Threat Scale 333
Appendix 3. Full inter-correlation tables for all self-report variables in each study 334
Appendix 4. Pilot testing for SMID task 335
A4.1 Pilot Study 1: Development of monetary stimuli for the SMID task 335
A4.1.1 Methods 335
A4.1.1.1 Monetary Stimuli 335
A4.1.1.2 Participants 335
A4.1.1.3 Measures 335
A4.1.1.4 Procedure 336
A4.1.2 Pilot Study 1 Results 336
A4.2 Pilot Study 2: Development of social stimuli and testing the stimuli 337
A4.2.1 Methods 337
A4.2.1.1 Social Stimuli 337
A4.2.1.2 Participants 339
A4.2.1.3 Measures 339
A4.2.1.4 Procedure 339
A4.2.2 Pilot Study 2 Results 339
A4.3 Pilot Study 2.1: Further development of the social stimuli 346
A4.3.1 Methods 346
A4.3.1.1 Stimuli 346
A4.3.1.2 Participants 346
A4.3.1.3 Procedure 346
A4.3.2 Pilot Study 2.1 Results 347
A4.4 Discussion 347
Appendix 5. Script for SMID task instructions 348

Appendix 6. Post-SMID task questions probing affective responses to the task 350
Appendix 7. Full correlations of post-SMID affect response questions with all other self-report variables and with SMID RT indices 351
Appendix 8. A preliminary study of the neural correlates of exposure to social and monetary incentives in the SMID task 352
A8.1.1 Methods...352
A8.1.2 Results..353
A8.1.2.1 Overlapping responses (mon and soc versus no feedback)..........................355
A8.1.2.2 Distinct responses to money outcomes (> social)......................................357
A8.1.2.3 Distinct responses to social outcomes (> money)......................................358
A8.1.3 Discussion...359
A8.1.4 Implications...360
A8.2 Links between social feedback-related BOLD activation and motivation for social incentives and autism-like social traits 360
A8.2.1 Methods...360
A8.2.2 Results..361
A8.2.3 Discussion...366
A8.3 Brain structure analysis 367
A8.3.1 Results..367
A8.4 Conclusion...367

Chapter 1

Introduction and conceptual overview

Social connectedness is consistently found to be one of the most important predictors of mental and physical well-being across cultures and across the lifespan (Cornwell & Waite, 2009; Fiori, Antonucci, & Akiyama, 2008; Holt-Lunstad, Smith, & Layton, 2010; National Opinion Research Center (NORC), 2005). Although many people are living longer, older people remain more likely to become socially isolated (Nielsen & Mather, 2011). Concurrently, the geographic and residential mobility of modern society poses challenges for maintaining social integration. Notably, however, there is enormous variation in how individuals respond to such social-demographic challenges, which is critically predictive of well-being (Oishi & Schimmack, 2010). It is important, therefore, that we understand the mechanisms by which social disconnectedness and perceived isolation arise. Whether these mechanisms are distinct from mechanisms which underpin the development and maintenance of connectedness and perceived integration is a central theme of this thesis.

In order to successfully navigate the social world and become socially integrated, individuals must engage in social cognition, or social information processing. This involves perceiving and attending to stimuli in the social environment, interpreting these perceptions and responding appropriately, in line with the situation and the individual's current goals and motivations. Individual differences in the perception and interpretation of social stimuli are strongly predictive of social connectedness and wellbeing (Cacioppo & Hawkley, 2009).

Individual differences in emotional (affective), attentional, and cognitive reactivity and self-regulation predispose individuals to respond to social stimuli in different ways (Crystal, Simonson, Mezulis, & Pegram, 2012; Hyde, Mezulis, & Abramson, 2008). High reactivity to negative stimuli involves more intense experiences of distress (affective reactivity) and increased deployment of attentional processes towards potentially threatening stimuli (Crystal et al., 2012; Niles, Mesri, Burklund, Lieberman, & Craske, 2013). Negative affective reactivity and attentional bias are strongly related; the induction or enhancement of one increases the other. The induction of anxiety increases attentional bias towards threat (Chen, 1996; MacLeod & Mathews, 1988; K. Mogg, Bradley, & Hallowell, 1994). Training attentional focus towards threatening stimuli increases self-reported distress in response to stressors (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002) while training attentional focus away from negative stimuli decreases self-reported anxiety regarding stressors (See, MacLeod, & Bridle, 2009). Thus self-regulation of attention and emotion are strongly interlinked.

The third facet of reactivity is cognitive reactivity; negative biases in cognitive reactivity prompt the generation of negative inferences about the causes, consequences and self-implications of negative events, and/or perseverative rumination on the negative aspects of situations or experiences (Crystal et al., 2012). Cognitive reactivity is also strongly interlinked with affective reactivity (Crystal et al., 2012).

High negative reactivity is associated with neuroticism, fear, dislike and/or avoidance of novel situations (Hyde et al., 2008), including social situations (Gable, 2006). Conversely, high positive reactivity is associated with extraversion and high social approach motivation (Hyde et al., 2008). In turn, higher social approach motivation is associated with less loneliness and greater satisfaction with social bonds, while higher social avoidance motivation is associated with more loneliness and lower satisfaction with social life (Gable, 2006). It appears, therefore, that reactivity to positive (rewarding) and negative (threatening or punishing) social stimuli may underpin broader personality traits relating to social behaviour and, ultimately, outcomes such as loneliness. This thesis addresses the relationships between social reward and threat/punishment reactivity and social motives, goals and outcomes.

1.1 Conceptualising social reward and punishment

Reward is defined as an outcome that individuals are willing to work to obtain, while punishment is an outcome that individuals will work to avoid (Ward, 2012). However, there are many different social incentives that humans will work to attain or avoid (Buss, 1983; Foulkes, Viding, McCrory, & Neumann, 2014). For instance, some individuals enjoy being the centre of attention and will work hard to achieve this experience (Ashton, Lee, & Paunonen, 2002); others may find the experience of being the centre of attention highly aversive and work hard to avoid it (D. M. Clark & Wells, 1995). Other social incentives include social responsibility, social attractiveness, power, intimacy, belongingness, receiving assistance, and giving advice (McCollum, 2005). Broadly, social incentives have been categorised into two types, corresponding to social stimulation (arousal or sensation-seeking) and social connection or intimacy (Buss, 1983; K. MacDonald, 1988). As the focus of this thesis is on social connectedness, the intimacy category will be used throughout. Thus social rewards are defined here as signals that one is accepted and valued. Social punishments are defined as signals that one is rejected or excluded. These signals are social cues or behaviours exhibited by individuals and perceived and interpreted by their social conspecifics. Buss (1983) called these 'content' social incentives, as they pertain to the valenced content of social signals. According to Buss's (1983) taxonomy, affection is the most intense of the social content rewards, usually reserved for those whom we know and already have a relationship with. The social punishment corresponding to affection (i.e. its opposite) is hostility (Buss, 1983).

Although warmth (interpersonal behaviour similar to affection) and hostility may on occasion be directed towards strangers, these social signals are not normally exhibited in interactions between individuals who do not know each other (Buss, 1983). Therefore they are not ideally suited for controlled experimental manipulations of social reward and punishment signals. Another dimension of Buss's social content incentives is better suited to this purpose. This is the dimension of praise and criticism or disapproval. Praise and criticism can be offered by strangers as well as those whom we know. Humans value praise, work hard to attain it, and view those who offer it favourably. Conversely humans dislike criticism, work hard to avoid it and devalue those who offer it (Buss, 1983; Leary, Springer, Negel, Ansell, & Evans, 1998; Leary, Twenge, & Quinlivan, 2006; Richman & Leary, 2009). Praise indicates that one (or one's performance) is valued while criticism indicates that one (or one's performance) is rejected as being not good enough. Therefore praise and criticism satisfy the definitions of social reward and punishment employed in this thesis, and are suitable for use in experimental studies as the dispensation of praise and criticism can be manipulated. Reactivity to these forms of social reward and punishment is explored in Chapter 6 of this thesis.

1.2 Outline of the thesis

In Chapter 2 I review literature relating social punishment and reward reactivity to broader personality traits, dispositions and affective biases. From this, a mechanistic model is derived, which is tested in the subsequent empirical chapters of the thesis.

Chapter 3 provides details and background on general methodology employed in the studies reported here. Chapter 4 homes in on the role of expectancies, an important component of cognitive reactivity. The development and validation of a novel scenario-based measure of social expectancies is described. Links between social reward and threat expectancies and personality variables are reported. In Chapter 5, the neuroanatomical correlates of social threat and reward expectancies are explored. Brain imaging studies hold enormous potential to reveal how the brain implements such cognitive representations of the social world. By better understanding the neural mechanisms of social cognitive and affective processes, our understanding of the links between processes such as attentional control and outcomes such as loneliness can be enhanced (John T. Cacioppo & Hawkley, 2009).

In Chapter 6 the focus shifts from expectancies to behavioural reactivity in response to social reward and punishment. The development and validation of a task-based paradigm designed to measure behavioural differences in individuals' motivation to attain social reward (praise) and to avoid social punishment (negative evaluation) is described. Associations between individual differences in behavioural motivation, affective reactivity and self-reported social approach and avoidance tendencies are explored. Chapter 7 (the general discussion) draws together the evidence derived from self-report, behavioural and neuroimaging methods and examines connections between different components of social reward and punishment reactivity. The psychological implications of these mechanistic insights are discussed.

Chapter 2

Literature Review

2.1 Introduction

It is well established that humans need other humans for survival. Extensive work on social support has found strong empirical evidence for a causal impact of quantity, and sometimes quality, of social relationships on life expectancy (House, Landis, & Umberson, 1988; Umberson & Montez, 2010; Holt-Lunstad, Smith, & Layton, 2010). That is, the more socially integrated a person is, the longer they are likely to live (as shown in Fig. 2.1). This relationship remains significant when physical and health-related variables such as activity level, alcohol consumption and social class are controlled for (House et al., 1988; Umberson & Montez, 2010; Holt-Lunstad et al., 2010). The association between social relationships and life expectancy also remains significant when personality variables are controlled for (House et al., 1988), although personality traits may mediate or otherwise modify the effects of social support on health and mortality (Pedersen, Middel, & Larsen, 2002; Oddone, Hybels, McQuoid, & Steffens, 2011). Thus social isolation constitutes a major risk factor for mortality (and morbidity) in its own right (House et al., 1988; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002; Holt-Lunstad et al., 2010).

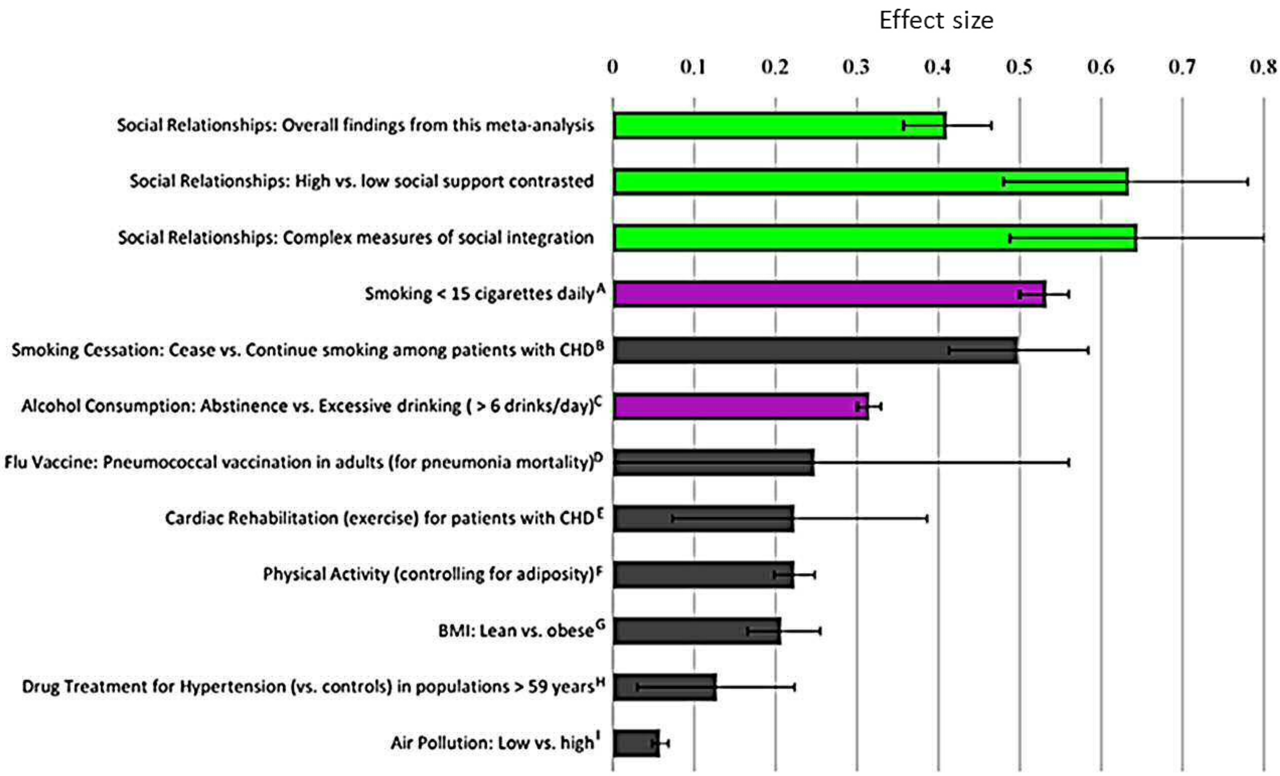

Figure 2.1: Comparison of the likelihood (natural log odds ratios) of mortality across several conditions associated with mortality. An effect size of zero would indicate that the variable had no effect upon humans' likelihood of dying. Larger effect sizes indicate greater impact upon likelihood of death. Variables relating to social integration (shown in green) exert an independent influence on risk for mortality that is comparable with other well-established risk factors such as smoking and excessive alcohol consumption (shown in purple). The effect sizes were estimated from meta-analyses.

Modified from Holt-Lunstad et al. (2010). Social Relationships and Mortality Risk: A Meta-analytic Review. *PLoS Med*

In recent years much progress has been made in identifying the behavioural and biological pathways by which a lack of social bonds impacts upon morbidity and mortality (G. Miller, Chen, & Cole, 2009; Uchino, 2006). However, far less is understood about the neurobiological mechanisms that underpin the need or desire for social bonds in the first place. That is, what psychobiological needs are met by social relationships? It has been argued that humans' responsivity to other people and to social situations is the result of innately specified social motives that have evolved by natural selection due to the huge survival benefit of living in a group compared with solitary existence (Fiske, 2004).

It is widely agreed that group cooperation has been a major factor in humans' evolutionary success (Fiske, 2004; Goetz, Keltner, & Simon-Thomas, 2010; Montepare, 2003; Stringer, 2011). From this it follows that humans are, in effect, adapted for life in social groups (Fiske, 2004) – which in turn implies the existence of an evolved neurobiological system, the function of which is to facilitate the formation and maintenance of social relationships. There is, indeed, a well-established field of research into such a system, which is termed an attachment system (Vrtička & Vuilleumier, 2012).

2.1.1 Attachment theory and adult attachment theory

The concept of an attachment system was first proposed more than forty years ago by Bowlby (1969). Bowlby drew upon fields including evolutionary biology, developmental psychology, and cognitive science in formulating his proposition that the mechanisms underlying infants' bonding behaviour emerged as a result of evolutionary pressure (Cassidy, 1999). Bowlby's attachment theory was a theory of motivation and behaviour regulation (Bretherton, 1992), based on the assumption that all humans are born with an innate motivation to obtain or maintain proximity to significant others in times of need or in the presence of threats (Vrtička & Vuilleumier, 2012). Attachment theory has been refined since Bowlby first proposed it (Bretherton, 1992), but its core mechanistic account of the development of the attachment system remains the same. According to attachment theory, infants engage in proximity seeking to one or more identified attachment figure(s) (carers, e.g. parents) for the purpose of survival. The responses of the attachment figure(s) to the proximity seeking attempts of the child are thought to induce in the child the formation of cognitive schemas for representing the self and others, and for behaving in interpersonal situations (Vrtička & Vuilleumier, 2012). It is thought that these cognitive schemas in turn lead to the establishment of 'internal working models' of attachment, which encode expectations of care and allow mental simulation and prediction of the likely outcomes of different attachment behaviours (Vrtička & Vuilleumier, 2012; Mario Mikulincer & Shaver, 2007). These will then constitute the basis of a person's individual attachment style (AS), which will guide the individual's emotional and cognitive perceptions, reactions and expectations in later relationships and social encounters (Vrtička & Vuilleumier, 2012). AS remains fairly stable into adulthood and, it is thought, remains active throughout the life span (Bowlby, 1988; Mario Mikulincer & Shaver, 2007). An individual's AS is considered to influence responses during social appraisals and interactions with previously unknown people (e.g. Niedenthal, Brauer, Robin, & Innes-Ker, 2002) as well as people with whom the individual already has a relationship (Vrtička & Vuilleumier, 2012). There is some debate as to how many distinct attachment styles (ASs) there are, and how many underlying dimensions give rise to them. Classic models (e.g. Hazan & Shaver, 1987), have described three main types of attachment style in adults: secure, anxious, and avoidant, in line with Ainsworth's three-category framework for attachment style in infants (Ainsworth, 1985). Individuals with an anxious attachment style (anx_att) tend to perceive others as unresponsive or inconsistent, worry about being rejected, and show heightened vigilance to signs of support or hostility; whereas individuals with an avoidant attachment style (av_att) prefer being distant and detached from others, report no need for close relationships, and tend to distrust affective signals from others. By contrast, individuals with a secure attachment style (s_att) report positive and trustful interactions with others. Various authors have subsequently suggested that there exist four (Bartholomew & Horowitz, 1991) or possibly even five (Chotai, Jonasson, Hägglöf, & Adolfsson, 2005) distinct attachment styles. Bartholomew (1990) proposed the four-group model on the basis of Bowlby's (1969, 1982) idea that people hold two separate internal working models, one of themselves (model of self) and one of their social world (model of others)[1]. Bartholomew reasoned that these two representational models interact with valence (positivity or negativity of self-concept and representations of others), giving rise to four distinct attachment styles. Bartholomew's (1990) proposed four-group model of adult attachment styles is depicted in Fig. 2.2.

[1] Bowlby (1982) referred to these as organismic and environmental working models. He defined them as models of one's own behavioural skills and potentialities, and of one's environment, respectively.

		Model of Self	
		Positive (low dependence)	Negative (high dependence)
Model of Others	Positive (low avoidance)	**SECURE** Comfortable with intimacy and autonomy	**PREOCCUPIED** Overly dependent
	Negative (high avoidance)	**DISMISSING** Denial of attachment	**FEARFUL** Fearful of attachment, socially avoidant

Figure 2.2: Bartholomew's (1990) classification of adult attachment styles. Adapted from Bartholomew, 1990, p. 163.

The extended (four and five group) categorical models of attachment have received little empirical support (Fraley, Hudson, Heffernan, & Segal, 2015). The notion that attachment orientations are underpinned by the positivity or negativity of individuals' internal working models has, however, been highly influential (Mario Mikulincer & Shaver, 2007). This topic is discussed further in section 2.2 of this chapter. In terms of categorical models of attachment, it is broadly agreed that there are two main types of AS: secure and insecure (Feeney, Noller, & Hanrahan, 1994). Whether insecure ASs should then be subdivided into two (anxious and avoidant) or more categories remains a point of contention in this literature.

It has also been proposed that different ASs might arise from variation on two basic underlying dimensions defined by orthogonal axes of avoidance and anxiety (Bartholomew & Horowitz, 1991). In this model, depicted in Fig. 2.3, secure AS corresponds to a combination of low anxiety and low avoidance. Neurobiological evidence supports this bi-dimensional model (Vrtička, Andersson, Grandjean, Sander, & Vuilleumier, 2008), as does a recent taxometric analysis (Fraley et al., 2015). Fraley et al. (2015) analysed self-reported attachment style in adults across a variety of relationship domains. Their results indicate that a dimensional conceptualisation of adult attachment style (AAS) is most useful for analysing individual differences in social behaviour. This holds regardless of the level of specificity and type of relationship the AAS is measured for (e.g. parental, romantic, abstract representations of others).

While it remains to be clarified whether individual differences in AAS correspond to a true taxonomy of personality traits or to variation on underlying dimensions, this does not undermine the usefulness of AAS classification schemes for analysing individual differences in social behaviour (Vrtička & Vuilleumier, 2012). The weight of recent evidence supports the view that individual differences in adult attachment are best conceptualised and measured in a bi-dimensional fashion; therefore this is the approach that will be taken in the work reported in this thesis.

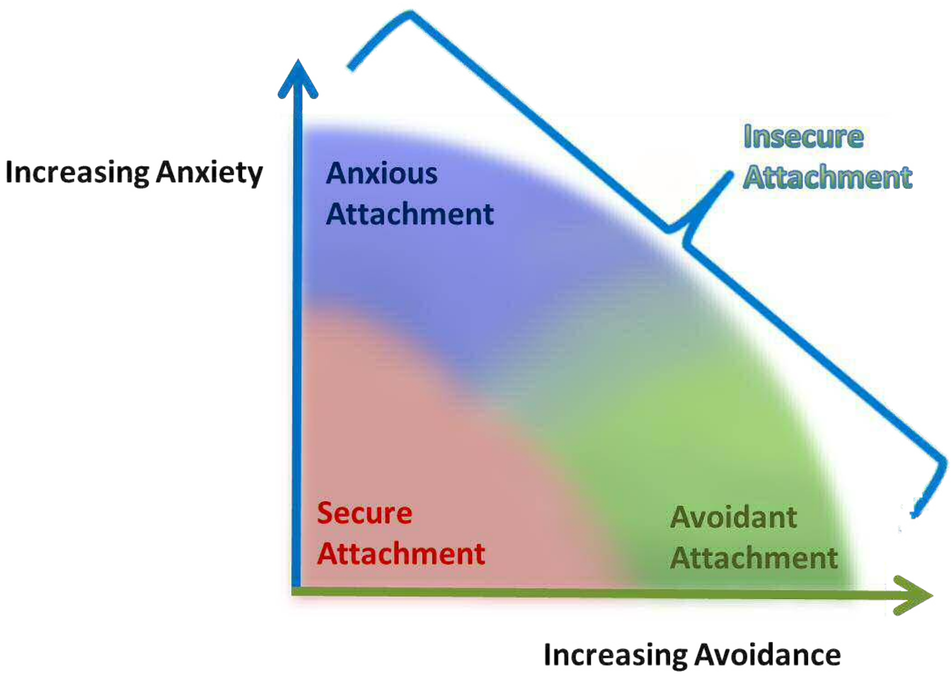

Figure 2.3: Bi-dimensional Model of Attachment Styles

From the attachment theory perspective, human infants are considered to have a need to form a secure relationship with at least one adult caregiver, without which normal social and emotional development will not occur. However, attachment bonds, much less attachment styles, do not develop overnight (Mario Mikulincer & Shaver, 2007). To provide a complete account of the attachment system, proximate as well as ultimate (or distal) level explanations are required. Proximate causation explains a behavioural system in terms of biological and/or environmental factors that affect its development and function. Ultimate explanations pertain to why the behaviour was selected for during evolution. Bowlby (1969, 1988) offered an ultimate level explanation for the existence of the attachment system: that human infants rely on others for survival, and humans generally have a greater chance of survival if they live with others rather than alone. Thus the attachment system could have evolved by natural selection because of the survival benefit conferred by competence in forming and maintaining social relationships and seeking proximity to others in times of need.

However, the proximate causation of attachment system development in general has not received much research interest. That is, there has been a great deal of interest in the potential environmental and biological contributions leading to the development of *different* attachment styles, such as secure versus insecure (e.g. Brussoni, Jang, Livesley, & Macbeth, 2000; Gillath, Shaver, Baek, & Chun, 2008) – but far less attention has been paid to the processes that enable the development of an attachment system per se, irrespective of different attachment styles that may concurrently develop. If it is discussed at all, the development of the attachment system is presumed to occur in a manner similar to that of the visual system (e.g. Joseph, 1999). That is, there are assumed to be experience-expectant critical or sensitive periods during which the system develops in response to environmental stimuli. For example, to develop binocular vision, it is necessary for both eyes to receive visual (light) input during the critical period (Bear, Connors, & Paradiso, 2006). If for some reason there is no opportunity for the system to develop, e.g. due to environmental restriction, it will be much more difficult, or impossible, for the system to develop subsequently (Beaumont, Kenealy, & Rogers, 1999). In the case of the attachment system, this can occur for instance in certain orphanages where consistent attachment figures are lacking (Hornor, 2008; Zeanah, 2000).

It is undoubtedly the case that the early environment is critical for the development of the so-called social brain and the attachment system (Leppänen & Nelson, 2009). But human infants do not just passively absorb social stimulation; they actively seek it by way of the proximity seeking behaviours described by Bowlby (1969, 1982, 1988) and others. Proximity promoting behaviours – such as crying, rooting, sucking and smiling – are displayed by infants in the so-called pre-attachment phase (0–2 months) during which time infants are inherently interested in and responsive to social interaction with virtually anyone (Ainsworth & Bell, 1970; Mikulincer & Shaver, 2007). These initial proximity promoting behaviours have been taken to indicate a genetic predisposition to developing attachment (Ainsworth & Bell, 1970) and such behaviours, as well as others' responses to them, are considered necessary for the development of an attachment system (Ainsworth & Bell, 1970; Joseph, 1999). A distal explanation has been offered as to why human infants indiscriminately seek social contact during the first months of life: it is suggested that this behaviour maximises the opportunities for social stimulation that the infant's developing social-emotional system requires in order to develop and function properly (Joseph, 1999). But little consideration has been given to the proximate cause(s) of infants' pre-attachment proximity promoting and seeking behaviours, except to say that infants are genetically or physiologically predisposed to engage in such behaviours (Ainsworth & Bell, 1970; Joseph, 1999) and inherently responsive to social interaction (Mario Mikulincer & Shaver, 2007).

At the most basic level, human behaviour is motivated by desire to seek pleasure and to avoid harm (Leotti & Delgado, 2011). Reward is the experience of a positive consequence of an action, while punishment is the experience of a negative consequence of an action. As stated in Chapter 1, individuals are willing to work to obtain rewards, while punishments are outcomes that individuals will work to avoid (Ward, 2012). Therefore, rewards and punishments are important for motivating behaviour that is consistent with immediate and longer-term goals (Leotti & Delgado, 2011).[2] Thus it follows that the outcomes of infants' proximity-promoting behaviours must usually be rewarding for them, such that they are motivated to repeat behaviours that are associated with reward. In the present context these rewards would be social in nature, for example the infant may derive pleasure from the closeness of a responsive adult. This comes back to the hypothesis that there exist innately specified (core) social motives that have evolved via natural selection because they help individuals to survive optimally in groups (Fiske, 2004).

2.1.2 Social motives and goals: The need to belong

Motives in general are what drive behaviour; the concept of core social motives describes a set of "fundamental, underlying psychological processes that impel people's thinking, feeling, and behaving in situations involving other people" (Fiske, 2004, pg. 14). Social and personality psychologists have listed and re-listed basic motives since the beginning of the 20th century; however the need to belong is widely accepted as a core social motive (Baumeister & Leary, 1995; DeWall, Deckman, Pond, & Bonser, 2011; Fiske, 2004; Gere & MacDonald, 2010; Morrison, Epstude, & Roese, 2012). Fiske (2004) characterises the need to belong as the most basic of the core social motives, arguing that it underlies all other core social motives. In line with this, MacDonald, Borsook, and Spielmann (2011) conceptualise social threat (punishment) and social reward as impacting upon individuals' sense of belonging (see also Gere & MacDonald, 2010). According to this framework, individuals are motivated to seek social rewards (indicating acceptance) and to avoid social punishments (indicating rejection), because of their inherent need to belong (Gere & MacDonald, 2010; Lavigne, Vallerand, & Crevier-Braud, 2011).

[2] The anticipation of positive and negative consequences of actions can also constitute intrinsic rewards and punishments in themselves.

There is considerable evidence that belonging is indeed a fundamental need, that it is fulfilled by social acceptance and heightened by social rejection, and that it is linked to mood and self-esteem (Gere & MacDonald, 2010). Traditionally, individual differences in the need to belong have been characterised as differences in the strength of the need (McClelland, 1987). However, in recent years it has been proposed that qualitative differences in the need to belong also exist. Specifically, Lavigne et al. (2011) posit that there exist two belongingness need orientations: a growth orientation directed towards the rewarding features of relationships with others, and a deficit-reduction orientation directed toward reducing or repairing perceived deficits in one's social environment. Individuals higher in the growth orientation may be motivated to seek connection with others because they are genuinely interested in them and because relationships are thought to provide an important basis for personal and interpersonal development (Lavigne et al., 2011). Lavigne et al. (2011) suggest that a growth orientation predisposes individuals to be open with social partners, e.g. to engage in self-disclosure in a non-defensive way without fear of negative evaluation.

Conversely, a deficit-reduction orientation is thought to trigger the motivation to connect with others for purposes of attenuating fears of rejection and loneliness (Lavigne et al., 2011).

Lavigne et al. (2011) propose that differences in the strength of individuals' belongingness orientations lead to different social experiences. Furthermore, Lavigne et al. suggest that one's dominant belongingness orientation also influences how one is perceived and treated by others. They argue that the growth orientation leads to adaptive social outcomes while the deficit reduction orientation may incline individuals to engage in behaviours that lead to less adaptive or maladaptive consequences. Specifically, Lavigne et al. suggest that individuals higher in growth-oriented belongingness need are more likely to express genuine interest in others, and thereby create social connections more rapidly. Further, the ability to engage with others without fear of negative evaluation may make such individuals more likable and more socially accepted by others (Lavigne et al., 2011).

On the other hand, the social insecurity of individuals who adopt a deficit-reduction orientation may cause them to be hyper-vigilant for signs of rejection. This preoccupation with potential signs of negative evaluation may reduce one's likability in the eyes of others, resulting in lower levels of social acceptance (Lavigne et al., 2011).

Lavigne et al. (2011) report results from four studies providing strong support for their distinction between growth-oriented and deficit-reduction-oriented dimensions of the need to belong. Their findings are consistent with earlier work by Mehrabian and colleagues on social motives (Mehrabian & Ksionzky, 1974; Russell & Mehrabian, 1978). Mehrabian and Ksionzky (1974) put forward a theory that there are two distinct categories of social motives - need for affiliation and fear of rejection – and that these are based on expectations of positive and negative reinforcements in interpersonal relationships, respectively. Their program of research has demonstrated that individuals high in affiliative tendency (defined by generalized positive social expectations and behaviours) tend to elicit more positive affect from others and are more self-confident, whereas individuals high on fear of rejection tend to be judged more negatively by others and are less confident (Mehrabian, 1994).

Although the distinction between approach-oriented and deficit-reduction-oriented (avoidance) motives in the social domain did not emerge until the 1970s, the view that approach and avoidance motives are distinct has been prominent in more general theories of motivation since much earlier in the 20th Century. Lewin (1935) was the first to discuss approach and avoidance motives in the context of personality. Influential contemporary theories of motivation and behavioural self-regulation also distinguish between motives to attain desired end-states and motives to avoid undesired end-states (Carver & White, 1994; Corr, 2009, 2013; Gray, 1987; Higgins, 1998).

For example, reinforcement sensitivity theory (RST; Corr, 2009; Corr & Cooper, 2016), which evolved from Gray's biopsychological theory of personality (Gray, 1987), proposes that there exist three major neuropsychological systems. One of these is positive, activated to attain desired end-states; this is known as the behavioural approach system, or BAS. The other two systems postulated by RST are both negative. The fight-flight-freeze system (FFFS) is activated by aversive stimuli, to avoid undesired end-states. The third system, the behavioural inhibition system (BIS) is activated by conflicting stimuli (e.g., situations which hold the potential for reward but also for harm). In this framework, activation of the BIS system results in anxiety (Corr & Cooper, 2016).

In the RST framework, the activation of the three motivation outputs systems (BAS, FFFS and BIS) occurs in response to a valuation assessment (Corr & McNaughton, 2012). That is, an individual must compute the potential for gain or loss (reward or harm/threat) associated with any situation and, once this has been decided, a response is generated by means of BAS, FFFS and/or BIS activation. Individual differences in valuation may therefore underpin individual differences in the propensity to activate approach (BAS) or fear (FFFS) or anxiety (BIS) responses to situations. This suggestion is supported by work showing that individual differences in generalised motivational dispositions are associated with differences in experiences of and affective reactions to daily events. Gable, Reis, and Elliot (2000) found that individuals higher in general approach motivation reported higher daily positive affect (PA). Individuals higher in avoidance motivation reported more daily negative affect (NA). The relationship between approach motivation and PA was explained by the experience of more frequent positive events (differential exposure). The association between avoidance motivation and NA was not due to the experience of more frequent negative events, but was explained by stronger affective reactions to the occurrence of negative events (differential reactivity; Gable et al., 2000). The research undertaken by Mehrabian and colleagues was the first to demonstrate that similar effects occur within the social domain (Mehrabian, 1994).

Further support for the bi-dimensional model of social motives has come from work on social goals. Elliot, Gable, and Mapes (2006) argue that, while social motives provide the impetus for social behaviour, they do not provide specific guidelines regarding the actions required to maximise one's chances of fulfilling the activated motive. Therefore, individuals often adopt more concrete, cognitively based short-term social goals that help direct behaviour toward or away from motive-relevant possibilities in the social environment (Elliot et al., 2006). Thus approach social motives are associated with short-term social approach goals (e.g., “to make friends”), while avoidance social motivations are associated with avoidance social goals (e.g., “to avoid getting hurt by my friends”).

Gable and colleagues conceptualise social motivation and goals as components in a hierarchical model in which individual differences in general reward sensitivity are associated with the strength of approach social motivation. Individual differences in general threat sensitivity are associated with the strength of avoidance social motivation. In turn, individual differences in dispositional social approach and avoidance motives, which are considered to be relatively stable traits, influence the type of short-term goals - approach or avoidance - that individuals most commonly adopt in service of the establishment and maintenance of social bonds (Gable & Gosnell, 2013). The hierarchical model proposed by Gable and colleagues is shown in Fig. 2.4.

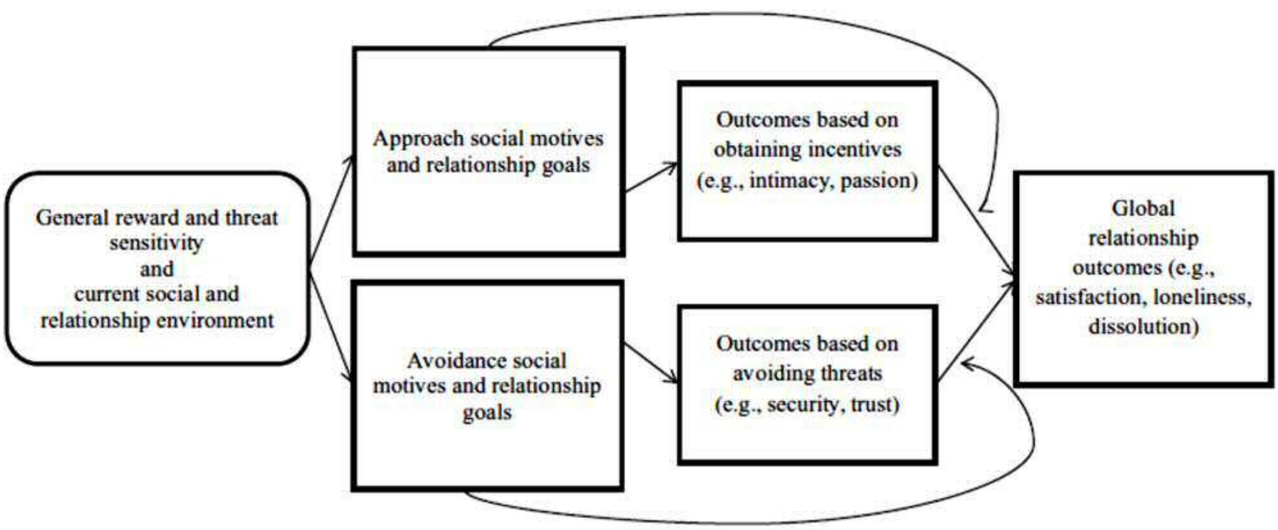

Figure 2.4: Model of approach-avoidance interpersonal motivation. From Gable and Gosnell, 2013, p. 270.

In line with the psychological distinction between growth and deficit-reduction, it has been proposed that social approach and avoidance processes are controlled by independent, mutually antagonistic systems in the brain (Vrtička, 2012). These two systems are thought to be responsive to signals of potential social reward (giving rise to approach) and signals of potential social punishment (i.e. threat, giving rise to avoidance; Vrtička, 2012). Literature relating to the neuroanatomical underpinnings of social reward and threat processing is reviewed in Chapter 5 of this thesis.

Gable and colleagues have tested the predictions of their hierarchical model in terms of affective expressions of social motives. That is, hope for affiliation and fear of rejection. Individuals who reported greater hope for affiliation were found to be more likely to adopt short-term social approach goals, and to view approach goals as important. Those who reported more fear of rejection were more likely to adopt short-term social avoidance goals, and to view avoidance goals as more important (Gable & Gosnell, 2013). However, attachment anxiety, which is characterised by strong fears of rejection, has been found to be associated with both stronger social avoidance goals *and* stronger social approach goals (Gable, 2015). This points to the fact that broad interpersonal traits, such as attachment style, cannot be defined in terms of uni-dimensional dispositions. Rather, such traits represent constellations of characteristic patterns of affective and cognitive expectations, perceptions, and reactions that tend to co-occur within individuals.

Parsimonious over-arching models such as the five-factor model (FFM) and RST provide excellent frameworks for describing personality, and for conducting and interpreting research into individual differences. To research the cognitive and biological mechanisms that underpin broad personality traits and dispositions, however, it seems preferable to investigate more specific components of such traits. That is, components within the constellations of characteristic cognitive, affective and behavioural tendencies that personality traits encompass. The reasons for this are two-fold. From an analysis perspective, the interpretation of data analyses linking a very broadly defined trait, e.g. extraversion, with biological correlates would be challenging. Extraversion and other such traits are likely to be associated with many different biological correlates, for instance, many genetic polymorphisms or brain regions – but from such a broad analysis it would be difficult to ascertain how the genetic or neural correlates affect or are affected by personality. Research could instead focus on sub-traits, such as assertiveness or sociability, but again it may be difficult to interpret the results mechanistically. Further, behavioural distinctions between such traits as assertiveness and sociability may not be clearly reflected in biological systems (Gangestad & Snyder, 1985; Lyons, 2001). In this case one might draw misleading inferences regarding the functions of certain brain regions, for instance.

Examining the biological correlates of trait components that appear to be particularly influential in shaping behaviour is an approach that may be less vulnerable to the problems of interpretation and inference described above. Of course, it is necessary to bear in mind that no matter how precisely one defines one's cognitive variable of interest, it is unlikely that there is a specific brain region dedicated to that form of cognition. This will almost always be the case with cognitive variables of interest in social neuroscience research, as social cognition requires multiple interrelated and complementary processes to be performed by a system, or network, of functionally related brain regions (Bressler, 1995; Fuster, 2003). Thus neural correlates of cognitive variables need to be interpreted in the context of what is understood about the cognitive variable, from existing theory and behavioural work, and in the context of what is currently understood about the brain. The first step in any case is to have a clearly defined cognitive variable of interest. A useful approach here is to consider the cognitive, affective and behavioural components that make up personality traits.

2.1.3 Affect, behaviour and cognition (ABC) models of personality traits

As alluded to in section 2.1.1, adult attachment style is considered to comprise a set of psychological processes that guide an individual's feelings, thoughts and behaviours in social encounters (Mario Mikulincer & Shaver, 2007; Mario Mikulincer & Sheffi, 2000; Rom & Alfasi, 2014; Troisi, Alcini, Coviello, Croce Nanni, & Siracusano, 2010; Vrtička & Vuilleumier, 2012). Formally, the approach that specifies that personality traits comprise the three components of affect (A), behaviours (B) and cognitions (C) is called the ABC approach (Zillig, Hemenover, & Dienstbier, 2002). The utility of this approach is particularly manifest in causal analyses about, for instance, characteristic behaviours associated with certain traits. In such analyses, characteristic affects and/or cognitions of the trait may explain the tendencies to respond in certain ways under certain circumstances (Zillig et al., 2002). For instance, the behavioural manifestation of violence or aggression (associated with trait anger) may be explained by increased dispositional hostility (representing characteristic cognitions) and/or increased angry affective reactivity (Martin, Watson, & Wan, 2000).

The ABC components of traits are themselves categories of characteristic reactions. Thus the category of affect comprises characteristic moods, affective biases, emotional arousal and emotional or affective reactivity (Hyde et al., 2008; Roberts, 2009; Wilt, Oehlberg, & Revelle, 2011). Behaviours constitute physical actions or reactions which may be overt and observable (e.g. walking, hiding) or not directly observable by social conspecifics (e.g. increases in heart rate; Wilt et al., 2011). Cognitions are the processes by which individuals interpret their perceptions of their environment. Cognitions include thoughts, beliefs, schemas, expectancies, norms[3] and modes of thinking, or cognitive reactivity (Crystal et al., 2012; Roberts, 2009; Wilt et al., 2011).

ABC models have been applied to the Big Five personality supertraits (Wilt & Revelle, 2015; Zillig et al., 2002) such as conscientiousness (Roberts, Lejuez, Krueger, Richards, & Hill, 2014) as well as the sub-traits or trait facets that these comprise. (Hyde et al., 2008; Wilt et al., 2011; Zillig et al., 2002). For instance, affective, behavioural and cognitive components of anxiety and depression have been described and integrated using the ABC framework (Hyde et al., 2008; Wilt et al., 2011). Anxiety and depression may be considered as trait facets of neuroticism (Zillig et al., 2002) or, taking an even broader view, these traits could be seen as components of generalised negativity. From the perspective of RST, generalised negative biases in individuals' cognitive and affective processing give rise to increased activation of the FFFS and BIS systems, and reduced activation of the BAS system (Corr & Cooper, 2016). If certain cognitive and affective mechanisms exist which exert pervasive effects on personality, it seems reasonable to suppose that these exist at the broad level of generalised negativity versus generalised positivity. In order to research the functional and biological mechanisms by which cognitive and affective biases influence personality and behaviour,

[3] For example, norms for comparison of oneself with others (Roberts, 2009).

applying the ABC framework to the constructs of generalised negativity and positivity seems a good starting point. To illustrate this, an ABC model of generalised negativity is shown in Fig. 2.5.

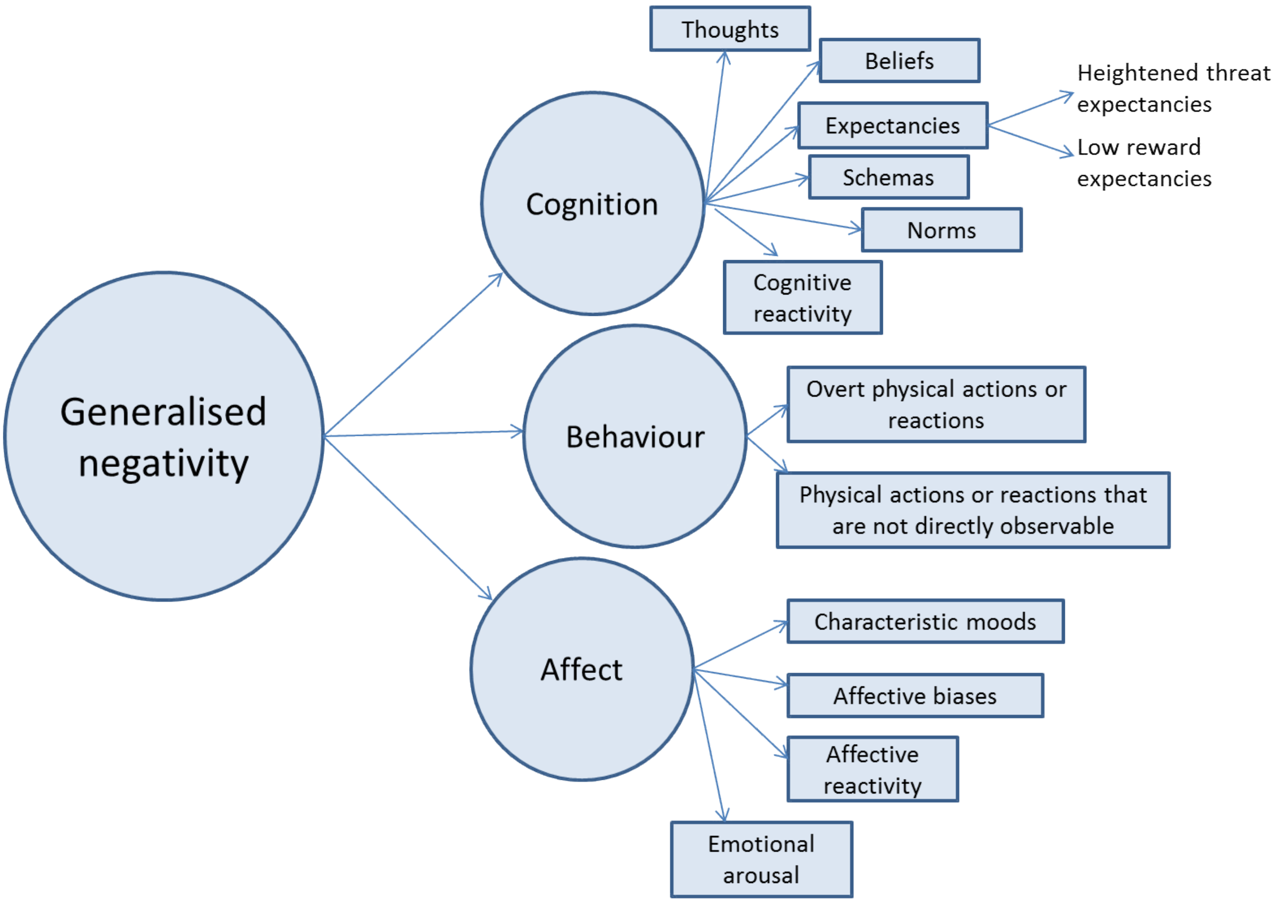

Figure 2.5: An affect, behaviour and cognition (ABC) model of generalised negativity.

As shown in Fig. 2.5, generalised negativity is assumed to be associated with heightened expectancies of threat and low expectancies of reward; the opposite is true for generalised positivity. In social contexts, this suggests that dispositional positivity or negativity bias results in differential levels of expectancies for social reward and threat. While Fig. 2.5 shows the components of generalised negativity as separate, this is purely for illustrative simplicity. In reality, cognitions, affect and behaviour all impact upon one another, as do the sub-categories of these. It is suggested here that expectancies are particularly important in influencing motivation, behaviour and outcomes, including affective outcomes.

2.1.3.1 The importance of expectancies

Although Mehrabian and Ksionzky (1974) suggested that need for affiliation and fear of rejection are based on generalized expectations of positive and negative reinforcements in interpersonal interactions, respectively, the role of cognitions in informing social motives has subsequently been somewhat neglected relative to the affect component. Individual differences in cognitive reactivity, including positively or negatively valenced biases in generalised expectancies, are strongly predictive of subsequent motivations, goals and behaviours (Haugen, Ommundsen, & Lund, 2004). The theoretical framework proposed in this thesis posits that positively or negatively valenced biases in social expectancies – that is, dispositional biases to expect social reward or punishment – will likewise predict subsequent social motives, goals and behaviours (see Fig. 2.7). Chapters 4 and 5 of this thesis present data relating to individual differences in expectancies of social reward and threat. Chapter 6 is concerned with sensitivity (responsivity) to social reward and punishment outcomes. It is hypothesised that these two components are strongly interlinked, such that valenced expectancies serve to bias individuals' subsequent perceptions of and reactions to social cues. Individual differences in interpretation of and reactivity to social reward and threat cues will in turn inform expectancies for future social scenarios. In the sense that dispositional social expectancies encode characteristic expectations of the likely behaviour of others and the likely affective experiences of oneself in social scenarios, these expectancies may arise from, and/or contribute to the internal working models of self and others that form the basis of adult attachment style.

2.2 Unifying principles

Integrating the bi-dimensional model of attachment portrayed in Fig. 2.3 with Bartholomew's (1990) models of self and others gives rise to the model depicted in Fig. 2.6.

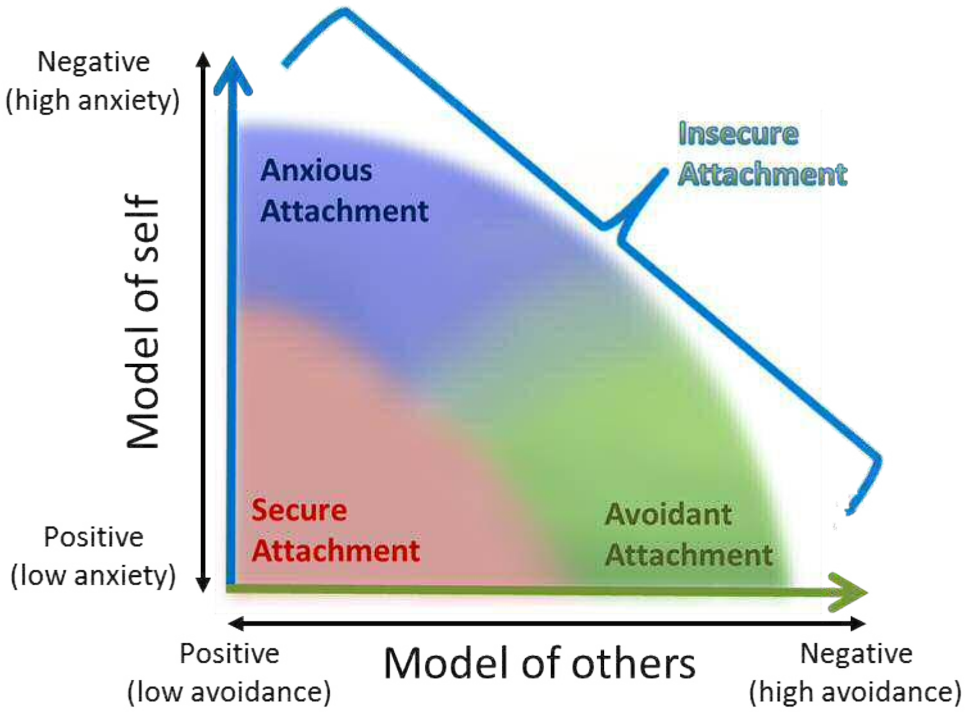

Figure 2.6: Representation of the bi-dimensional model of attachment in terms of valenced internal working models of self and others.

The effects of one's valenced perceptions of oneself and others, including one's generalised expectancies regarding the likely behaviour of others and one's own likely affective experiences (for instance in an upcoming social situation) are not limited to attachment style however. Any personality trait or affective disposition that relates to social behaviour will likely be informed by expectancies. Thus, in line with previous findings that generalised expectancy constitutes a central component in personality (Haugen et al., 2004), it is suggested here that generalised expectancies of social threat and reward constitute an important cognitive component of personality traits and dispositions relating to social motives and behaviour. For example, the broad autism phenotype (BAP), which refers to the presence of sub-clinical autistic-like traits in the general population, includes a component known as aloofness or aloof personality (Hurley, Losh, Parlier, Reznick, & Piven, 2007). Aloofness is defined as a "lack of interest in or enjoyment of social interaction" (Hurley et al., 2007, p. 1681). It seems plausible that reduced interest in social interactions may arise as a direct result of low expectancies of social reward. Lack of enjoyment of social interactions will have more contributing factors, but low expectancy of social reward is here hypothesised to be an important cognitive factor influencing this affective outcome.

2.3 Research questions and outline of the empirical approach employed

The aim of this project was to investigate the relationships between individual differences in social expectancies and motivation, and how these relate to broader personality traits and to social integration outcomes such as individuals' sense of belonging. As discussed above, it is hypothesised that individual differences in cognitive reactivity, particularly in dispositional expectancies, underpin individual differences in social motivation and ensuing behaviour. Fig. 2.7 illustrates the model investigated in this project. The predictions arising from the links between social expectancies, motives, and social integration outcomes posited in this model are tested in Chapter 4 of this thesis. In the work presented there, the predictions are tested by means of self-report measures that index the individual difference variables of interest. In Chapter 5, correlations between self-reported social expectancies and individual differences in localised grey matter volume in the brain are reported. Information about the neuroanatomical correlates of social reward and threat expectancies may enhance our understanding of their associations with other cognitive and affective variables. In Chapter 6, a behavioural, task-based approach is used to further assess the predictions arising from the proposed model.

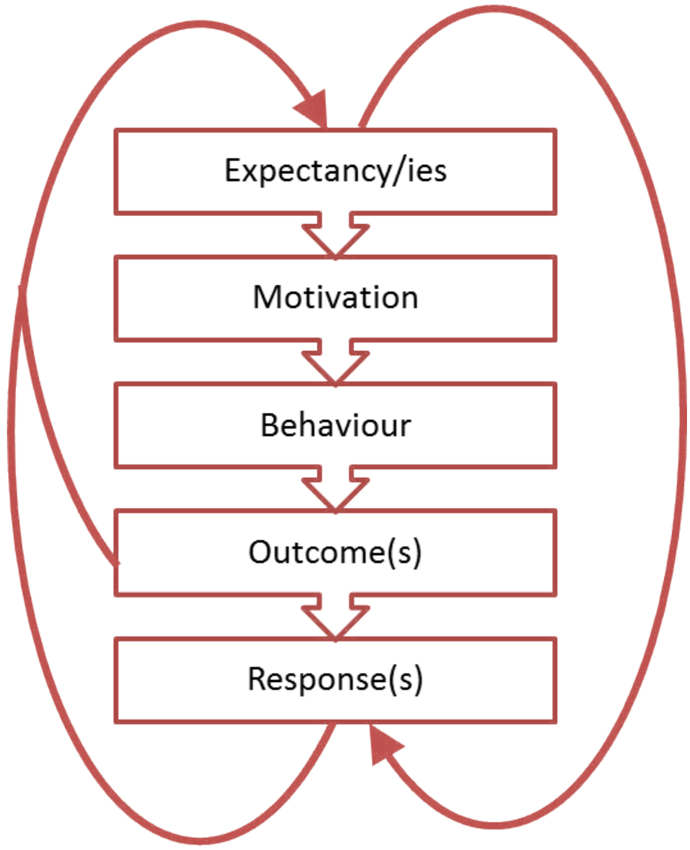

Figure 2.7: The theoretical framework proposed in this thesis. It is suggested that dispositional biases in expectancies of social reward and punishment directly inform social approach and avoidance motives and goals. These motives and goals direct social behaviour accordingly. Individual differences in interpretation of and reactivity to social feedback from others (i.e. the outcomes of one's interpersonal behaviour) are considered to be intimately linked with expectancies, such that valenced expectancies serve to bias one's subsequent perceptions of and reactions to social cues. These perceptions and reactions in turn inform expectancies for future social scenarios.

Chapter 3

General Methods

3.1 Overview

This chapter provides a summary of and general background for the specific methods used in each study reported in the thesis. Several psychometric and process-based measures were used across one or more of the behavioural studies, including the behavioural components of the neuroimaging experiments. The procedures for administering the behavioural studies were held constant throughout the project. These methods and procedures are described in section 3.2. Section 3.3 offers a primer on the rationale and principles behind magnetic resonance imaging (MRI) and its application to identifying structural and functional properties of the brain that are relevant to the study of personality.

3.2 Psychometric and Process-Based Measures

Both psychometric and process-based approaches to understanding social reward and threat sensitivity were used in the studies reported here. These two approaches to the study of personality offer complementary levels of insight into how and why individuals differ. The psychometric approach to studying personality traits involves the use of self-report questionnaires, which are analysed and validated using factor analytic techniques (Kline, 1993). Well-validated psychometric measures can provide detailed and nuanced information regarding how individuals differ. How individuals differ in their explicit expectations for social threat and reward is best addressed using a psychometric measure. I developed and validated such a measure – the Levels of Dispositional Expectancies for Social Threat and Reward Scales (LODESTARS) – as part of this project (see

Chapter 4 for full details). I explored the nomological network of the LODESTARS using psychometric measures of other well-established constructs, including the five-factor (or big five) model of personality, the broad autism phenotype, and attachment style. These measures are described in section 3.2.4.

Having discussed how individuals differ in their social reward and threat expectancies and related characteristics (in Chapter 4), the attention of this thesis turns to why individuals differ in these trait-related tendencies. To address this, a process-based approach is taken. This assumes that motivations, emotions etc. arise from the functioning of cognitive-affective processes (implemented in the brain) and that differences in these processing mechanisms can explain individual differences in, for example, emotional reactivity (Robinson, 2007). That is, there is thought to be a set of cognitive-affective neural processes that explain, for instance, why more extraverted individuals experience greater pleasure in response to positive events and why individuals higher in neuroticism experience more distress in response to negative events (Robinson, 2007).

In the present project, motivation for and responsivity to social reinforcements was investigated from a process-based perspective by means of a reaction-time task and brain imaging measures. The development and validation of the social and monetary incentive delay (SMID) task is described in detail in Chapter 6. Behaviourally, reaction times from this task can be used to index participants' relative motivations for gaining social rewards (positive feedback) and avoiding negative social feedback. Following extensive piloting, the SMID task was employed in one large behavioural study, enabling exploration of the associations between self-reported personality variables and relative motivations as indexed by reaction times. The SMID task was also used in a preliminary functional magnetic resonance imaging (fMRI) experiment (reported in Appendix 8), in which we aimed to identify brain regions that exhibit greater blood oxygenation-level-dependent (BOLD) response to social outcomes versus material outcomes.

The studies that constitute this thesis, including participant and data collection details, are summarised in sections 3.2.1 – 3.2.3 below.

All studies reported in this thesis were approved by the Cardiff University School of Psychology Research Ethics Committee (http://psych.cf.ac.uk/aboutus/ethics.html).

3.2.1 Studies

The first study, Study 1A, was predominantly for the purpose of paradigm development, validation and refinement. I used this study to assess construct validity of the LODESTARS by exploring its nomological network (Cronbach & Meehl, 1955). The other major purpose of Study 1A was to calibrate the SMID task such that participants win on average 50% of trials (this is described in Chapter 6).

Study 1B constituted the main behavioural experiment for this project, including both psychometric measures and the SMID task.

The Imaging study also included psychometric measures, which participants did two-three days prior to their scanning session. High-resolution structural brain scans were acquired for each participant. Some participants in this study also performed the SMID task while in the MRI scanner.

A study employing Cyberball (Williams, Cheung, & Choi, 2000; Williams & Jarvis, 2006), a widely used paradigm for experimentally manipulating social inclusion/exclusion, was conducted. Participants in this study also completed several psychometric measures.

Psychometric data were also collected during Introduction to Research ('pre-test') sessions. This is an established event that most first-year Psychology students at Cardiff University participate in during their first week on the course. It is a timetabled session in their schedule for that week and although it is voluntary, most choose to participate.

A final study, termed the Autumn 2014 study, was conducted to test if key associations and effects found in earlier studies were replicable.

Recruitment strategies for participants in Studies 1A, 1B and the Imaging study included advertisement on the School of Psychology's online Experimental Management System (EMS), email advertisements to other departments of Cardiff University, and posters stuck in the Students'

Union and Arts and Social Sciences Library. Recruitment for the Cyberball and Autumn 2014 studies was carried out exclusively using the EMS.

3.2.2 Participants

Table 3.1 gives the number of participants who took part in each study, along with demographic details.

3.2.3 Data collection

Data for study 1A were collected during August and September 2012. Data for the Pre-test 2012 were collected in two sessions on 27th September 2012. Data for study 1B were collected in two waves, the first in December 2012 and the second in summer 2013. Data for the Imaging study were collected from July to December 2013. Pre-test 2013 was conducted on 25th and 26th September 2013 (two sessions, one on each day). Data for the Cyberball study was predominantly collected in February and March 2014. Pre-test 2014 was conducted on 24th and 25th September 2014 (two sessions, one on each day). Data for the Autumn 2014 study were collected between 25th October and 27th November 2014.

3.2.4 Psychometric measures

Studies 1A and 1B were partially exploratory in nature. A major purpose of these two studies was to establish which measures have the best psychometric properties for this work, in order to refine the design for later behavioural work and neuroimaging studies. A number of self-report measures were therefore included. The self-report measures that were administered in each of the eight studies conducted are listed in Table 3.2 and described in the text that follows. In Study 1A, paper versions of the questionnaires were administered. SurveyMonkey (SurveyMonkey Inc., Palo Alto, California, USA; available from www.surveymonkey.com) was used to administer the questionnaires in the December wave of Study 1B. For all subsequent studies Qualtrics was used (Qualtrics, Provo, UT, http://www.qualtrics.com).

Study	Number	Recruited from	Gender	Age
1A	61	Psychology, Biosciences, Engineering, Maths, Students' Union; predominantly postgraduate and summer project students	23 males, 38 females	Mean 23.95 Range 19 - 51
Pre-test 2012	203*	Psychology 1st year undergraduate students	22 males, 184 females, 1 not specified	Mean 18.61 Range 17 - 42
1B	128	Psychology 1st and 2nd year undergraduate students; various other departments at Cardiff University	64 males, 64 females	Mean 19.6 Range 18 - 25
Imaging	56	Various departments at Cardiff University, including healthcare departments based at the University Hospital of Wales. Several employees of a nearby solicitors' firm also participated.	56 females	Mean 24.3 Range 18 - 52
Pre-test 2013	197	Psychology 1st year students	24 males, 158 females, 15 not specified	Data not available
Cyberball	28	Psychology 1st and 2nd year students	28 females	Data not available
Pre-test 2014	204	Psychology 1st year students	23 males, 181 females	Mean 19.1 Range 17 - 50
Autumn 2014	168	Psychology 1st year students	18 males, 150 females	Mean 18.8 Range 17 - 30

Table 3.1: The number of participants in each of the eight studies reported here, along with demographic details. The studies are presented here in chronological order.

*209 in total participated in pre-test 2012; however 203 of these completed the questionnaire used in the present study, so only data for these individuals are reported.

Measure	Study 1A	Pre-test 2012	Study 1B	Imaging	Pre-test 2013	Cyberball	Pre-test 2014	Autumn 2014
Levels of Dispositional Expectancies for Social Threat and Reward Scales (LODESTARS)	✓	✓	✓	✓	✓	✓	✓	✓
The Behavioural Inhibition System (BIS) Scale	✓		✓	✓				
Reward Responsivity (RR) Scale (revised BAS scale)	✓			✓				
Adult Attachment Style Questionnaire (ASQ)	✓		✓	✓				✓
The Broad Autism Phenotype Questionnaire (BAPQ)	✓		✓	✓				✓
Rosenberg (1979) self-esteem scale	✓			✓				
State Self Esteem (SSE) Scale	✓ (partially)[1]		✓			✓		
Delaying Gratification Index (DGI)	✓ (partially)[2]		✓	✓				
Rejection Sensitivity Questionnaire (RSQ) – short version	✓							
Need to Belong scale		✓						
Hurt Proneness Scale						✓		
General Belongingness Scale (GBS)			✓					
Levenson Brief Psychopathy Scale			✓					
Brief fear of negative evaluations scale			✓					
Friendship Goals Questionnaire			✓					✓

Measure	Exp.1A	Pre-test 2012	Exp.1B	Imaging	Pre-test 2013	Cyberball	Pre-test 2014	Autumn 2014
Interpersonal Orientation Scale (IOS)			✓					
Big Five Inventory (BFI)			✓			✓ (partially)[3]		✓
Social Network Index (SNI) - Adjusted for students			✓ (partially)[4]	✓		✓		✓
Post-Cyberball Needs-Threat Scale						✓		
Anxiety Depression Distress Inventory-27 (ADDI-27)				✓				
UPPS Impulsive Behaviour scale (original 45-item version)				✓				
Schlotz Perceived Stress Reactivity Scale				✓				

Table 3.2: Self-report measures used in each of the studies reported here.

[1]30 participants in study 1A completed the SSE;

[2]29 participants in study 1A completed just the social and monetary scales of the DGI;

[3]23 participants in the Cyberball study completed the BFI.

[4]89 participants in study 1B completed the SNI.

Levels of Dispositional Expectancies for Social Threat and Reward Scales (LODESTARS): This 10-item questionnaire measures generalised expectancies of social threat and reward. Participants are asked to imagine that this evening they will attend a social event with individuals they have never met before. Participants imagine how they feel in anticipation of this event and indicate their agreement with each item of the questionnaire using a Likert-type scale ranging from 1 ('strongly disagree') to 5 ('strongly agree'). Items include "I feel a little anxious about the interactions" (threat) and "I will probably meet one or more people who I will like a lot" (reward). Please see Chapter 4 for details of the development and validation of this scale. Cronbach's alphas for the threat scale ranged from .80 to .89 in the present work; alphas for the reward scale ranged from .63 to .74. Full results of the internal consistency analyses are given in Chapter 4.

The Behavioural Inhibition System and Reward Responsiveness (BIS/RR) Scales: The BIS/RR scales (Van den Berg, Franken, & Muris, 2010) are a revision of the original BIS/BAS self-report scales (Carver & White, 1994)[1]. The BIS/RR scale contains 15 items that are allocated to two subscales: responsiveness to reward (RR; 8 items) and behavioural inhibition (BIS; 7 items). The BIS (RP) and RR scales measure tendencies to experience avoidant motivation (e.g., "I feel worried when I think I have done poorly at something") and appetitive motivation (e.g., "When I'm doing well at something, I love to keep at it"). Responses are provided on a 4-point scale (1 = 'strongly disagree' to 4 = 'strongly agree'). Van den Berg, Franken, and Muris (2011) reported high internal consistency (Cronbach's alphas in the .80 range) for this questionnaire. However, the RR was not found to be psychometrically useful in study 1A. Several participants in study 1A also complained that some of the items were too subjective and/or situation dependent and so either did not answer them or stated that they were not sure about their answers. The RR was therefore not included in study 1B. It was included in the Imaging study (along with the Delaying Gratification Index (DGI; described later)) in case a measure of general reward responsivity was required during the analysis of the functional brain imaging data. Cronbach's alphas for the BIS scale were .84 in Study 1A, .74

[1] The BIS scale is re-named the responsiveness to punishment (RP) scale by Van den Berg, Franken, & Muris, (2011).

and .76 in Study 1B for males and females respectively; and .80 in the Imaging study. Cronbach's alphas for the RR scale were .66 in Study 1A and .63 in the Imaging study.

Adult Attachment Style Questionnaire (ASQ; Feeney, Noller, & Hanrahan, 1994): The ASQ is a forty-item questionnaire that measures the two attachment dimensions of anxious and avoidant attachment. Anxious attachment (anx_att) is measured with 13 items (e.g., "I worry that others won't care about me as much as I care about them"). Avoidant attachment (av_att) is measured with 16 items (e.g., "I worry about people getting too close"). Responses are given on a 6-point scale (1 = 'totally disagree' to 6 = 'totally agree'). Cronbach's α was .85 for both anx_att and av_att in Study 1A; .85 and .90 for anx_att in Study 1B for males and females respectively, and .85 and .86 for av_att in Study 1B for males and females respectively. Cronbach's α was .88 for anx_att and .86 for av_att in the Imaging study; .89 for anx_att and .90 for av_att in the Autumn2014 study.

The Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007; Sasson et al., 2013): This 36-item inventory examines a set of personality and language characteristics in non-autistic individuals. Participants indicate how often they engage in various behaviours or cognitions on a 6-point Likert-type scale ranging from 1 = 'very rarely' to 6 = 'very often'. The questionnaire comprises three sub-scales:

- Aloof personality:
  - Lack of interest in or enjoyment of social interaction.
  - Includes statements such as "I would rather talk to people to get information than to socialize" and "I like being around other people".
- Pragmatic language problems:
  - Deficits in the social aspects of language, resulting in difficulties communicating effectively or in holding a fluid, reciprocal conversation.
  - Includes statements such as "I find it hard to get my words out smoothly" and "I feel disconnected or "out of sync" in conversations with others"*.

- Rigid personality:
  - Little interest in change or difficulty adjusting to change.
  - Includes statements such as "I am flexible about how things should be done" and "I alter my daily routine by trying something different".

*It is emphasised in the questionnaire that items like this refer to casual interaction with acquaintances, rather than special relationships such as with close friends and family members.

Cronbach's alphas for each of the BAPQ sub-scales, as well as the questionnaire as a whole, are reported in Table 3.3.

Sample	Aloof personality	Pragmatic language problems	Rigid personality	Full Scale
Study 1A	.90	.68	.86	.91
Study 1B males	.72	.53	.84	.83
Study 1B females	.92	.75	.85	.91
Imaging (females)	.92	.70	.82	.91
Autumn 2014	.88	.68	.86	.89

Table 3.3: Inter-item reliability coefficients (Cronbach alphas) for each sub-scale of the BAPQ as well as for the questionnaire as a whole.

The Delaying Gratification Index (DGI; Hoerger, Quirk, & Weed, 2011): The full version of the DGI comprises 35 items and yields gratification delay scores on 5 sub-domains: food, physical pleasures, social interactions, money and achievement, as well as a 35-item composite score. In study 1A, the DGI was included as a follow-up online survey, without recompense for completing it. In order to minimise the time required - and thus increase the likelihood of responses - only the social and money sub-scales were administered in this study. These sub-scales were selected because they are directly relevant to the types of reward and punishment used in the present work. The items were presented in an intermixed order. In study 1B and the Imaging study the full 35-

item DGI was administered in the experimental session with the rest of the self-report measures. This was to enable greater discriminant validity and range.

The items from the DGI-social interactions and money sub-scales are listed below:

<u>Social Interactions</u>

I hate having to take turns with other people. (R)

Usually I try to consider how my actions affect others.

I think that helping each other benefits society. (R)

I try to consider how my actions will affect other people in the long-term.

I do not consider how my behaviour affects other people. (R)

I value the needs of other people around me.

There is no point in considering how my decisions affect other people. (R)

<u>Money</u>

When I am able to, I try to save away a little money in case an emergency should arise.

It is hard for me to resist buying things I cannot afford. (R)

I try to spend my money wisely.

I cannot be trusted with money. (R)

When someone gives me money, I prefer to spend it right away. (R)

I manage my money well.

I enjoy spending money the moment I get it. (R)

Items in the other sub-domains include “It is easy for me to resist sweets and bowls of snack foods” (food); “When faced with a physically demanding chore, I always tried to put off doing it” (reverse-scored; physical pleasures); and “I am capable of working hard to get ahead in life” (achievement).

Hoerger et al. (2011) found strong internal consistency for scores on the DGI-35 composite scale ($\alpha \geq .90$). Sub-scale scores were also found to have good reliability ($\alpha = .69 – .89$) in Hoerger et al.'s (2011) work. In general similar results were found in the present work, although the reliability coefficients for the 'social interactions' scale were relatively low, as can be seen in Table 3.4.

Sample	DGI - food	DGI - physical pleasures	DGI - social interactions	DGI - money	DGI - achievement	DGI-35 Composite (full scale)
Study 1A			.60	.91		
Study 1B males	.63	.60	.55	.89	.81	.87
Study 1B females	.79	.72	.66	.83	.86	.88
Imaging (females)	.64	.69	.60	.90	.87	.87

Table 3.4: Inter-item reliability coefficients (Cronbach alphas) for each sub-scale of the DGI as well as for the scale as a whole

State Self-Esteem Scale (SSES; Heatherton & Polivy, 1991): The SSES has three correlated but differentially sensitive sub-scales which measure different components of participants' self-concept. These are: academic performance, social evaluation, and appearance state self-esteem. The SSES comprises 20 items; participants are asked to indicate to what extent each is true of them right at this moment, using a 5-point scale where 1 = 'Not at all' and 5 = 'Extremely'. Sample items include "I feel confident about my abilities" (performance); "I am worried about what other people think of me" (social, reverse scored); and "I feel unattractive" (appearance, reverse scored). The SSES has been shown to have good discriminant and construct validity (Heatherton & Polivy, 1991). In the present work the SSES was administered directly before and after the SMID task (Studies 1A and 1B) and directly before and after the Cyberball game. Participants' responses to the 'before' SSES were used to calculate inter-item reliability coefficients (Cronbach alphas). These are reported in Table 3.5.

Sample	SSE - academic performance	SSE – social evaluation	SSE - appearance	SSE - total
Study 1A	.87	.90	.90	.95
Study 1B males	.83	.88	.84	.92
Study 1B females	.90	.91	.87	.95
Cyberball (females)	.93	.93	.89	.96

Table 3.5: Inter-item reliability coefficients (Cronbach alphas) for each sub-scale of the SSES as well as for the scale as a whole

Rejection Sensitivity Questionnaire – short form (RSQ; Downey & Feldman, 1996): The full RSQ is an 18-item questionnaire that examines the extent to which individuals expect rejection and are anxious about it. Each item presents a hypothetical scenario in which the participant makes a request (e.g., "You approach a close friend to talk after doing or saying something that seriously upset him/her"), and participants record their responses to these items on two 6-point scales. The first response scale pertains to the extent to which participants feel anxious about rejection in relation to the request (1 = 'Very unconcerned' to 6 = 'Very concerned'). The second scale examines the extent to which individuals expect that their request would be rejected (1 = 'Person(s) in the scenario would be very likely to reject the request' to 6 = 'Person(s) in the scenario would be very likely to comply with the request'). Scores are calculated by multiplying the expectancy of rejection score by the concern about rejection score for each item. These scores are then averaged to obtain a rejection sensitivity score. The short version used here simply consists of the 8 items that have the highest factor loadings in the full version. Inter-item reliability (Cronbach's α) was .78 for the concern responses, .75 for the likelihood responses, and .72 for the composite scores (concern*likelihood) in the Study 1A sample.

Need to Belong Scale (NTBS; Leary, Kelly, & Schreindorfer, 2001): This 10-item scale was developed to measure individual differences in the need to belong, characterized by needs for acceptance and the physical presence of others. Individuals high in the need to belong experience strong negative affective reactions to real or anticipated exclusion (Pickett, Gardner, & Knowles, 2004). The NTBS includes items that tap both desire for acceptance and the physical presence of others (e.g. “I want other people to accept me”; “I do not like being alone”) and concerns about rejection and exclusion (e.g. “I try hard not to do things that will make other people avoid or reject me”). In the Pre-test 2012 study participants responded to each item on a 7-point agreement scale (1 = ‘Strongly disagree’ to 7 = ‘Strongly agree’). The internal consistency of the NTBS in the Pre-test 2012 sample was high (Cronbach’s α = .79).

Hurt Proneness Scale (Leary & Springer, 2001): Also known as the *Hurt Feelings Scale*. This 6-item measure assesses how easily respondents’ feelings are hurt. Items include “My feelings are easily hurt,” and “I take criticism well” (reverse scored). Participants indicate how characteristic each item is of them on a 5-point Likert-type scale with 1 = ‘Not at all characteristic of me’ and 5 = ‘Extremely characteristic of me’. Leary and Springer (2001) have shown that this measure relates specifically to the experience of social pain and cannot be reduced to other negative emotions. In the Cyberball study sample, the Hurt Feelings Proneness Scale was found to have high internal consistency (Cronbach’s α = .85).

Rosenberg (1979) self-esteem scale: This 10-item scale assesses the valence (positivity or negativity) of global self-evaluations. Participants are asked to indicate how much they agree or disagree with items such as, “I take a positive attitude toward myself,” on a 4-point scale with 1 = ‘Strongly disagree’ and 4 = ‘Strongly agree’. Cronbach’s α was .88 in Study 1A and .92 in the Imaging study.

General Belongingness Scale (Malone, Pillow, & Osman, 2012): This 12-item questionnaire assesses achieved belongingness (as opposed to the need to belong). That is, it measures respondents' subjective sense of belonging with other people broadly, and with friends and family. Participants use a 7-point agreement scale (1 = ‘Strongly disagree’; 7 = ‘Strongly agree’) to rate statements such as “When I am with other people, I feel included” and “I have close bonds with family and friends”. The scale comprises two sub-scales: rejection/exclusion and acceptance/inclusion. While the chi-square difference test conducted by Malone et al. supported the 2-factor model ($p < .001$), the two factors are highly correlated ($r = -.67$ in Malone et al.'s study; -.88 in study 1B reported here). Malone et al. therefore recommend reverse scoring the negatively worded (rejection/exclusion) items and using the scale as one "unidimensional, parsimonious" instrument, to yield a single belongingness score. This is suitable for most applications but there were indications in Malone et al.'s analyses that the two factors relate more to approach and well-being, avoidance and depression, respectively. Malone et al. speculate that the acceptance/inclusion factor better taps approach-based psychological processes, whereas the rejection/exclusion factor better assesses avoidance-based processes. As these processes are of interest in the current study, the GBS was scored both as separate sub-scales and as a unitary measure. Differences in the sub-scales' relations to other variables could therefore be assessed if present. Cronbach’s α was .91 for male participants in Study 1B and .96 for female participants.

Levenson Brief Psychopathy Scale (Levenson, Kiehl, & Fitzpatrick, 1995): This 26-item questionnaire assesses levels of both primary and secondary psychopathic attributes. The primary psychopathy sub-scale (16 items) measures inclination to lie, lack of remorse, callousness, and manipulativeness. The secondary psychopathy sub-scale (10 items) measures impulsivity, tolerance of frustration, quick temperedness, and lack of long-term goals. Items include “For me, what’s right is whatever I can get away with” (primary psychopathy); “When I get frustrated, I often "let off steam" by blowing my top” and “I quickly lose interest in tasks I start” (both secondary psychopathy). Good internal reliability was found for the total score (Cronbach’s $\alpha = .83$ for males and .85 for females in Study 1B), and for primary psychopathy (Cronbach’s $\alpha = .86$ and .83 for males and females in Study 1B, respectively). The internal consistency was lower for secondary psychopathy, particularly for male participants (Cronbach’s $\alpha = .56$; for female participants $\alpha = .74$). This pattern of results is very similar to those found in previous studies with university students (Singh, Arteche, & Holder, 2011).

Brief fear of negative evaluations scale (Leary, 1983): This 12-item scale measures the extent to which respondents experience apprehension about potentially being evaluated negatively by others. The items include statements such as “I worry about what other people will think of me even when I know it doesn't make any difference”. Participants indicate how much each item is reflective of them on a 5-point Likert-type scale (1 = ‘Not at all characteristic of me’; 5 = ‘Extremely characteristic of me’). Cronbach’s α was .91 for male participants in Study 1B and .92 for female participants.

Friendship Goals Questionnaire (Elliot et al., 2006)*:* This 8-item questionnaire measures friendship-approach and friendship-avoidance goals. Approach goals focus on positive possibilities (e.g. “I am trying to share many fun and meaningful experiences with my friends”) whereas avoidance goals focus on avoiding negative possibilities (e.g. “I am trying to avoid disagreements and conflicts with my friends”). Participants respond on a 7-point Likert-type scale (1 = ‘Not at all true of me’; 7 = ‘Very true of me’). Cronbach’s α coefficients were .88 and .78 for friendship-approach goals in male and female participants respectively in Study 1B. For friendship-avoidance goals, Cronbach’s α was .72 for male participants in Study 1B and .67 for females. In the Autumn 2014 sample, Cronbach’s α was .86 for friendship-approach goals and .74 for friendship-avoidance goals.

Interpersonal Orientation Scale (Hill, 1987): This 26-item scale probes four dimensions assumed to underlie affiliation motivation. These are emotional support, attention, positive stimulation and social comparison. The scale measures tendencies to seek these four different aspects of interpersonal contact that are proposed to serve as potential sources of gratification. Positive stimulation refers the capacity of affiliation to provide enjoyable affective and cognitive stimulation. Attention relates to the potential for enhancement of feelings of self-worth and importance through praise and focusing of others' attention on oneself. Social comparison is defined as the capacity for reduction of ambiguity through acquisition of self-relevant information. Finally, emotional support or sympathy refers to the reduction of negative affect through social contact.

Items include “One of my greatest sources of comfort when things get rough is being with other people” (emotional support) and “I prefer to participate in activities alongside other people rather than by myself because I like to see how I am doing on the activity” (social comparison). Participants respond to each item on a 5-point scale (1 = ‘Not at all true’; 5 = ‘Completely true’).

Cronbach’s alphas for each of the IOS sub-scales are reported in Table 3.6.

Sample	Positive stimulation	Emotional support	Social comparison	Attention
Study 1B males	.88	.89	.85	.84
Study 1B females	.87	.87	.82	.83

Table 3.6: Inter-item reliability (Cronbach alphas) for each sub-scale of the IOS.

Big Five Inventory (BFI; John & Srivastava, 1999): This 44-item scale measures the five major personality dimensions extraversion, agreeableness, conscientiousness, neuroticism and openness to experience. The items describe characteristics, e.g. “is talkative” (extraversion), “tends to be lazy” (reverse scored, conscientiousness). Participants rate the extent to which each item is reflective of them on a 5-point agreement scale (1 = ‘Strongly disagree’; 5 = ‘Strongly agree’). Cronbach’s α coefficients were between .70 and .85 for all sub-scales. These are reported in Table 3.7.

Sample	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Study 1B males	.87	.63	.81	.79	.76
Study 1B females	.88	.82	.82	84	.79
Cyberball (females)	.86	.70	.84	.61	.69
Autumn 2014	.88	.78	.77	.84	.78

Table 3.7: Inter-item reliability (Cronbach alphas) for each sub-scale of the BFI.

Social Network Index (*SNI;* C*ohen, Doyle, Skoner, Rabin, & Gwaltney, 1997):* This scale assesses participation in a variety of different categories of social relationships. For the present work, several adjustments to the wording of the original scale were made, to make it more appropriate to undergraduate student samples. Appendix 1 shows the changes that were made to the original scale. The SNI yields 3 measures:

- Number of high-contact roles (network diversity) – the number of social roles in which the respondent has regular contact with at least one person (sees or talks to the person on the phone at least once every two weeks). The potential high-contact roles are: partner, parent, child, close relative, close friend, church/temple member, student, employee, neighbour, volunteer, and group member. In the present work, each separate group a person belongs to (question 12) was counted as a separate social role.
- Number of people in social network (network size) – the total number of people that the respondent sees or talks to on the phone at least once every two weeks. In the original SNI the highest available response option is '7 or more' for many of the social roles. So for social networks with '7 or more' ticked, the 'number of people in social network' will not be fully accurate, as it may be the number computed (using 7 wherever '7 or more' was ticked) or it may be more. The SNI (adapted for students) was administered with the response options in this form in Study 1B, the Imaging study, and the Cyberball study. For the Autumn 2014 study, the questionnaire was modified so that if participants selected '7 or more', they were then asked to specify the precise number. This was then used for the calculation of the number of people in their social network.
- Number of embedded networks (network complexity) – this measure is meant to reflect the number of different network domains in which a respondent is active. The maximum possible is 8. They are: family, friends, church/temple, school, work, neighbours, volunteering, and groups. To receive a point for a domain, a respondent must have at least 4 high-contact people within that domain. The 5 family roles are collapsed into one network for this measure. To receive a point for family, they are required to have at least 3 high-contact family roles as well as 4 high-contact people. This measure is rarely reported and was not used in the present work.

Post-Cyberball Needs-Threat Scale (NTS; Williams et al., 2002, 2000): The version of this scale used in the present study is described in the account of the Cyberball study procedure (section 3.2.5.6) later in this chapter.

Anxiety Depression Distress Inventory-27 (ADDI-27; Osman et al., 2011): This 27-item questionnaire comprises 3 subscales (Positive Affect, Somatic Anxiety, and General Distress), which correspond to the tripartite model of affect (L. A. Clark & Watson, 1991). Low positive affect (that is, the absence of affective experiences such as "felt happy," "felt optimistic," or "felt good") is specifically indicative of depression. High anxious somatic arousal (such as "felt dizzy," "hands were shaky," and "had trouble swallowing") is specifically indicative of anxiety/panic. General distress – that is, high levels of negative affect (such as worry, fear, and irritability) – represents shared (nonspecific) or overlapping symptoms of anxiety and depression. Participants respond to each item by indicating how often they have felt or experienced things in this way during the past two weeks, using a 5-point scale ranging from 1= 'not at all' to 5 = 'extremely'.

UPPS Impulsive Behaviour scale (Whiteside & Lynam, 2001): This 45-item questionnaire assesses impulsivity across 4 dimensions: urgency (also known as rash impulsivity), perseverance (also known as self-discipline), premeditation (also known as deliberation or planning), and sensation seeking (UPPS). Items include "When I feel rejected, I will often say things that I later regret" (urgency); "Once I get going on something I hate to stop" (perseverance); "I am a cautious person" (premeditation); and "I would enjoy water skiing" (sensation seeking). Participants indicate how characteristic each item is of them using a 4-point agreement scale from 1 = 'strongly agree' to 4 = 'strongly disagree'.

Perceived Stress Reactivity Scale (PSRS; Schlotz, Yim, Zoccola, Jansen, & Schulz, 2011): The construct of perceived stress reactivity is defined as a disposition that underlies relatively stable individual differences in physiological and psychological stress responses (Schlotz et al., 2011, p. 81). The PSRS is a 23-item questionnaire which measures this construct and its components with 5 subscales and 1 overall scale:

- Prolonged Reactivity (PrR): difficulty in relaxing/unwinding after experiencing a high workload
- Reactivity to Work Overload (RWO): feeling nervous, agitated and/or irritated in response to a high workload
- Reactivity to Social Conflict (RSC): feeling affected, annoyed and/or upset in response to social conflict, criticism or rejection
- Reactivity to Failure (RFa): feeling annoyed, disappointed, or 'down' in response to failure
- Reactivity to Social Evaluation (RSE): feeling nervous and/or losing self-confidence in response to social evaluation
- Perceived Stress Reactivity total score (PSRS-tot): sum of the five scale scores.

The 23 items comprising the PSRS describe situations which frequently occur in many people's lives and which may cause stress (e.g. "When tasks and duties build up to the extent that they are hard to manage…"). Participants respond by selecting the answer that most closely describes their reaction in general. There are 3 possible answers for each item, corresponding to low/absent stress reactivity, moderate reactivity and high reactivity (e.g. "I am generally untroubled"; "I usually feel a little uneasy"; "I normally get quite nervous").

3.2.5 Procedures

3.2.5.1 Pre-tests

First-year Psychology students at Cardiff University attended the pre-test session during their first week on the course. Following an introduction and outline of the aims of the session, the students could choose to either participate or leave. Following completion of a consent form, those who participated completed nine questionnaires (from different researchers in the School of Psychology), including the LODESTARS. Each researcher who contributed a questionnaire then gave a short oral debrief and description of their research to the group - who also received debrief information booklets. On their way out, participants could select fruit and/or chocolate bars as a thank you.

3.2.5.2 Study 1A

Each participant attended a testing session in the Psychology building at Cardiff University. Participants completed an online social value orientation (SVO) slider task (Murphy, Ackermann, & Handgraaf, 2011; not reported here), followed by the set of questionnaires (in random order[2]), and finally the SMID task run via Cogent 2000 (http://www.vislab.ucl.ac.uk/cogent.php) in MATLAB 2012 (http://www.mathworks.co.uk/products/matlab). Participants were paid the amount they earned in the SMID task (minimum payment £5; maximum £10) and debriefed at the end of the session.

3.2.5.3 Study 1B

Each participant attended a testing session in the Psychology building at Cardiff University. Participants completed the set of questionnaires in random order, with the exception of the State Self Esteem (SSE) scale, which always occurred last (i.e. directly before the task), followed by the SMID task. After the SMID task, participants again completed the SSE. Undergraduate psychology participants (December 2012 data collection) were remunerated for their time with course credits, but in order that the monetary trials in the SMID task were meaningful and motivating, participants were also paid the amount they earned in the task (minimum payment £0; maximum £1.50). The participants who completed the task in the summer of 2013 were paid £5 for their time, plus whatever they earned in the SMID task. Participants were debriefed at the end of the session.

3.2.5.4 Brain structure data acquisition

Participants in Studies 1A and 1B were asked, during the debriefing at the end of their session, whether they had previously had a brain scan in CUBRIC. If they had, they were asked if they would object to us accessing the scan and linking it with the self-report data they had just provided, in order to use their data in our brain structure study. If they were interested and happy to participate, they were provided with further information (in the form of an information sheet and the opportunity

[2] With the exception of the State Self Esteem (SSE) scale: the Study 1A participants who completed this did so twice, directly before and directly after the SMID task.

to ask the experimenter any questions they might have) and a consent form to sign. If participants had not previously had a brain scan in CUBRIC, they were asked if they would like to do so. Again, if they were interested they were provided with a copy of the information sheet and the opportunity to ask questions. If they agreed, they were later contacted to arrange a time for a structural brain scan.

3.2.5.5 Imaging study

Participants attended a testing session in the Psychology building at Cardiff University two or three days prior to their scheduled scanning session. During this session participants completed the set of questionnaires in random order. They were then given the opportunity to ask any questions they might have about the scanning session.

Upon arrival at Cardiff University Brain Research Imaging Centre (CUBRIC) for their scanning session, participants were fully checked to ensure that they could safely be scanned. Participants who engaged in the SMID task did a demo version prior to entering the scanner room, to enable the experimenter to check they understood the task. Participants were scanned using a 3-Tesla MRI scanner manufactured by General Electric. High-contrast T1-weighted fast spoiled gradient (FSPGR) anatomical images were acquired for each participant. Participants who did the SMID task were scanned using blood oxygenation-level-dependent (BOLD) functional imaging while they performed the task. Please see section 3.3 of this chapter for details of these MR imaging methods.

Participants were fully debriefed at the end of their scanning session and given the opportunity to ask questions.

3.2.5.6 Cyberball study

On arrival, participants were told that the study concerned associations between interpersonal dispositions and mental visualisation skills, in the sense of how vividly people imagine or mentally visualise things. If they were happy to proceed, participants then read and signed a consent form for confidential data. Having been settled in the testing room, participants then completed the study without further input from the experimenter. First they answered questionnaires about their interpersonal dispositions (see Table 3.2), as well as a short form of Betts' Questionnaire upon Mental Imagery (Sheehan, 1967). As in Studies 1A and 1B, the SSE was the last questionnaire administered before the task. The Cyberball game was then launched (described as an interactive task used for testing mental visualisation skills). The standard procedure for this was used. Participants were told that they would play a ball-tossing game via a local server with two other participants in neighbouring testing rooms. In reality, these other 'players' were controlled by the computer program. This mild deception is necessary to ensure that participants' affective responses to inclusion/exclusion during the game are as close as possible to what they would be in response to playing such a game with real people. Over 135 previous studies have used the Cyberball paradigm (listed at www1.psych.purdue.edu/~willia55/Announce/Cyberball_Articles.htm), mostly with the deception that participants are playing real people. None has reported that participants were distressed upon finding out about the deception.

On the computer screen, participants first viewed a screen displaying a message stating "waiting for other players to join the game". The other two players will appear to join; these were named Emily Jones and Jess Hughes. Neither of these were the names of real students within the department but were constructed from relatively frequently occurring first and surnames, in order that the names would seem familiar to the participants.

During the game, participants saw cartoon images representing the other players, as well as a cartoon image of their own 'hand', which they controlled using the computer's keyboard. An example view is shown in Fig. 3.1.

Figure 3.1: An example view from the Cyberball paradigm. At the time this screenshot was taken, the 'player' shown in the top left part of the screen has the ball and is about to throw it.

During the game, participants were 'included' for the first 10 rounds, and then 'excluded' by the other participants for the remainder of the game (20 rounds). Throughout the inclusion portion, the computerized players were equally likely to throw the ball to the participant or to the other computerized player. However, during the exclusion condition, the two computerized players stopped throwing the ball to the participant, and threw the ball only to each other.

Immediately following completion of the Cyberball game, participants completed the SSE scale followed by some mental imagery questions about the Cyberball game and the Need-Threat Scale (NTS; Williams et al., 2002, 2000). The NTS, which is the standard follow-up to the game in this paradigm, assesses 12 subjectively experienced levels of fulfilment of four fundamental social needs: belongingness (e.g. "I had the feeling that I belonged to the group during the game"), control (e.g. "I felt in control over the game"), self-esteem (e.g. "I had the feeling that the other players did not like me"), and meaningful existence (e.g. "I think that my participation in the game was useful"). See Appendix 2 for a copy of the full scale. Participants responded on a 5-point scale ranging from 1 (not at all) to 5 (extremely). In addition, the questionnaire contained two ancillary affective variables ("I felt angry during the Cyberball game" and "I enjoyed playing the Cyberball game" ; Zadro, Williams, & Richardson, 2004). Participants were also asked how much they would like to play again with each of the two virtual participants in the Cyberball game, rated on a 5-point scale, similar to the procedure used by Alvares, Hickie, and Guastella (2010).

There were also three manipulation checks to confirm participants' perception of their inclusionary status: "I was ignored," and "I was excluded," both answered on the same 5-point scale as the Need-Threat Scale, and an open question: "Assuming that 33% of the time you would receive the ball if everyone received it equally, what percent of the throws did you receive?". These additions to the post-Cyberball questionnaire were first used by Zadro et al., 2004, and have been extensively employed since (e.g. Alvares et al., 2010; Peterson, Gravens, & Harmon-Jones, 2011).

Following completion of the questionnaire(s) participants were asked whether they believed they had been playing real others and then fully debriefed. The deception involved in the Cyberball game was explained and the participants carefully questioned about their feelings regarding this deception. Previous studies with this paradigm have indicated that participants do not generally feel distressed upon finding out about the deception. The participants were also asked not to tell others about the study, to prevent potential future participants knowing in advance that the 'other players' are not real. This type of debrief is typical for this paradigm. Additionally, although we expected any mood alteration resulting from our manipulation to be extremely mild, participants were offered the opportunity to view a mood-reparation video clip.

3.2.5.7 Autumn 2014 study

This study was conducted online, using the EMS both to recruit participants and, once they signed up and consented to participate in the study, to provide them with a link to the Qualtrics survey. Participants completed the set of questionnaires in random order. Upon completion they were automatically re-directed to a debriefing webpage.

3.3 Magnetic resonance imaging (MRI) methods

In Chapter 5 and Appendix 8 of this thesis I report experiments in which we used MRI methods to linking individual differences in social threat and reward cognition to brain structure and function.

This section briefly introduces the rationale and principles behind MRI in general, and the two techniques we employed in particular.

3.3.1 MRI

To acquire an MRI scan, a strong, spatially uniform magnetic field is applied across the part of the body being scanned (the head, in the case of neuroimaging experiments). Most human tissue is water-based and the single protons (the hydrogen nuclei) in water molecules have weak magnetic fields. Individual protons spin, or precess, about an axis determined by the magnetic field. In the absence of a strong external magnetic field, the axes of the brain's protons are orientated randomly. However, in the presence of the strong magnetic field of the MRI environment, a fraction of the brain's hydrogen nuclei align with the external magnetic field (Huettel, Song, & McCarthy, 2009; Savoy, 2002). Thus, during an MR scan, precessing protons can be in one of two states: aligned with the magnetic field, which is a lower-energy state; or anti-parallel, which is a higher energy state. The parallel, lower-energy state is slightly more stable and so in the presence of a constant external magnetic field there will be more protons in the aligned than anti-parallel state. The relative proportion of protons in the two states depends on the temperature and the strength of the static magnetic field. In this thesis, all MRI experiments were conducted in scanners having a 3 Tesla magnetic field.

Once protons are in the aligned state, a carefully controlled sequence of brief radio-frequency (r-f) pulses is applied that temporarily knocks the aligned protons into a new orientation that is 90 degrees to their previously aligned orientation. The protons now precessing in this new, anti-parallel, higher-energy state, will subsequently return into alignment with the external magnetic field. As they do so, they release the additional energy they had gained. This signal can be detected by a radio-frequency receiver coil, and the nature of this MR signal varies depending on the molecular environment of the protons. By analysing components of the MR signal it is possible to infer the properties of the protons and their surrounding environment. Different types of image can be created using different components of the MR signal.

3.3.2 Structural MRI

Structural MRI methods capitalise on the fact that different types of biological tissue have different physical properties. This means that protons in different tissues (e.g. skull, grey matter, white matter, cerebrospinal fluid) respond differently to the electro-magnetic environment of MRI.

For a given substance (e.g. water or fat) in a magnetic field of given strength, the rates at which protons return to the aligned state following a given excitation pulse are given as time constants. The process by which protons in the anti-parallel state return to their lower-energy, aligned state is called longitudinal relaxation. This generally occurs within a few seconds. The time constant associated with longitudinal relaxation is called T1. Variations in T1 relaxation time can be detected by MRI with excellent spatial resolution and used to distinguish between different types of tissues.

Voxel-based morphometry (VBM) is a method that capitalises on the ability of MRI to detect differences in the amount of grey matter (GM) and white matter (WM) in individuals' brains.

Local individual differences in brain tissue composition, e.g. in GM volume (GMvol), can be analysed to identify regions in the brain where GMvol significantly differs between groups or co-varies with a predictor of interest. In Chapter 5, I use VBM to test for correlations between regional GMvol and social threat and reward expectancies as measured by the LODESTARS.

3.3.3 Functional MRI (fMRI)

The component of the MR signal that is analysed in fMRI studies is sensitive to local magnetic field distortions caused by deoxyhaemoglobin in the blood. Measuring this distortion therefore provides an indication of the amount of deoxyhaemoglobin present in the blood. This technique is called blood oxygenation-level-dependent (BOLD) contrast (Ogawa, Lee, Kay, & Tank, 1990). In essence, BOLD fMRI measures changes in the amount of deoxyhaemoglobin in each voxel of the brain over time.

fMRI thus measures changes in local brain physiology (specifically, changes in the concentration of oxygen in the blood) that are associated with altered neural activity in that region of the brain (Attwell & Iadecola, 2002). Based on the assumption that cognitive processing is associated with changes in neural activity, which in turn are associated with changes in local blood oxygenation levels, fMRI data can be used to identify those brain regions that were differentially active during certain experimental conditions compared with others. The generation of the BOLD signal is illustrated in Fig. 3.2. In Appendix 8, I report preliminary work using BOLD fMRI to non-invasively detect changes in activity in the human brain associated with experiences of social versus non-social feedback in the SMID task.

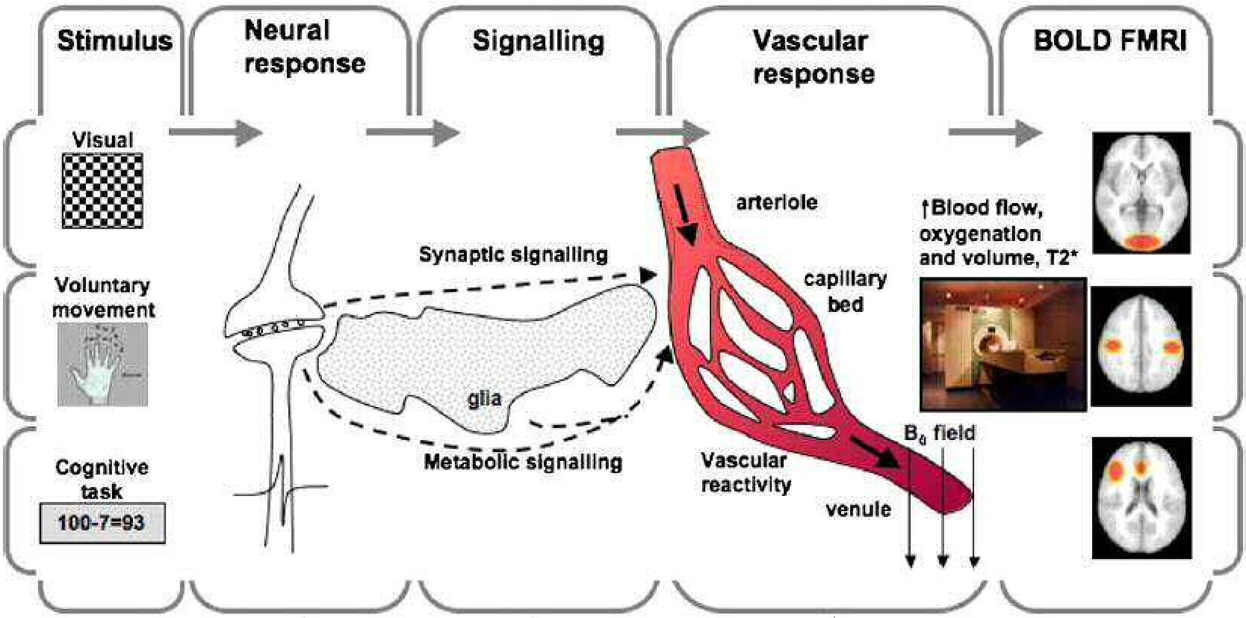

Figure 3.2: Schematic illustration of the generation of the blood oxygen level-dependent (BOLD) signal. From Iannetti & Wise (2007), p. 979.

Chapter 4

Development and validation of a measure of generalised social threat and reward expectancies

4.1 Introduction

As discussed in Chapter 2, I hypothesise that individual differences in social reward and threat sensitivities may be a basic and unifying dimension critical for understanding more complex social dispositions and traits such as attachment style and perhaps some characteristics of the broad autism phenotype (BAP). It is postulated in this thesis that an important cognitive component of such personality traits is individuals' dispositional, or generalised, expectancies regarding social interactions. That is, individuals' perceptions of the potential for social reward or likelihood of social punishment. Differences in generalised expectancies may underpin individual differences in social motivation and behaviour (as depicted in Fig. 2.7).

Examining individual differences in social expectancies and related approach/avoidance motivations, as well as at the higher level of the traits themselves, may yield informative evidence about the cognitive and neural mechanisms of social dispositions and traits. Previous work has demonstrated that dispositional social approach and avoidance motives are relatively stable traits (Gable & Gosnell, 2013). In this work, motives are conceptualised as generalised, affectively based motivational tendencies. These are thought to interact with more cognitive expectancies to energise and orient behaviour toward or away from motive-relevant social interaction possibilities (Gable & Prok, 2012). In 1976, Mehrabian suggested that expectancies of positive and negative reinforcers in interpersonal interactions shape approach and avoidance social motivation, respectively.

However, subsequent work has mainly focussed on the affective components driving individual differences in dispositional social motivation, such as hope for affiliation and fear of rejection (Elliot, Gable, & Mapes, 2006). Few studies have looked explicitly at cognitive expectancies of social reward or threat. While cognitive expectancies may include an element of anticipated emotion (Gilbert & Wilson, 2007), the representation of this is thought to be more conceptual, consciously accessible (metacognitive) in nature (Ochsner & Gross, 2014), compared with the emotional experience of hope or fear.

In this chapter I describe the development and validation of a self-report scale designed to measure dispositional, generalised cognitive expectancies of social threat and reward.

4.1.1 Existing self-report measure of social reward and threat expectancies

MacDonald and colleagues have developed a self-report measure of expectations of social reward and threat (MacDonald, Borsook, & Spielmann, 2011; MacDonald, Tackett, & Bakker, 2011; Spielmann, Macdonald, & Tackett, 2011). This measure, the Social Threat and Reward Scales (STARS), is a 10-item inventory examining the extent to which participants expect to experience social reward and social threat during an imminent social encounter with a previously unknown person. The authors conceptualise social reward as "the degree to which the social environment contains signals of the potential to develop intimacy and connection with others" (MacDonald et al., 2011, p. 142). Social threat is defined as "the degree to which the social environment contains signals of the potential for negative evaluation and rejection by others" (MacDonald et al., 2011, p. 142). In the STARS procedure, participants are told that they will meet another participant after completing a questionnaire. Participants then respond to a series of items relating to the anticipated interaction on a 5-point scale (1 = 'strongly disagree' to 5 = 'strongly agree'). There are 5 social reward items (Cronbach's α = .73 in both studies reported by MacDonald, Tackett, et al., 2011), which include statements such as "I will probably like my interaction partner a lot" and "I look forward to sharing things about myself in the interaction". There are also 5 social threat items

(Cronbach's α = .74 and .77 in MacDonald, Tackett, et al.'s (2011) studies), which include such statements as "If I say something dumb during the interaction, it will bother me all day" and "I'm not worried about anything going wrong during the interaction" (reverse coded).

The STARS is the first instrument explicitly designed to measure cognitive expectancies of social reward and punishment/threat. Several existing measures assess constructs related to social punishment expectations, such as rejection sensitivity (Downey & Feldman, 1996) and fear of negative evaluation (Leary, 1983). However, far less research attention has been directed towards the role of social reward expectancies in motivating social behaviour[1]. That this dimension is deserving of greater attention is supported by MacDonald et al.'s program of research, in which they have found that expectations of social reward (connection and intimacy) are often statistically independent of expectations of social threat (concerns about negative evaluation) (MacDonald, Borsook, et al., 2011; MacDonald, Tackett, et al., 2011; Spielmann et al., 2011). Further, MacDonald et al. have found dissociable relationships of social threat and reward expectancies with interpersonal dispositions and traits. In particular, their work has focussed on attachment style. Their research indicates that individuals higher in anxious attachment expect higher levels of social threat in anticipation of meeting a stranger. The association between avoidant attachment and social threat expectancies was not significant (MacDonald, Tackett, et al., 2011). Conversely, higher avoidant attachment was found to be strongly associated with lower levels of social reward expectancies (MacDonald, Tackett, et al., 2011). These effects held when controlling for a host of general motivation and personality variables, including the Big Five and BIS/BAS. Overall, the work by MacDonald et al. provides support for the bi-dimensional model of attachment, and for the view that a similar bi-dimensional model may apply to individuals' sense of belonging (Lavigne, Vallerand, & Crevier-Braud, 2011; MacDonald, Tackett, et al., 2011; Mehrabian, 1994; Mehrabian & Ksionzky, 1974). While some perspectives have construed belongingness as a single continuum

[1] Previous work has investigated related constructs such as hope for affiliation (Elliot, Gable, & Mapes, 2006) and need to belong, but these are not the same thing as social reward *expectancies*. Indeed, there is evidence that the need to belong correlates more strongly with fear of being alone than with perceived social acceptance (Leary, Kelly, Cottrell, & Schreindorfer, 2013).

with exclusion at one endpoint and acceptance at the other (e.g., Buckley, Winkel, & Leary, 2004, as cited in MacDonald, Tackett, et al., 2011), MacDonald et al.'s (2011) work suggests that an absence of perceived social threat or rejection does not necessarily equate to perceived intimacy and acceptance. Therefore, their work is consistent with the view that belongingness may perhaps be better conceptualised as falling along two independent dimensions corresponding to feelings of rejection and acceptance (MacDonald, Tackett, et al., 2011). This is consistent with the work of Lavigne et al. (2011) and with the earlier work by Mehrabian (1994; Mehrabian & Ksionzky, 1974) discussed in Chapter 2.

At the level of neural computation, neuroimaging findings are mixed in that some work indicates a degree of spatial dissociation between regions involved in processing threat versus reward (e.g. Robin & Martin, 2010). However, the results of other studies have suggested that potential punishment (monetary loss) can be encoded by deactivation of regions that are activated by monetary reward (Tom, Fox, Trepel, & Poldrack, 2007). Whether reward and punishment in general are encoded in the same or different ways, and whether social reward and punishment are encoded in the same or different ways to material reward and punishment are open questions. The development of the STARS is an important step towards enabling research that will answer these questions, and MacDonald et al.'s finding of independent expectancies of social reward and social punishment is intriguing.

While it is a validated and important measure, the STARS is nonetheless not ideally suited for the aims of the current project. In MacDonald et al.'s procedure, participants are informed that they will engage in an interaction with another participant after they have completed the questionnaire. Following completion of the questionnaire, participants are told that no interaction will in fact take place, at which point they are debriefed. The problems with this procedure are, first, that the nature of the apparent interaction is very unusual (in a laboratory setting). Participants' expectations of the potential for social reward and threat may not be the same in this scenario as in their real-life social interactions. Another potential problem is that participants in psychology studies, particularly when they are psychology students, are liable to disbelieve experimenters' assertions that they will interact with another participant. This might potentially affect their responses on the STARS questionnaire.

Further, the aim in the present work is to investigate *generalised* expectancies, as discussed in Chapter 2. The upcoming interaction presented in the STARS procedure is quite specific (albeit with a person as yet unknown to the participant). In generating expectancies for a specific anticipated interaction, two main components contribute. These are the individual's generalised dispositional tendencies to expect social threat and/or reward, plus person-specific and situation-specific representations of the likely behaviour of the interaction partner (G. MacDonald, personal communication, 26th May, 2015). STARS scores seem likely to reflect both components. For the purpose of the present research, I aimed to develop a measure tapping mainly into the dispositional component, while not being so general that participants struggle to respond accurately.

4.1.2 Aims of the present research

The aims of the studies presented in this chapter are as follows:

1) To test a slightly modified version of the STARS. This new scale, the LODESTARS (Levels of Dispositional Expectancies for Social Threat and Reward Scale), is designed to measure participants' generalised threat and reward expectancies regarding social encounters. The modifications are also intended to minimise the problems associated with ecological validity and participant belief outlined above.
2) To investigate if and how the LODESTARS is associated with constructs that have been shown to be correlated with STARS scores, including attachment style, rejection sensitivity, behavioural inhibition/responsiveness to punishment, reward responsiveness and self-esteem.

3) To investigate if and how the LODESTARS sub-scales are associated with other cognitive, affective and motivational constructs relating to social behaviour, such as the broad autism phenotype (BAP).

4.2 LODESTARS development

To try to minimise the potential problems associated with ecological validity and belief described above, the STARS was modified to reflect participants' feelings in anticipation of an imagined social event. Participants were presented with a screen on which the following was written:

Please imagine that you have joined a new club or society and that this evening you will be going to a social event organized by this club or society. This is the first time that you will meet other people who are in this club or society. It is best if you choose a club or society that you are not currently a member of in real life, as this will make it easier for you to imagine that you do not yet know anybody in the club/society. It does not have to be a club or society that really exists.

Please note below the name of the club or society that you have chosen: ……………………………………………………………………………………………………

Extensive research has demonstrated very reliable and robust behavioural and BOLD fMRI responses to stories written in the second person, i.e. "you do this, you think that" (Saxe, 2011), indicating that participants are able to respond to imaginary scenarios presented in this way. Participants were required to note their chosen club or society to ensure that they had engaged with the task and generated a mental representation of a social group before proceeding to answer the questionnaire items.

At the bottom of the screen was an instruction to click a button to progress to the following screen and answer the questions presented there. The items in the questionnaire were modified from the original STARS items to relate to meeting several new people in a general social situation, rather than meeting one interaction partner in a psychology lab. The original and adapted STARS items are shown in Table 4.1.

	Original STARS Item	Adapted (LODE)STARS Item
1.	I will probably like my interaction partner a lot.	I will probably meet one or more people who I will like a lot.
2.	If I say something dumb during the interaction, it will bother me all day.	If I say something silly during one of the interactions, it will bother me all evening.
3.	I'm not worried about anything going wrong during the interaction.	I'm not worried about anything going wrong during the interactions.
4.	I look forward to sharing things about myself in the interaction.	I look forward to sharing things about myself in the interactions.
5.	I feel a little anxious about the interaction.	I feel a little anxious about the interactions.
6.	I think I could develop a meaningful connection with my interaction partner.	I think I could develop a meaningful connection with one or more people that I meet this evening.
7.	I am a bit worried about feeling embarrassed during this interaction.	I am a bit worried about feeling embarrassed during these interactions.
8.	I don't expect to get much out of this interaction.	I don't expect to get much out of these interactions.
9.	I'm concerned my partner won't like me very much.	I'm concerned the people I meet won't like me very much.
10.	It will be interesting to learn about my interaction partner.	It will be interesting to learn about the people I will meet and interact with.

Table 4.1: Original and adapted STARS items.

4.3 Study 1A: Comparison of results with those of the original STARS study

Although the LODESTARS is intended to tap dispositional tendencies while the STARS is more situation-specific, work on affective motives suggests that dispositional biases strongly influence more short-term situation-specific motivations, goals and behaviours (Gable, 2006). It was hypothesised that the LODESTARS would have broadly similar psychometric properties to the STARS, and therefore correlate in similar ways with scores derived from other measures. It was predicted that correlations between the LODESTARS sub-scales and attachment style, rejection sensitivity, behavioural inhibition/responsiveness to punishment, reward responsiveness and self-esteem be similar to the findings by MacDonald et al. (2011) shown in Table 4.2.

	STARS reward	STARS threat	BIS	BAS	Anxious Attachment	Avoidant Attachment	Self esteem
STARS threat	-.02						
BIS	-.15*	.41***					
BAS	.23***	-.22**	-.09				
Anxious Attachment	.01	.46***	.50***	.00			
Avoidant Attachment	-.25***	.32***	.24***	-.21**	.36***		
Self esteem	.09	-.45***	-.45***	.25***	-.70***	-.40***	
Rejection Sensitivity	-.02	.24***	.34***	-.13+	.46***	.28***	-.45***

+ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.2: Inter-correlations between variables from Study 1 reported by MacDonald, Tackett, et al. (2011).

4.3.1 Methods

Sixty-one participants (23 male) took part in Study 1A. Please see Chapter 3 for full details of these participants, as well as the measures and procedure employed in the study.

4.3.2 Results

Correlations between all study variables were computed (reported in Table 4.3). Most of the inter-correlations between LODESTARS, rejection sensitivity, self-esteem, BIS, anxious attachment and avoidant attachment are consistent with those found by MacDonald et al. (2011), as shown in Table 4.3.

	Age	LODESTARS Threat	LODESTARS Reward	Rejection Sensitivity	Self esteem	BIS	RR	Anxious Attachment
LODESTARS Threat	-.201							
LODESTARS Reward	.106	-.286* D						
Rejection Sensitivity	-.203	.264* C	-.135 C					
Self esteem	.110	-.536*** C	.119 C	-.311* C				
BIS	-.298*	.635*** C	-.011 D	.255* C	-.474*** C			
RR	.140	.002	.097	-.257*	.176	-.027		
Anxious Attachment	-.151	.569*** C	-.167 C	.061 D	-.603*** C	.495*** C	-.009	
Avoidant Attachment	-.085	.385** C	-.190 D	.003 D	-.490*** C	.344** C	.036	.827*** C

Table 4.3: Inter-correlations between self-report variables in Study 1A: Comparison with results of original STARS study.

* $p < .05$, ** $p < .01$, *** $p < .001$; C: consistent with MacDonald et al.'s findings; D: different from MacDonald et al.'s findings.

4.3.2.1 Gender differences in self-report measures (n = 23 males; 38 females)

Independent-samples *t*-tests revealed significant gender differences in BIS and RR, and the social interactions sub-scales of the BAPQ (i.e. aloof personality and pragmatic language problems). Specifically, female participants, on average, scored higher on the BIS scale (mean 3.33, compared with the mean score for males of 3.01; t (59) = -2.166, p = .034). Female participants also scored higher, on average, on RR (mean 3.42, compared with the mean score for men of 3.06; t (58) = -4.760, p < .001).

Male participants, on average, had higher scores on the aloof personality (mean 2.68 compared with females' mean score of 2.17; t (59) = 2.887, p = .005) and pragmatic language deficits (mean 2.71

compared with females' mean score of 2.38; t (31.326[2]) = 2.305, p = .028) subscales of the BAPQ, but not on the rigid personality subscale. This resulted in higher overall scores for males on average (2.91 compared with females' mean overall score of 2.56; t (59) = 2.519, p = .015).

These gender differences in the scores from the BIS and RR scales replicate those previously found (Gard & Kring, 2007; Jorm et al., 1998), as does the finding that females tend to score lower on measures of autistic spectrum characteristics such as those assessed by the BAPQ (Nishiyama et al., 2013; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010).

4.3.3 Discussion: Comparison of results with those of the original STARS study

Most of the inter-correlations between LODESTARS, rejection sensitivity, self-esteem, BIS, anxious attachment and avoidant attachment are consistent with those found by MacDonald et al. (2011), as shown in Table 4.3. Of the inter-correlations that are different from the findings of MacDonald et al., all but one reflect correlations that were significant in MacDonald et al.'s work but were not found to be significant in the present study. These discrepancies may be due to the fact that MacDonald et al.'s sample sizes were larger (226 in study 1 and 149 in study 2). It is possible that these variables are associated with one another, but not strongly enough to have given rise to significant correlations in the present study of 61 participants. This seems particularly likely for the correlations between attachment style and rejection sensitivity, as the same measures were used. Although MacDonald et al. used the full 18-item version of the rejection sensitivity questionnaire (RSQ), the short version used here simply consists of the 8 items that have the highest factor loadings in the full version. The two versions have been found to have similar psychometric properties (Romero-Canyas et al., 2010), so it seems reasonable to compare MacDonald et al.'s findings with the present results.

[2] Because Levene's test for equality of variances showed that the variances were unequal, so the 'Equal variances not assumed' values are reported.

With regard to the correlations involving the STARS/LODESTARS however, it is possible that the modifications made to the measure have resulted in the LODESTARS having slightly different psychometric properties to the STARS. As can be seen in Table 4.3, most of the correlations between the LODESTARS and other variables are consistent with those found for the STARS (MacDonald, Tackett, et al., 2011). This indicates that the measures have similar psychometric properties. Of the three differences, the correlation between BIS and STARS-reward by MacDonald et al. may not be robust, as they did not replicate that in study 2 of their paper. In both studies, MacDonald et al. did however find very strong negative correlations ($p < .001$) between avoidant attachment style and STARS-reward. There seems no likely theoretical reason why the LODESTARS should be different from the STARS in its association with avoidant attachment, so perhaps the non-significant association found here is due to the relatively small size of the sample.

As noted in Chapter 3, several participants in the present study complained that some of the items in the RR scale were too subjective and/or situation dependent and so either did not answer them (in the case of 2 participants, both of whom did not answer item 5, "When I go after something I use a "no holds barred" approach") or stated that they were not sure about their answers. Cronbach's alpha for the RR scale was .66 for the present sample ('fair' internal consistency, according to the criteria of Ponterotto and Ruckdeschel, 2007, further demonstrating the difficulty participants experienced with this scale. It may be for this reason that the correlations found by MacDonald et al. with the BAS in their study was not observed in the present sample, using the RR. The RR comprises a sub-set of the original BAS items, so in theory should display similar psychometric properties.

The most notable difference between the present results and those of MacDonald et al. is that, in the current study, LODESTARS-threat and LODESTARS-reward are negatively correlated ($r = -.286$, $p = .025$). That is, the higher participants' expectation of social threat, the lower their expectation of social reward. MacDonald et al. (2011) found STARS-threat to be uncorrelated with STARS-reward in both their studies. Possibly the correlation emerged in the present work due to the more ‘real-world’ nature of the LODESTARS compared with the STARS. That is, in day-to-day life, perhaps social threat and social reward expectations are correlated, although in the ‘interaction partner’ context in MacDonald et al.'s lab, they were not. Indeed, MacDonald, Borsook et al. (2011) speculate that, although they found perceptions of social threat and reward potential to be orthogonal in the context of anticipated interactions with strangers, this may not be the case when a known social entity is evaluated. Rejection by a stranger does not lead to a loss of connection (as there is no existing bond), whereas rejection by a friend is associated with a loss of a source of social reward. Although in the LODESTARS context participants are evaluating anticipated interactions with strangers, these are strangers with whom the participant may hope – or even expect – to form bonds, as they are members of a club or society that the participant has chosen to join. The fact that they are considering strangers who are members of a given club or society in itself means that participants completing the LODESTARS have a pre-conception of at least one interest that their potential interaction partners have. This contrasts with the STARS situation, in which participants have no knowledge of any specifics of their interaction partner (MacDonald, Borsook, et al., 2011). Perhaps even this relatively minor distinction of the LODESTARS from the STARS paradigm is sufficient to alter the nature of participants’ expectancies, such that the manifestation of social threat (rejection) would also signify an absence of expected social reward.

4.4 Internal consistency and reliability of the LODESTARS

For the purpose of confirming the internal consistency of the LODESTARS, data were analysed from six of the studies conducted during the PhD project. These were: Study 1A, Pre-test 2012, Study 1B, the Imaging study, Pre-test 2013 and Pre-test 2014 (see Chapter 3 for full methodological details). A total of 848 participants completed the LODESTARS across these 6 studies. Data from the Cyberball study and the Autumn 2014 study were not used for internal consistency analyses, as many of the Cyberball participants also participated in Study 1A or Study 1B, and all participants in the Autumn 2014 study also participated in Pre-test 2014.

To assess the test-retest reliability of the LODESTARS, a sub-set of participants from the Pre-test 2014 study completed the LODESTARS again at later timepoints (as part of the Autumn 2014 study). Of the 204 individuals who participated in Pre-test 2014, 160 completed the LODESTARS a second time. Fifty-seven of these participants completed the LODESTARS a third time; 11 completed the measure a fourth time and 2 completed the measure on a fifth occasion.

4.4.1 Methods: Internal consistency

Before the Imaging study was conducted, a principal-components factor analysis with oblique (direct oblimin) rotation was conducted on the available LODESTARS data. That is, the LODESTARS responses of participants in Study 1A, Pre-test 2012 and Study 1B. Although it was anticipated that the LODESTARS items would give rise to two factors – threat and reward – exploratory factor analysis (EFA) was considered preferable to confirmatory factor analysis (CFA) for this assessment. This is because CFA will not reassign an ill-fitting item to a new factor, whereas EFA will (Streiner & Norman, 2008). Therefore, as an initial test of internal consistency, seeking to demonstrate that the items for each construct load unambiguously on their own factor, EFA is preferable.

Following the subsequent completion of the Imaging study and Pre-tests 2013 and 2014, CFA was conducted on the LODESTARS responses of participants in these studies.

Internal consistency of the LODESTARS sub-scales was also assessed by calculating their Cronbach's alpha values. As these are sample-specific, they are reported for each study separately.

4.4.2 Results: Internal consistency

4.4.2.1 Factor analytic results

Studies 1A, 1B and Pre-test 2012 yielded LODESTARS responses from 392 participants. These were entered into an EFA with direct oblimin rotation, conducted using IBM SPSS Statistics for Windows version 20 (IBM Corp., 2011).

As expected, EFA of participants' responses to the ten LODESTARS items resulted in two factors which had eigenvalues greater than one. Together, these explain 54% of the variance among the scores of these 392 participants (see Fig. 4.1). Inspection of the factor loading matrix (Table 4.4) revealed that the five LODESTARS threat items load on the first factor, while the five reward items load on the second.

Component	Initial Eigenvalues		
	Total	Percent of Variance	Cumulative percent
1	3.683	36.830	36.830
2	1.764	17.642	54.472
3	.833	8.335	62.806
4	.761	7.608	70.415
5	.650	6.497	76.912
6	.560	5.600	82.512
7	.509	5.092	87.604
8	.449	4.495	92.099
9	.410	4.095	96.194
10	.381	3.806	100.000

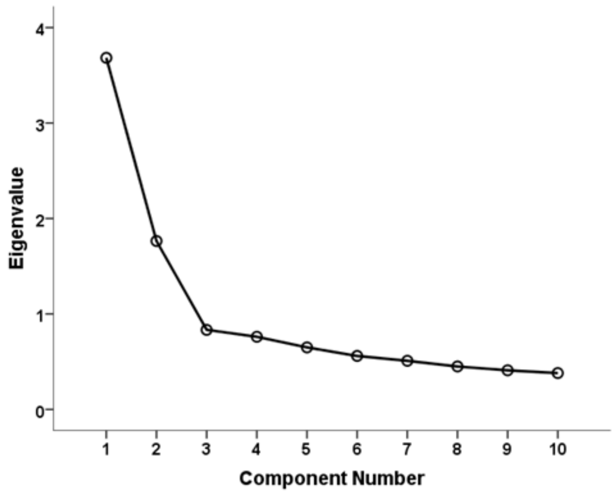

Figure 4.1: Table and Scree plot showing the eigenvalues and variance explained by all factors. The first two factors were extracted, on the criterion that they had eigenvalues greater than 1.

	Component	
	1	2
Q1_Reward		.686
Q2_Threat	.740	
Q3_R_Threat	.701	
Q4_Reward		.554
Q5_Threat	.771	
Q6_Reward		.778
Q7_Threat	.847	
Q8_R_Reward		.763
Q9_Threat	.820	
Q10_Reward		.608

Table 4.4: Rotated factor loading matrix for the LODESTARS. For clarity, small coefficients (< .3) are not displayed.

The Imaging study and Pre-tests 2013 and 2014 yielded LODESTARS responses from 456 participants. To provide further validation of the factor structure of the LODESTARS, these data were used to perform a CFA. The CFA analysis was conducted using a maximum likelihood estimation in SPSS Amos version 20 (Arbuckle, 2011). A two-factor model was tested, based on the factor structure indicated by the earlier EFA (shown in Table 4.4). The two latent factors were allowed to correlate.

This model showed good global fit, χ^2 (34, N = 456) = 61.1, p = .003; CFI = .975; RMSEA = .042.

All factor loadings were above 0.4, and most were above 0.6 (shown in Table 4.5). The two latent factors, corresponding to LODESTARS threat and LODESTARS reward, were significantly negatively correlated with each other, r = -.292, p < .001.

	Factor	
	1: Threat	2: Reward
Q1_Reward		.602
Q2_Threat	.637	
Q3_R_Threat	.670	
Q4_Reward		.467
Q5_Threat	.686	
Q6_Reward		.506
Q7_Threat	.707	
Q8_R_Reward		.655
Q9_Threat	.809	
Q10_Reward		.462

Table 4.5: Rotated factor loading matrix for the LODESTARS. For clarity, small coefficients (< .3) are not displayed.

4.4.2.2 Cronbach's alphas

Cronbach's alphas for the LODESTARS threat and reward scales are reported in Tables 4.6 and 4.7, respectively. The adequacy of these internal consistency alpha coefficients was assessed using the matrix proposed by Ponterotto and Ruckdeschel (2007), which takes into consideration both the length of the scale and the size of the sample tested. The LODESTARS-threat scale appeared to have excellent internal consistency, with alphas ranging from .796 to .887. The internal consistency of the reward scale was less satisfactory, with alphas ranging from .625 to .736.

Tables 4.8 and 4.9 show the item-total statistics for the LODESTARS threat and reward scales, respectively. For both scales and across all samples, all items correlate well with the scale total score. The only exception is the second Reward item (Q4 of the LODESTARS, "I look forward to sharing things about myself in the interactions") in the imaging study, which had an item-total correlation coefficient of .181. However, this item's item-total correlation coefficients were not markedly lower than those of the other Reward items in any of the other samples tested.

All items in both scales appear worthy of retention. There are only six instances where deleting an item would increase Cronbach's alpha (highlighted in red in Tables 4.8 and 4.9). Three of these six instances occur in the Cyberball study data, which is somewhat underpowered with only 28 participants. In these (Cyberball study) data, deleting Threat item Q5 ("I feel a little anxious about the interactions") would increase alpha by .024. Deleting Reward item Q6 ("I think I could develop a meaningful connection with one or more people that I meet this evening") would increase alpha by .014; deleting Reward item Q10 ("It will be interesting to learn about the people I will meet and interact with") would increase alpha by .026. In Study 1A, deleting Reward item Q10 would increase alpha by .018. In Study 1B, deleting Reward item Q4 ("I look forward to sharing things about myself in the interactions") would increase alpha by .006; in the imaging study, deleting this item would increase alpha by .065.

LODESTARS Threat

Study	Cronbach's Alpha	No. of Items	Rating
1A (n = 61)	.832	5	Excellent
Pre-test 2012 (n = 203)	.828	5	Excellent
1B (n = 128)	.852	5	Excellent
Imaging (n = 56)	.887	5	Excellent
Pre-test 2013 (n = 197)	.832	5	Excellent
Cyberball (n = 28)	.816	5	Excellent
Pre-test 2014 (n = 204)	.796	5	Good

Table 4.6: Cronbach's alphas for the LODESTARS threat scale.

LODESTARS Reward

Study	Cronbach's Alpha	No. of Items	Rating
1A (n = 61)	.736	5	Good
Pre-test 2012 (n = 203)	.733	5	Moderate
1B (n = 128)	.683	5	Fair
Imaging (n = 56)	.627	5	Fair
Pre-test 2013 (n = 197)	.695	5	Fair
Cyberball (n = 28)	.646	5	Moderate
Pre-test 2014 (n = 204)	.625	5	Unsatisfactory

Table 4.7: Cronbach's alphas for the LODESTARS reward scale.

LODESTARS Threat

Study		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Exp1A	Q2_Threat	.509	.832
	Q3_R_Threat	.615	.803
	Q5_Threat	.721	.781
	Q7_Threat	.679	.785
	Q9_Threat	.661	.791
Pre-test 2012	Q2_Threat	.598	.802
	Q3_R_Threat	.589	.804
	Q5_Threat	.586	.805
	Q7_Threat	.660	.783
	Q9_Threat	.696	.773
Exp1B	Q2_Threat	.665	.821
	Q3_R_Threat	.573	.844
	Q5_Threat	.669	.820
	Q7_Threat	.740	.800
	Q9_Threat	.671	.819
Imaging	Q2_Threat	.676	.874
	Q3_R_Threat	.640	.881
	Q5_Threat	.714	.865
	Q7_Threat	.760	.854
	Q9_Threat	.841	.834
Pre-test 2013	Q2_Threat	.592	.810
	Q3_R_Threat	.657	.790
	Q5_Threat	.558	.818
	Q7_Threat	.732	.767
	Q9_Threat	.623	.800
Cyberball	Q2_Threat	.823	.705
	Q3_R_Threat	.521	.814
	Q5_Threat	.356	.840
	Q7_Threat	.750	.734
	Q9_Threat	.632	.771
Pre-test 2014	Q2_Threat	.502	.783
	Q3_R_Threat	.529	.772
	Q5_Threat	.621	.748
	Q7_Threat	.680	.724
	Q9_Threat	.576	.758

Table 4.8: Item-total statistics for the LODESTARS threat scale.

LODESTARS Reward

Study		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Exp1A	Q1_Reward	.653	.651
	Q4_Reward	.546	.672
	Q6_Reward	.578	.658
	Q8_R_Reward	.474	.705
	Q10_Reward	.300	.754
Pre-test 2012	Q1_Reward	.395	.722
	Q4_Reward	.466	.707
	Q6_Reward	.651	.626
	Q8_R_Reward	.561	.659
	Q10_Reward	.451	.709
Exp1B	Q1_Reward	.542	.601
	Q4_Reward	.333	.689
	Q6_Reward	.512	.600
	Q8_R_Reward	.529	.589
	Q10_Reward	.326	.676
Imaging	Q1_Reward	.587	.454
	Q4_Reward	.181	.692
	Q6_Reward	.377	.576
	Q8_R_Reward	.500	.529
	Q10_Reward	.351	.590
Pre-test 2013	Q1_Reward	.451	.646
	Q4_Reward	.405	.674
	Q6_Reward	.504	.624
	Q8_R_Reward	.508	.620
	Q10_Reward	.428	.664
Cyberball	Q1_Reward	.736	.471
	Q4_Reward	.356	.643
	Q6_Reward	.273	.660
	Q8_R_Reward	.616	.483
	Q10_Reward	.173	.672
Pre-test 2014	Q1_Reward	.439	.543
	Q4_Reward	.363	.586
	Q6_Reward	.320	.600
	Q8_R_Reward	.493	.508
	Q10_Reward	.298	.608

Table 4.9: Item-total statistics for the LODESTARS reward scale.

4.4.3 Methods: Test-retest reliability

4.4.3.1 Data screening

Before reliability analyses were conducted, the data were screened for outlying scores. Univariate outliers were identified using standard (z) scores. As the sample size is larger than 80, a case was considered an outlier if its standard score was ±3 or beyond. Multivariate outliers were investigated for Time1-Time2 combinations for LODESTARS-Threat and LODESTARS-Reward. Outliers were identified using the probability associated with their Mahalanobis D2. If this probability was 0.001 or less, the case was considered a multivariate outlier.

Data which met the multivariate outlier criterion were removed. In all cases data that met criteria for univariate outliers also met the criterion for multivariate outliers and thus were removed. Data from five participants were excluded from the test-retest analyses, as their LODESTARS-Threat or -Reward scores met the criterion for multivariate outliers. Following the removal of these data, the study yielded data from 155 participants who completed the LODESTARS twice, of whom 54 completed the LODESTARS a third time. Ten of these participants completed the measure a fourth time and 2 completed the LODESTARS on a fifth occasion.

4.4.3.2 Reliability

Test-retest reliability (repeatability) was assessed by calculating the intraclass correlation coefficients (ICCs) for each sub-scale (Threat and Reward) of the responses given at Time 1 and Time 2 (n = 155). Like all correlation coefficients, ICCs are expressed as values that can range from 0 to 1. ICC values closer to 1 indicate greater reliability. An ICC of 1 would indicate perfect reliability, with no measurement error. Measurement error itself can be estimated using the coefficient of variation (CV); lower values indicate less measurement error (Learmonth, Hubbard, McAuley, & Motl, 2014).

CVs were calculated for each participant, using all available data. That is, if a participant completed the LODESTARS on 4 or 5 occasions, all responses were included. Because the CV calculated here is a within-subjects statistic, obtained by calculating the standard deviation of each participant's scores and dividing this by the participant's mean score, the validity of the calculations is not affected by there being more repeated measures for some participants than others. The motivation for computing CVs in addition to ICCs was to interrogate the test-retest repeatability in a way that is independent of between-subjects variation. Although the ICC is the most highly recommended method of assessing test-retest reliability (Rankin & Stokes, 1998; Streiner & Norman, 2008), this coefficient, like all correlation coefficients, is affected not only by the reliability of participants' scores over time, but also by the magnitude of between-subjects variation (Rankin & Stokes, 1998). Thus if a test-retest sample happened to be of a homogeneous group of participants who had very similar scores on a measure, the resulting ICC would be low even if the scores are highly reliable across time, due to the lack of variance between participants. Calculating within-participant CVs provides information that can separate these two sources of influence upon the ICC.

4.4.4 Results: Test-retest reliability

A sample of 155 participants completed the LODESTARS at Time1 (which, for all participants was either the 24th or 25th of September, 2014) and at Time2 (which ranged from 25th October 2014 to 25th November 2014). Of these participants, 140 were female (15 male). Participants' mean age at Time1 was 18.55 (range 17–30; std. dev = 1.35). The mean number of days between test (Time1) and retest (Time2) was 38.56 (range 30–62 days; std. dev = 7.87).

Descriptive statistics for the LODESTARS scores of the sample at Time1 and Time2 are shown in Table 4.10 and Fig. 4.2. As can be seen, the distributions of both threat and reward scores were negatively skewed, but this was more pronounced in the case of the reward scores.

The differences in participants' scores (Time2 - Time1) were also negatively skewed, although less so for the reward scores (see Table 4.11 and Fig. 4.3). There was a significant difference in participants' social reward expectations at Time2 compared with Time1: $t(154) = 6.06$, $p < .001$;

paired-samples. The difference in social threat expectations was not significant: $t(154) = 0.79$, $p = .43$; paired-samples.

	N	Minimum	Maximum	Mean	Std. Deviation	Skew
LODESTARS_Threat_Time1	155	1.4	4.8	3.42	.71	-.23
LODESTARS_Reward_Time1	155	2.6	5.0	3.92	.43	-.25
LODESTARS_Threat_Time2	155	1.0	5.0	3.38	.83	-.22
LODESTARS_Reward_Time2	155	2.6	4.8	3.72	.46	-.41

Table 4.10: Descriptive statistics for the LODESTARS scores of the test-retest sample at Time1 and Time2.

	N	Minimum	Maximum	Mean	Std. Deviation	Skew
Diff in LODESTARS-Threat scores (Time2 - Time1)	155	-1.6	1.2	-.035	.5504	-.265
Diff in LODESTARS-Reward scores (Time2 - Time1)	155	-1.2	.8	-.200	.4109	-.082

Table 4.11: Descriptive statistics for the LODESTARS difference scores of the test-retest sample.

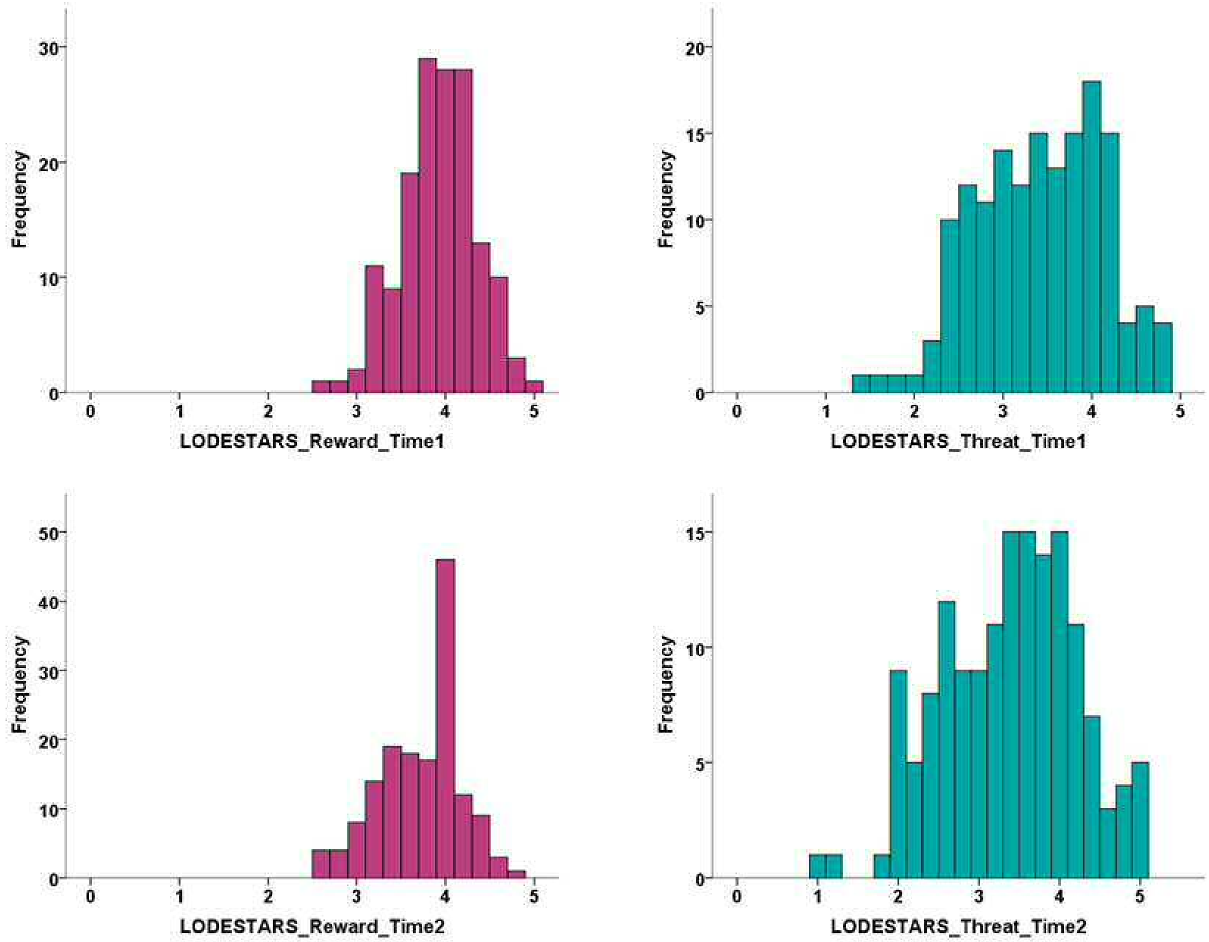

Figure 4.2: Histograms showing the distribution of LODESTARS reward (purple) and threat (blue) scores in the test-retest sample (n = 155) at Time1 and Time2.

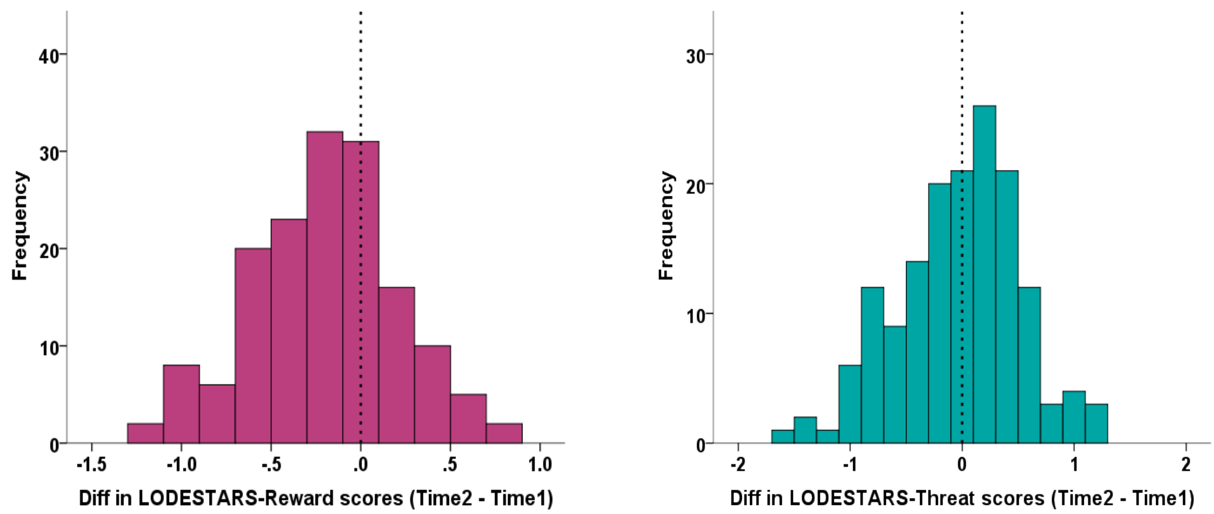

Figure 4.3: Histograms showing the distribution of LODESTARS reward (purple) and threat (blue) difference scores in the test-retest sample (n = 155).

4.4.4.1 Intraclass correlation coefficients (ICCs)

The ICC variant ICC(3,1) (Shrout & Fleiss, 1979)[3] was used and absolute agreement (as opposed to consistency) was assessed. ICC(3,1) denotes that the ICC 'model' is the 3rd one listed by Shrout and Fleiss, in which each participant is assessed by each rater – in this case, scale - and the raters are the only raters of interest. The 'form' of the ICC in this variant is 1, indicating that the reliability is to be calculated on the basis of a single measurement. The LODESTARS is designed as a self-report measure, generally to be completed once by each participant in future studies. Therefore the single measures form of ICC is the appropriate statistic to quantify the reliability of the LODESTARS. Absolute agreement was evaluated because the aim of the analysis was to see how repeatable the LODESTARS scores are over time. Systematic variation between Time1 and Time2 (e.g. if all participants' scores were to increase by 1) does not affect ICCs for consistency, but does impact upon ICCs for absolute agreement.

The ICC for the LODESTARS threat scale between Time1 and Time2 was 0.75, with a 95% confidence interval (CI) of 0.67 – 0.81. The test-retest ICC for the reward scale was 0.53, with a 95% CI of 0.33 – 0.67.

Significance testing of the test-retest ICCs was conducted using *F* tests as described by McGraw and Wong (1996). Using a standard *F* test, the observed value of the ICC can be compared with the expected value of the ICC under the null hypothesis. McGraw and Wong (1996) note that researchers commonly test the hypothesis that the observed ICC is greater than zero. However, this is not very informative in studies of test-retest reliability, as non-zero correlations are expected and assumed (McGraw & Wong, 1996). In this context, it is more useful to determine whether the observed ICC exceeds values corresponding to the small, medium, or large effect size criteria specified by Cohen (1988, as cited in McGraw & Wong, 1996). These are 0.1, 0.3, and 0.5 for small, moderate, and large effect sizes respectively (Field, 2005).

[3] In SPSS this is called a 'two-way mixed' model, with single measures.

Using the above criteria, it was determined that the ICC for the threat scale significantly exceeds 0.5, $p < .001$. The ICC for the reward scale did not significantly exceed 0.5, but was significantly greater than 0.3 ($p = .003$). While these results could have been inferred from the 95% CIs reported above, significance testing in this way enables the definitive statement that, in this sample, the test-retest reliability coefficient of the LODESTARS threat scale was of large effect size, and the reliability of the reward scale was of moderate effect size.

4.4.4.2 Coefficients of variation (CVs)

Within-subjects CVs were calculated by computing the standard deviation of each participant's scores and dividing this by the participant's mean score. The result is multiplied by 100 and expressed as a percentage. The average within-subjects CV for the LODESTARS threat scale across all available timepoints was 10.3%; for the reward scale the average CV was 6.9%. For the threat scale, the individual participants' CVs ranged from 0 (perfect agreement of scores across timepoints) to 36.7%. For the reward scale the CVs ranged from 0 to 25.0%.

4.4.5 <u>Discussion: Internal consistency and test-retest reliability of the LODESTARS</u>

The results presented in this section demonstrate that the LODESTARS has a clear two-factor structure and good test-retest reliability. The threat scale appears to have excellent internal consistency. While the internal consistency of the reward scale was less satisfactory, it was acceptable in all but one of the samples tested, and all items appear worthy of retention. All the reward items load on the reward factor (Table 4.4) and all correlate with the scale total (Table 4.9).

The finding that the reward scale consistently yields lower Cronbach's alphas than the threat scale merits further discussion however. This may have to do with the nature of the scales themselves. The LODESTARS is probably tapping into both cognitive expectations and anticipatory feelings (Gilbert & Wilson, 2007). However there appears to be a systematic distinction between the reward and threat scales, such that the majority of the reward items are more cognitive in nature, while most of the threat items are more affective (depicted in Table 4.12).

Reward Items	
I will probably meet one or more people who I will like a lot.	More cognitive
I think I could develop a meaningful connection with one or more people that I meet this evening.	More cognitive
I look forward to sharing things about myself in the interactions.	
I don't expect to get much out of these interactions. (R)	
It will be interesting to learn about the people I will meet and interact with.	More cognitive
Threat Items	
If I say something silly during one of the interactions, it will bother me all evening.	
I'm not worried about anything going wrong during the interactions. (R)	More affective
I feel a little anxious about the interactions.	More affective
I am a bit worried about feeling embarrassed during these interactions.	More anticipatory affect
I'm concerned the people I meet won't like me very much.	More affective

Table 4.12: Table depicting which of the LODESTARS items appear clearly to be tapping cognitive expectations (highlighted in green) versus anticipatory feelings or affective expectations (highlighted in orange).

The LODESTAR scales might be described as follows: the reward scale is asking participants to what extent they *think* the interactions will go well, whereas the threat scale is asking participants how *worried* they are that things might not go well. This may account for some differences in their psychometric properties. It may be that the threat scale is more internally consistent because people are better at imagining their anticipatory feelings than their cognitive expectations. Or, perhaps worries about social threat are more homogenous across individuals than expectations for social reward.

There is some support in the literature for this second hypothesis, that the experience (and by extension, expectations) of social reward varies substantially in type across individuals. Although there have been relatively few attempts to identify different forms of social reward, and how the value attached to social rewards might vary between individuals, two papers have addressed exactly this question. The first, authored by Hill in 1987, presents a scale, developed on the basis of theory, that is designed to measure four dimensions assumed to underlie affiliation motivation. These are: positive stimulation, attention, social comparison, and emotional support (Hill, 1987). Hill defines positive stimulation as “the ability of affiliation to provide enjoyable affective and cognitive stimulation” (p. 1009). Attention is defined as “the potential for enhancement of feelings of self-worth and importance through praise and the focusing of others' attention on oneself” (p. 1009). Social comparison is considered to be “the capacity for reduction of ambiguity through the acquisition of self-relevant information” (p.1009) while emotional support is derived from the “reduction of negative affect through social contact” (p. 1009).

Hill (1987) found factor-analytic support for his four-dimensional model using his interpersonal orientation scale (IOS). In the present work, Hill’s IOS was administered to 128 participants as part of Study 1B (see Chapter 3 for full methodological details). A principal-components factor analysis with orthogonal (varimax) rotation of the responses of the 128 participants to the IOS was conducted. The results, shown in Table 4.13, broadly support factors corresponding to emotional support (component 1), positive stimulation (component 2), and attention (component 3). However, this present analysis resulted in the extraction of 5, rather than 4, factors, and there was no factor that clearly corresponded to the dimension of social comparison. These details notwithstanding, the data do support the general point that the tendency of humans to seek out social interactions as a source of reward may arise as a result of different underlying motivations or desired results of interpersonal interactions.

	Component				
	1	2	3	4	5
Q1_Emo_sup	.689			.304	.335
Q2_Soc_comp				.530	.455
Q3_Pos_stim	.413	.481			.353
Q4_Emo_sup	.798				
Q5_Att			.381		.634
Q6_Pos_stim		.543			.399
Q7_Soc_comp			.357	.672	
Q8_Att			.660		
Q9_Emo_sup	.640			.312	
Q10_Pos_stim		.819			
Q11_Pos_stim		.739			
Q12_Soc_comp				.730	
Q13_Pos_stim		.506		.428	.348
Q14_Soc_comp				.709	
Q15_Emo_sup	.702			.424	
Q16_Att			.739		.368
Q17_Emo_sup	.790				
Q18_Soc_comp			.629	.483	
Q19_Att			.650		.371
Q20_Pos_stim				.365	.718
Q21_Att			.731		
Q22_Att			.755		
Q23_Emo_sup	.825				
Q24_Pos_stim	.364	.752			
Q25_Pos_stim		.301		.301	.554
Q26_Pos_stim		.648			

Table 4.13: Rotated factor loading matrix for the Interpersonal Orientation Scale. For clarity, small coefficients (< .3) are not displayed. Loadings of the emotional support items are highlighted in purple; loadings of the social comparison items in pink; loadings of the positive stimulation items are highlighted in blue, and the attention items' loadings are highlighted in green.

A different approach was taken by Foulkes, Viding, McCrory, and Neumann (2014). These researchers reviewed theoretical and empirical literature which either explicitly discussed social reward or which assessed related constructs (such as social goals). Through this process, 19 potential categories of social reward were identified. Questionnaire items were then generated to reflect these. Following completion of this initial questionnaire by 305 participants, exploratory factor analysis (EFA) was conducted to identify the latent structure of the item set. Informed by this, a refined questionnaire was created and administered to a second sample of participants.

Confirmatory factor analysis was conducted, along with assessment of construct validity. Overall, this work supported a six-factor model of social reward, that is, that there exist six categories of social rewards which individuals may seek out and derive from social interactions. These are described in Table 4.14.

Name of factor	Description	Example item
Admiration	Being flattered, liked and gaining positive attention	*"I enjoy achieving recognition from others"*
Negative Social Potency	Being cruel, callous and using others for personal gains	*"I enjoy embarrassing others"*
Passivity	Giving others control and allowing them to make decisions	*"I enjoy following someone else's rules"*
Prosocial Interactions	Having kind, reciprocal relationships	*"I enjoy treating others fairly"*
Sexual Relationships	Having frequent sexual experiences	*"I enjoy having an active sex life"*
Sociability	Engaging in group interactions	*"I enjoy going to parties"*

Table 4.14: Description of factors identified via EFA in Foulkes et al.'s (2014) study. From Foulkes et al. (2014), p. 3.

Again, the work conducted by Foulkes et al. (2014) supports the hypothesis that humans pursue and experience several different types of social reward or desired outcomes of interpersonal interactions. Inter-individual differences in the value attached to different types of social reward may account for the relatively low internal consistency coefficients found for the LODESTARS reward scale. The STARS/LODESTARS reward items are designed to tap expectations of social reward in terms of "the potential to develop intimacy and connection with others" (MacDonald, Borsook, et al., 2011, p. 42). Nonetheless, in light of the findings of Hill (1987) and Foulkes et al. (2014), it is possible that different participants might interpret some of the items of the LODESTARS reward scale in different ways, depending on their personal preferences or emphasis placed on different forms of social reward. For instance, participants might agree strongly with the item "I look forward to sharing things about myself in the interactions" because they see this as a mechanism for establishing intimacy and connection with a social partner. However, they may also agree strongly with this item if they see it as reflecting an opportunity to evoke admiration in others, or to otherwise gain the attention of others. Heterogeneity of reasons why participants might agree or disagree with items of the LODESTARS could account for the relatively low internal consistency found for this scale.

If the lower internal consistency coefficients for the LODESTARS reward scale are indeed due to heterogeneity of social reward preferences and expectations across individuals, then it follows that the higher internal consistency of the LODESTARS threat scale must be due to this scale tapping worries about social threat that are relatively homogenous across individuals. That this is the case is supported by the fact that social anxiety revolves around the conceptualisation of social threat as the potential for negative evaluation and/or rejection by others. The complete range of potential social threats appears capable of being captured in a single sentence within the DSM-5 criteria for social anxiety: "The individual fears that he or she will act in a way or show anxiety symptoms that will be negatively evaluated (i.e., will be humiliating or embarrassing; will lead to rejection or offend others)." (American Psychiatric Association, 2013). This lends support to the hypothesis that social threat is a relatively homogenous construct compared with social reward, and that social threat may be conceptualised in a similar way by most individuals. The LODESTARS-threat scale specifically measures fear of negative evaluation. Although other dimensions of social anxiety are present in clinical manifestations of this condition (namely fear of physical symptoms and fear of uncertainty in social situations; Campbell-Sills, Espejo, Ayers, Roy-Byrne, & Stein, 2015) these appear to be more specific to clinical extremes of social anxiety and are unlikely to be present in healthy individuals. The LODESTARS is not intended to measure clinical social anxiety, so the operationalization of expectancies of social threat as concerning the potential for negative evaluation seems appropriate.

In terms of test-retest reliability, the observed ICCs appear to show that the threat scale is more reliable over time. However, the average within-subject CVs suggest the opposite: the lower average CV for the reward scale (6.9% compared with 10.3% for the threat scale) suggests that there was less measurement error associated with the reward scale, which should correspond with greater repeatability. It may be the case that the ICC for the threat scale is inflated compared to that for the reward scale due to the greater spread of the threat expectancy scores. As can be seen in Table 4.10 and Fig. 4.2, the threat scale yielded a broader range and dispersion of scores at both Time1 and Time2 (std. deviations of .71 and .83 respectively for the threat scale, compared with .43 and .46 for the reward scale). As discussed in section 4.4.3.2, ICCs are affected by the magnitude of between-subjects variation as well as the repeatability of the measure being assessed.

It is difficult to categorically quantify the adequacy of test-retest reliability coefficients. Not only is the observed reliability affected by between-subjects variation and sample size, but also by the very nature of the construct being measured. Scales measuring relatively stable traits, such as extraversion, have test-retest coefficients ranging from the high .70s to low .80s when re-administered within the same year (Streiner & Norman, 2008). IQ tests have higher reliability coefficients, while measures of more variable psychological states, such as anxiety, have coefficients that are lower than trait measures (Streiner & Norman, 2008). However, according to the commonly used guidelines suggested by Cicchetti (2001), ICCs of < .41 can be classified as poor; ICCs between .41 and .59 are considered fair; ICCs between .60 and .74 are classified as good, and ICCs of >.74 as excellent.

Using the above rules of thumb, it appears that the LODESTARS threat scale, which yielded a test-retest ICC of .75 in the current study, has excellent reliability, approaching the levels observed in measures of stable traits such as extraversion. The LODESTARS reward scale yielded a test-retest ICC of .53 (fair) and appears more similar, on the basis of this metric, to scales measuring variable psychological states, as opposed to stable traits. These interpretations of the ICCs are to be treated with caution however; as noted earlier it seems likely that the reward ICC was lowered in this sample due to the relative homogeneity of the scores compared with the threat scores.

The within-subject CVs were on average lower for the reward scale than the threat scale (6.9% and 10.3% respectively) indicating that the reward scores were on average closer to one another, when taken across all available time points, than the threat scores. CVs of less than 12% are generally considered good (e.g. Miller, Cohen, & Kim, 2002; Wrosch, Miller, Scheier, & Pontet, 2007) so by this classification both the LODESTAR scales exhibited good test-retest reliability.

Taking both the ICCs and CVs into consideration, as well as the distributions of the underlying scores, it appears that both the threat and reward LODESTAR scales exhibit robust test-retest reliability.

4.4.5.1 Limitations

It is worth noting that the participants in the test-retest study were first-year students in their first few weeks at university. For the vast majority of students, this is a time characterised by marked and rapid changes in their social networks (Paul & Brier, 2001). Many new university students live away from their parental home for the first time during the first term of university. This entails the renegotiation of family relationships and relationships with pre-university friends, as well as the establishment of new friendships at university (Paul & Brier, 2001). Life transitions such as moving away to university are associated with heightened development and change in factors such as identity and individuation, while simultaneously increasing the potential for self-doubt and disappointment if expectations are not met (Ethier & Deaux, 1994; Paul & Brier, 2001).

It is likely that the new students who formed the test-retest sample had expectations of university life which they formed before the term commenced. Kantanis (2000) found that the two most common expectations of first-year students prior to commencement of university were “meeting new and different people” and “having fun” (p.101). Time1 of the test-retest study (Pre-test 2014) was during the participants’ induction week. Thus their responses to the LODESTARS at this time may have been partially influenced by their social expectations of university life. In a follow-up survey, Kantanis (2000) found that 69.6% of her sample reported that less than half their expectations had been met, the main factor being that "making friends had proved to be difficult" (p. 102). Nearly half (49.1%). of Kantanis' respondents had not experienced success in establishing a friendship group by the end of their first semester. If Kantanis' findings are general to most first-semester students, then such high social expectations – which are not necessarily met within the first few weeks at university – may account for the decrease in social reward expectations reported by the majority of participants in the present study at Time2 compared with Time1.

4.5 LODESTARS reward and threat correlations

It was noted in Study 1A that the social reward expectancies as measured by the LODESTARS correlated negatively with LODESTARS threat expectancies. This finding was replicated in each of the following 7 studies, as shown in Table 4.15.

Sample	**N**	**LODESTARS Reward correlation with LODESTARS Threat**
Study 1A	61	-.286* (*p* = .025)
Pre-test 2012	203	-.395*** (*p* < .001)
Study 1B	128	-.342*** (*p* < .001)
Imaging	56	-.347** (*p* = .009)
Pre-test 2013	197	-.261*** (*p* < .001)
Cyberball	28	-.453** (*p* = .016)
Pre-test 2014	204	-.196** (*p* = .005)
Autumn 2014	168	-.353*** (*p* < .001)

Table 4.15: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores across all samples.

4.6 Construct validity of the LODESTARS

Dispositional, generalised expectancies of social threat and reward are thought to constitute an important cognitive component of personality traits and dispositions relating to social behaviour, such as attachment style and extraversion. A valid measure of dispositional social expectancies should therefore demonstrate how the constructs of dispositional social threat and reward expectancies relate to other cognitive, affective and behavioural constructs in a nomological network (Cronbach & Meehl, 1955). The broader nomological network surrounding the LODESTARS constructs is examined in this section.

4.6.1 Methods

Six studies examined the construct validity of the LODESTARS. These are referred to as: Study 1A, Pre-test 2012, Study 1B, the Imaging study, the Cyberball study, and the Autumn 2014 study. Participants in these studies completed a set of self-report measures tapping constructs relating to social behaviour. See Table 3.2 for a full list of which measures were administered in which studies. Full inter-correlations tables for all variables in each study can be found in Appendix 3. Gender differences were observed in many of the measures; therefore all results are reported separately for males and females in this section. See Table 3.1 for demographic details of the participant samples in each study. As the subscales of the LODESTARS were correlated across all samples, partial correlations (LODESTARS-threat controlling for reward and LODESTARS-reward controlling for threat) are reported in addition to zero-order correlations for all analyses.

4.6.1.1 LODESTARS associations with measures of social motivation, affiliative traits and tendencies

The first question addressed is how dispositional social threat and reward expectancies relate to motivations to affiliate with others. Individuals who generally expect to derive a high degree of reward from social interactions will presumably be more motivated to engage in social activities and affiliation. Conversely individuals with high expectancies of social threat may hesitate to interact with others due to concerns about potential rejection. To assess these predictions, correlations between the LODESTARS and measures of constructs relating to tendencies to desire and enjoy the company of others were examined. The following measures were administered (see Chapter 3 for details):

- BAPQ Aloof – measuring (lack of) interest in or enjoyment of social interaction.
- Friendship Approach Goals – measuring goals focussing on positive interpersonal possibilities in the context of the participants' friendships.
- Interpersonal Orientation: Emotional support – measuring tendencies to seek social contact as a means of reducing negative affect.
- Interpersonal Orientation: Attention – measuring desire to enhance feelings of self-worth through the focussing of others' attention on oneself.
- Interpersonal Orientation: Positive stimulation – measuring tendencies to seek social interaction as a source of enjoyable affective and cognitive stimulation.
- Interpersonal Orientation: Social comparison – measuring tendencies to seek social interaction as a means to reduce ambiguity through acquisition of self-relevant information.

4.6.1.2 LODESTARS associations with measures of self-concept, attachment and concerns about rejection

MacDonald et al.'s work suggests that attachment-related anxiety and rejection sensitivity are associated with heightened social threat perceptions, while attachment-related avoidance is related to low expectations of social reward (MacDonald, Borsook, et al., 2011; MacDonald, Tackett, et al., 2011; Spielmann et al., 2011). Similar associations were found using the LODESTARS in Study 1A. To further investigate the discriminant validity of the LODESTARS with respect to anxiety versus avoidance-related social concerns, the following measures were administered:

- Adult Attachment Style Questionnaire – measuring the two attachment dimensions of anxious and avoidant attachment in adults.

- Need to Belong Scale (NTBS) – measuring individual differences in the need to belong, characterized by needs for acceptance and the physical presence of others.
- Rejection Sensitivity Questionnaire, short form – measuring the extent to which individuals expect rejection and are anxious about it.
- Rosenberg self-esteem scale – measuring valence (positivity or negativity) of global self-evaluations.
- Propensity for Hurt Feelings scale – measuring how easily respondents' feelings are hurt.
- Brief fear of negative evaluations scale – measuring the extent to which respondents experience apprehension about potentially being evaluated negatively by others.
- Friendship Avoidance Goals – measuring goals focussing on avoiding negative possibilities in the context of respondents' friendships.

Reactivity to social rejection was also assessed using the Cyberball paradigm, which yielded responses to the Post-Cyberball Needs-Threat Scale (NTS). The NTS measures the extent to which participants felt their social needs (belongingness, control, self-esteem, and meaningful existence) were threatened during the Cyberball game. Following the Cyberball social exclusion experience, participants also rated their level of agreement with manipulation check statements ("I was ignored" and "I was excluded") to confirm their perception of their inclusionary status. Responses to these items are also considered here, along with responses to the ancillary affective variables ("I felt angry during the Cyberball game" and "I enjoyed playing the Cyberball game").

4.6.1.3 LODESTARS associations with the Big Five

Many personality and individual differences researchers suggest that the construct validation of any measure should include reference to its relationships with the Big Five personality trait variables: extraversion, neuroticism, agreeableness, conscientiousness, and openness to experience. It is important to understand how any dispositional tendency, including dispositional expectancies, relates to these basic dimensions of personality. Further, during the construct validation of a new measure, it is important to demonstrate that it is not redundant with one of the Big Five (Leary, Kelly, Cottrell, & Schreindorfer, 2013). The Big Five Inventory (BFI; John & Srivastava, 1999) was therefore administered in three of the studies reported here (see Chapter 3 for details).

4.6.1.4 LODESTARS associations with measures tapping affective dispositions

Broad affective tendencies, such as generalised positivity, negativity or anxiety, are hypothesised to relate to generalised valenced social expectancies. Higher levels of generalised negativity, anxiety and stress reactivity are predicted to relate to greater dispositional tendencies to expect social threat, while lower generalised negative affect and higher generalised positive affect is predicted to relate to higher social reward expectancies. The following measures were administered to enable assessment of these predictions:

- The Behavioural Inhibition System (BIS) and Reward Responsiveness (RR) Scales – measuring tendencies to experience avoidant motivation and appetitive motivation, respectively.
- Anxiety Depression Distress Inventory-27 (ADDI-27) – measuring (low) positive affect (indicative of depression), somatic anxiety (indicative of anxiety), and general distress (symptoms common to both anxiety and depression).
- Perceived Stress Reactivity Scale – measuring prolonged reactivity (difficulty in relaxing/unwinding after experiencing a high workload), reactivity to work overload, reactivity to social conflict, reactivity to failure, and reactivity to social evaluation, as well as overall perceived stress reactivity (sum of the five sub-scale scores).

4.6.1.5 LODESTARS associations with measures of social integration and perceived belonging

It is suggested in this thesis that dispositional expectancies represent a pivotal cognitive component in determining social integration outcomes such as loneliness and satisfaction with social bonds. Expectancies and outcomes are separated by two stages (motivation and behaviour) in the proposed model. Nonetheless, if the model is correct then expectancies should be associated – to some extent at least – with social outcomes. It may be the case that individuals who expect greater levels of social reward attend more social events. Further, interpersonal behaviour during interactions may be influenced by expectancies. For example, individuals with high expectancies of social threat may seek to avoid self-disclosure during social encounters, for fear of being negatively evaluated. Conversely, individuals who expect interpersonal connection may be more likely to offer personal information about themselves and to ask questions that encourage greater self-disclosure in their interaction partners, thus promoting intimacy (MacDonald, Borsook, et al., 2011). Frequently experiencing positive social interactions and attaining a sense of belonging will presumably feed back into an individual's expectancies, encouraging them to expect future social encounters to be rewarding. It is hypothesised, therefore, that individuals with higher social reward expectancies and/or lower social threat expectancies will have more extensive social networks and greater sense of belonging than individuals with low reward and/or high threat expectancies. The following measures were used to test these predictions:

- Social Network Index (SNI): Number of people in social network – measuring the number of people that the respondent sees or talks to on the phone at least once every two weeks.
- General Belongingness Scale – measuring respondents' subjective sense of belonging with other people broadly, and with friends and family.

4.6.1.6 LODESTARS associations with measures of interpersonal attitudes and impulsivity

It is possible that the LODESTARS may tap aspects of delaying gratification ability and level of concern about the future. Individual differences in focus on the future may therefore constitute part of the variance captured by LODESTARS scores. For instance, the reward item, "I think I could develop a meaningful connection with one or more people that I meet this evening" may resonate particularly with individuals who have a high propensity to imagine positive future scenarios and engage in gratification delay (Peters & Büchel, 2010). Conversely, individuals who exhibit a relative lack of concern with the future (e.g. those high in primary or secondary psychopathy) may also be relatively unconcerned about the potential to form bonds or to be rejected in future social scenarios. To explore these possibilities, the following measures were administered (see Chapter 3 for details):

- Delaying Gratification Index (DGI), social interactions subscale – measuring tendencies to engage in prosocial self-control during social interactions.
- Primary psychopathy scale – measuring inclination to lie, lack of remorse, callousness, and manipulativeness.
- Secondary psychopathy scale – measuring impulsivity, tolerance of frustration, quick temperedness, and lack of long-term goals.
- BAPQ Rigid – measuring (lack of) interest in change or difficulty adjusting to change.
- UPPS Impulsive Behaviour scale – measuring tendencies to impulsivity across the dimensions of urgency, (lack of) perseverance (also known as self-discipline), (lack of) premeditation (also known as deliberation), and sensation seeking.

4.6.2 Results

Results (Pearson's *r* correlations coefficients) for all analyses conducted are reported in Tables 4.16 – 4.24.

4.6.2.1 Measures of social motivation, affiliative traits and tendencies

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
BAPQ Aloof	Study 1A males	23	.251	-.256	.236	-.241
	Study 1A females	38	.465**	-.390*	.364*	-.248
	Study 1B males	64	.327**	-.463***	.225	-.406**
	Study 1B females	64	.547***	-.695***	.416**	-.624***
	Imaging (females)	56	.502***	-.343**	.434**	-.208

	Autumn 2014 males	18	-.036	.028	-.038	.031
	Autumn 2014 females	150	.486***	-.592***	.326***	-.490***
Friendship Approach Goals	Study 1B males	64	-.190	.540***	-.038	.516***
	Study 1B females	64	.014	.455***	.234	.500***
	Autumn 2014 males	18	.081	.154	.069	.148
	Autumn 2014 females	150	-.082	.400***	.102	.404***
Interpersonal Orientation: Emotional support	Study 1B males	64	.109	.247*	.196	.294*
	Study 1B females	64	-.045	.326**	.095	.336**
Interpersonal Orientation: Attention	Study 1B males	64	.329**	.032	.354**	.143
	Study 1B females	64	.217	.240	.347**	.361**
Interpersonal Orientation: Positive stimulation	Study 1B males	64	.081	.267*	.174	.305*
	Study 1B females	64	.188	.349**	.377**	.468***
Interpersonal Orientation: Social comparison	Study 1B males	64	.204	.128	.255*	.201
	Study 1B females	64	.238	.297*	.402**	.436***

Table 4.16: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and measures of social motivation, affiliative traits and tendencies.
* $p < .05$, ** $p < .01$, *** $p < .001$

It was noted that scores on the 'aloof personality' sub-scale of the BAPQ were negatively correlated with reward expectancies and positively correlated with threat expectancies in several of the samples examined (Table 4.16). However, as the aloof sub-scale of the BAPQ is correlated with the other two sub-scales, it is possible that some of these associations arose spuriously, driven by the other sub-scales. Therefore partial correlations of the LODESTARS with BAPQ-aloof scores controlling for the other BAPQ sub-scales were examined. These supplementary results are reported in Table 4.17.

Measure	Sample	N	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
BAPQ Aloof ct. for BAPQ Rigid & BAPQ Prag. lang.	Study 1A males	23	.018	-.074
	Study 1A females	38	.332	-.310
	Study 1B males	64	.021	-.313*
	Study 1B females	64	.169	-.583***
	Imaging (females)	56	.229	-.201
	Autumn 2014 males	18	-.420	-.024
	Autumn 2014 females	150	.174*	-.447***

Table 4.17: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and BAP-aloof, controlling for BAP-rigid and BAP-pragmatic language difficulties.
* $p < .05$, ** $p < .01$, *** $p < .001$

4.6.2.2 Measures of self-concept, attachment and concerns about rejection

Avoidant and anxious attachment tendencies are correlated (as depicted in Fig. 2.3 and shown in Appendix 3) so partial correlations (anx_att controlling for av_att and av_att controlling for anx_att) are reported in addition to zero-order correlations.

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
Anx_att	Study 1A males	23	.627**	-.272	.628**	-.275
	Study 1A females	38	.539***	-.144	.532**	.099
	Study 1B males	64	.561***	-.165	.544***	.001
	Study 1B females	64	.720***	-.301*	.686***	-.031
	Imaging (females)	56	.724***	-.315*	.691***	-.098
	Autumn 2014 males	18	.740***	-.033	.746**	-.139

	Autumn 2014 females	150	.697***	-.401***	.636***	-.169*
Anx_att ct. for Av_att	Study 1A males	23	.550**	-.306	.569**	-.348
	Study 1A females	38	.468**	.040	.519**	.256
	Study 1B males	64	.561***	-.069	.568***	.126
	Study 1B females	64	.675***	-.152	.668***	.081
	Imaging (females)	56	.650***	-.060	.650***	.072
	Autumn 2014 males	18	.571*	-.282	.594*	-.340
	Autumn 2014 females	150	.586***	-.121	.578***	.023
Av_att	Study 1A males	23	.453*	-.150	.446*	-.122
	Study 1A females	38	.343*	-.209	.289	-.081
	Study 1B males	64	.068	-.492***	-.092	-.495***
	Study 1B females	64	.341**	-.347**	.239	-.246
	Imaging (females)	56	.423**	-.491***	.310*	-.405**
	Autumn 2014 males	18	.580*	.146	.576*	.122
	Autumn 2014 females	150	.468***	-.504***	.328***	-.384***
Av_att ct. for Anx_att	Study 1A males	23	-.296	.209	-.326	.252
	Study 1A females	38	-.170	-.159	-.257	-.250
	Study 1B males	64	-.065	-.474***	-.214	-.507***
	Study 1B females	64	-.052	-.234	-.121	-.257*
	Imaging (females)	56	.041	-.401**	-.036	-.400**

	Autumn 2014 males	18	-.098	.313	-.156	.334
	Autumn 2014 females	150	.045	-.352***	-.031	-.351***
Need to belong	Pre-test 2012 males	21	.498*	-.148	.481*	-.038
	Pre-test 2012 females	179	.375***	.009	.413***	.188*
Rejection sensitivity - brief	Study 1A males	23	.078	-.206	.061	-.201
	Study 1A females	38	.377*	-.089	.375*	.076
Rosenberg self esteem	Study 1A males	23	-.342	-.011	-.345	-.046
	Study 1A females	38	-.640***	.205	-.623***	-.080
	Imaging (females)	55	-.658***	.214	-.637***	-.017
Propensity for Hurt Feelings	Cyberball (females)	28	.451*	-.196	.414*	.010
Fear of Negative Evaluations	Study 1B males	64	.516***	-.148	.500***	.005
	Study 1B females	64	.657***	-.214	.638***	.062
Friendship Avoidance Goals	Study 1B males	64	.258*	-.048	.256*	.030
	Study 1B females	64	.310*	.136	.398**	.294*
	Autumn 2014 males	18	.099	-.147	112	-.156
	Autumn 2014 females	150	.152	.064	.197*	.142

Table 4.18: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and measures of self-concept, attachment and concerns about rejection.
* $p < .05$, ** $p < .01$, *** $p < .001$

Measure	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
Enjoyed game	14	-.335	.308	-.242	.201
Felt angry during game	14	.434	-.404	.324	-.278
NT Belongingness	14	-.524*	.486	-.411	.353
NT Control	14	-.560*	-.050	-.634*	-.362
NT Self-Esteem	14	-.778**	.438	-.732**	.218
NT Meaningful Existence	14	-.691**	.075	-.724**	-.307
Ignored	14	.732**	-.266	.708**	.045
Excluded	14	.709**	-.471	.644*	-.288

Table 4.19: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and post-Cyberball manipulation check and Needs-Threat Scale (NTS) responses.
* $p < .05$, ** $p < .01$, *** $p < .001$

4.6.2.3 The Big Five

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
Extraversion	Cyberball (females)	23	-.655**	.487*	-.550**	.260
	Study 1B males	64	-.430***	.311*	-.373**	.214
	Study 1B females	64	-.465***	.576***	-.319*	.484***
	Autumn 2014 males	18	-.322	.098	-.332	.131
	Autumn 2014 females	150	-.474***	.429***	-.360***	.288***
Agreeableness	Cyberball (females)	23	.270	.277	.478*	.481*
	Study 1B males	64	-.021	.226	.049	.230
	Study 1B females	64	-.062	.320**	.073	.322**
	Autumn 2014 males	18	-.084	.098	-.092	.106
	Autumn 2014 females	150	-.184*	.273**	-.080	.220**

Conscientiousness	Cyberball (females)	23	-.084	.218	.024	.203
	Study 1B males	64	-.217	-.100	-.259*	-.176
	Study 1B females	64	-.148	.244	-.059	.205
	Autumn 2014 males	18	-.073	-.095	-.066	-.089
	Autumn 2014 females	150	-.184**	.143	-.138	.074
Neuroticism	Cyberball (females)	23	.628**	-.560**	.495*	-.380
	Study 1B males	64	.257*	-.266*	.194	-.206
	Study 1B females	64	.567***	-.336**	.503***	-.151
	Autumn 2014 males	18	.601**	-.140	.620**	-.237
	Autumn 2014 females	150	.525***	-.359***	.442***	-.180*
Openness	Cyberball (females)	23	.152	.336	.378	.471*
	Study 1B males	64	-.320*	.259*	-.264*	.182
	Study 1B females	64	-.018	.107	.027	.109
	Autumn 2014 males	18	.007	.008	.006	.007
	Autumn 2014 females	150	-.036	.028	-.027	.015

Table 4.20: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and the Big Five personality variables.
* $p < .05$, ** $p < .01$, *** $p < .001$

4.6.2.4 Measures tapping affective dispositions

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
BIS	Study 1A males	23	.706***	.033	.711***	.118
	Study 1A females	38	.650***	-.159	.649***	.152
	Study 1B males	64	.372**	-.426***	.286*	-.356**
	Study 1B females	64	.522***	-.064	.542***	.179
	Imaging (females)	56	.550***	-.174	.530***	.019
RR	Study 1A males	23	-.082	-.071	-.088	-.078
	Study 1A females	38	.060	-.004	.064	.022
	Imaging (females)	55	-.235	.126	-.206	.050
ADDI-27 Pos. Affect	Imaging (females)	56	-.355**	.178	-.318*	.064
ADDI-27 Gen Distress	Imaging (females)	56	.543***	-.221	.510***	-.044
ADDI-27 Somatic Anx	Imaging (females)	56	.241	-.038	.243	.049
Prolonged Reactivity	Imaging (females)	55	.239	-.114	.214	-.035
Reactivity to Work Overload	Imaging (females)	55	.471***	-.064	.479***	.119
Reactivity to Social Conflict	Imaging (females)	55	.276*	-.286*	.197	-.212
Reactivity to Failure	Imaging (females)	55	.325*	-.274*	.256	-.183
Reactivity to Social Evaluation	Imaging (females)	55	.767***	-.164	.767***	.164
Perceived Stress Reactivity total score	Imaging (females)	55	.612***	-.235	.583***	-.033

Table 4.21: Correlations (Pearson's r) between LODESTARS-threat and LODESTARS-reward expectancy scores and measures tapping affective dispositions.
* $p < .05$, ** $p < .01$, *** $p < .001$

4.6.2.5 Measures of social integration and perceived belonging

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
SNI: Number in social network	Study 1B males	63	-.255*	.378**	-.167	.329**
	Study 1B females	26	-.102	.243	-.066	.230
	Imaging (females)	56	-.131	.075	-.113	.031
	Cyberball (females)	28	-.136	.423*	.068	.409*
	Autumn 2014 males	18	.064	-.139	.076	-.145
	Autumn 2014 females	150	-.086	.046	-.073	.012
GBS General Belongingness	Study 1B males	64	-.379**	.314*	-.318*	.233
	Study 1B females	64	-.485*	.220	-.466*	.164

Table 4.22: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and measures of social integration and perceived belonging.
* $p < .05$, ** $p < .01$, *** $p < .001$

4.6.2.6 Measures of interpersonal attitudes and impulsivity

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
DGI Social Interactions	Study 1A males	11	.166	.308	.345	.424
	Study 1A females	18	.121	-.305	-.098	-.297
	Study 1B males	64	.034	.131	.076	.148
	Study 1B females	63	.082	.108	.137	.154
	Imaging (females)	56	-.046	.282*	.057	.284*
Primary Psychopathy	Study 1B males	64	-.131	-.119	-.175	-.166
	Study 1B females	64	.017	-.009	.015	-.002
Secondary Psychopathy	Study 1B males	64	.146	.149	.201	.203
	Study 1B females	64	.224	-.013	.238	.083
BAPQ Rigid	Study 1A males	23	.344	-.325	.333	-.314
	Study 1A females	38	.103	-.069	.082	-.030
	Study 1B males	64	.206	-.345**	.116	-.304*
	Study 1B females	64	.636***	-.357**	.578***	-.153
	Imaging (females)	56	.447**	-.401**	.359**	-.293*
	Autumn 2014 males	18	.396	.130	.390	.107
	Autumn 2014 females	150	.501***	-.392***	.404***	-.233**
UPPS (Lack of) Premeditation	Imaging (females)	56	-.161	.355**	-.043	.323*
UPPS Neg. Urgency	Imaging (females)	56	.165	.071	.202	.138

UPPS Sensation Seeking	Imaging (females)	56	-.186	.244	-.112	.195
UPPS (Lack of) Perseverance	Imaging (females)	56	.293*	.105	.353**	.231

Table 4.23: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and measures of interpersonal attitudes and impulsivity.
* $p < .05$, ** $p < .01$, *** $p < .001$

It was noted that scores on the 'rigid personality' sub-scale of the BAPQ were negatively correlated with reward expectancies and positively correlated with threat expectancies in several of the samples examined (Table 4.23). However, as the rigidity sub-scale of the BAPQ is correlated with the other two sub-scales, it is possible that these associations arose spuriously, driven by the other sub-scales. This hypothesis is plausible, as the other two elements of the BAP (aloof personality and pragmatic language difficulties) are social in nature and may have sufficiently strong correlations with social expectancies to drive an apparent correlation with the rigid personality sub-scale. Therefore partial correlations of the LODESTARS with BAPQ-rigid scores controlling for the other BAPQ sub-scales were examined. These are reported in Table 4.24.

Measure	Sample	N	LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
BAPQ Rigid ct. for BAPQ Aloof & BAPQ Prag. lang.	Study 1B males	64	.065	-.276*	.014	-.269*
	Study 1B females	64	.522***	-.068	.521***	-.059
	Imaging (females)	56	.229	-.281*	.171	-.238
	Autumn 2014 females	150	.313***	-.124	.297***	-.071

Table 4.24: Correlations (Pearson's *r*) between LODESTARS-threat and LODESTARS-reward expectancy scores and BAP-rigid, controlling for BAP-aloof and BAP-pragmatic language difficulties.
* $p < .05$, ** $p < .01$, *** $p < .001$

As can be seen in Table 4.24, the correlations between BAP-rigidity and LODESTARS-threat remained highly significant when controlling for the social elements of the BAP. Whether BAP-rigidity is associated with other threat-sensitivity measures was examined, to enable better interpretation of this result. These correlations are reported in Table 4.25.

Measure	Sample	BIS	ASQ Anxiety	ASQ Avoidance	Neuroticism	Fear of Neg. Evaluation	Friendship Avoidance Goals	ADDI 27 Pos. Aff.	ADDI 27 Gen. Distress	ADDI 27 Som. Anx.
BAPQ Rigid	Study 1B males	.426**	.126	.160	.204	.096	.150	-	-	-
ct. for BAPQ Aloof & BAPQ Prag. lang.	Study 1B females	.321*	.292*	.020	.315*	.180	.040	-	-	-
	Imaging (females)	.272*	.378**	.157	-	-	-	-.064	.304*	-.027
	Autumn 2014 males	-	.003	.079	.203	-	-.554*	-	-	-
	Autumn 2014 females	-	.261**	.127	.383***	-	.001	-	-	-

Table 4.25: Correlations of BAP-rigid with other threat-sensitivity measures, controlling for BAP-aloof and BAP-pragmatic language difficulties.

4.6.3 Summary and discussion of key findings

Construct validation of the LODESTARS was assessed by examining the scales' associations with an array of other cognitive, affective and behavioural constructs relating to social behaviour. It was predicted that higher dispositional expectancies of social reward would be associated with greater propensity to engage in social activities and affiliation. Conversely individuals with high expectancies of social threat may hesitate to interact with others due to concerns about potential rejection. Strong support for these predictions was found across multiple samples using multiple measures, validating the LODESTARS as a measure of valenced dispositional social expectancies. BAP-Aloof scores were associated with diminished reward expectancies and heightened threat expectancies. Friendship approach goals were associated with reward expectancies and not with threat expectancies. Conversely friendship avoidance goals were associated with threat expectancies and not with reward expectancies (except in Study 1B females, where there was a correlation between avoidance goals and reward expectancies, in addition to the stronger correlations between avoidance goals and threat expectancies). Higher social reward expectancies were correlated with tendencies to seek social interaction as a source of enjoyable affective and cognitive stimulation (as measured by the IOS positive stimulation sub-scale). Similarly extraversion was associated with higher reward expectancies and lower threat expectancies.

As predicted, neuroticism and higher BIS were associated with higher social threat expectancies. Similarly, higher levels of generalised negativity, anxiety and stress reactivity were related to greater dispositional tendencies to expect social threat. Lower frequencies of positive affective experiences and higher general distress (both measured by the ADDI-27) were associated with threat expectancies and not with reward expectancies. Perceived stress reactivity – and in particular, reactivity to social evaluation – was strongly associated with threat expectancies and not with reward expectancies. Similarly, fear of negative evaluation was associated with threat expectancies and not with reward expectancies.

While the data indicate that dispositional valenced social expectancies are closely associated with generalised positivity and negativity, there are also several points of differentiation among the correlations. These indicate that the LODESTARS does indeed measure the more focussed constructs of social threat and reward expectancies, rather than simply capturing generalised positive/negative bias or related broad personality variables such as BIS and BAS. For example, self-esteem, that is, positivity or negativity of global self-evaluations, is negatively correlated with LODESTARS threat expectancies, but not correlated with LODESTARS-reward (shown in Table 4.18). If social reward expectancies were redundant with generalised positivity, one would expect a correlation between LODESTARS-reward and self-esteem.

The differential correlations of BIS and LODESTARS-threat with self-reported stress reactivity are consistent with the characterisation of BIS as a global propensity towards anxiety, while LODESTARS-threat captures more specifically anxiety that is related to social interactions. While BIS scores correlate strongly and to a similar degree with all stress reactivity sub-categories, LODESTARS-threat is most strongly associated with stress reactivity in response to social evaluation (see Appendix 3, Imaging study full set of zero-order correlations, for r and p values). Together, correlations of LODESTARS scores with scores on the well-established personality trait scales reported here provide strong evidence for the convergent and discriminant validity of the LODESTARS.

Reactivity to social exclusion during the Cyberball paradigm was also strongly correlated with participants' prior expectancies of social threat. Notably, even participants' perceptions of the extent to which they were ignored and/or excluded during the Cyberball game were strongly predicted by their social threat expectancies. While almost all participants responded that they were ignored and excluded (Table 4.26), the level of exclusion they perceived was seemingly influenced by their dispositional expectancies of social threat (see Table 4.19). This is consistent with previous work showing that individuals who more anxiously expect rejection are hyper-vigilant to signals of threat in the social environment (Bögels & Mansell, 2004). Consequently such individuals more readily perceive signals of rejection or exclusion (Bögels & Mansell, 2004).

Ignored				Excluded			
Response	Frequency	Valid Percent	Cumulative Percent	Response	Frequency	Valid Percent	Cumulative Percent
2	1	7.1	7.1	2	1	7.1	7.1
3	2	14.3	21.4	3	2	14.3	21.4
4	6	42.9	64.3	4	6	42.9	64.3
5	5	35.7	100.0	5	5	35.7	100.0
Total	14	100.0		Total	14	100.0	

Table 4.26: Responses of Cyberball participants indicating their experience of being ignored and excluded during the game. Participants used a 5-point scale where 1 = 'Not at all' and 5 = 'Extremely'. Note: although the response frequencies for 'Ignored' and 'Excluded' were the same in this sample, it was not the case that all participants selected the same response for both items.

Social integration as measured by the number of people in individuals' social networks appears to be associated with social reward expectancies, although this was only significant in two of the six samples tested. Perceived belongingness on the other hand appears to be more strongly associated with social threat expectancies. This suggests that greater sense of belonging is more related to an absence of social threat expectancies rather than heightened social reward expectancies.

The hypothesised correlation of the LODESTARS-reward scale with delaying gratification tendencies in the social domain was present only in the Imaging study sample. The average age of participants in the Imaging study was higher than in the other studies, and DGI-social scores have previously been found to increase with age. However, DGI-social scores were similar in the Imaging study sample to those obtained in Study 1A and 1B (as shown in Table 4.27). One-way ANOVA confirmed that there were no significant differences in DGI-social scores across the samples (F (4,174) = 1.032, p = .39) so age differences in delaying gratification tendencies seem unlikely to account for this result being present only in the Imaging sample. Whether LODESTARS-reward is associated with DGI-social remains uncertain therefore but the available data indicate that, if there is an association, it is not particularly large or robust.

Sample	N	Minimum	Maximum	Mean	Std. Deviation
Study 1A males	11	21	30	25.18	2.892
Study 1A females	18	23	31	26.72	2.321
Study 1B males	64	18	31	26.11	2.738
Study 1B females	63	20	32	26.71	2.605
Imaging (females)	56	22	31	26.86	2.540

Table 4.27: Descriptive statistics for the DGI-social interactions sub-scale across all available samples.

LODESTARS-reward scores were correlated with lower premeditation tendencies as measured by the UPPS impulsive behaviour scale. This is consistent with the hypothesis that individual differences in future-focus account for part of the variance captured by the LODESTARS. However, this finding is contrary to the hypothesis that greater (positive) focus on the future would be associated with higher LODESTARS-reward scores. Rather, this finding suggests that greater impulsivity – less consideration of the future – is related to higher expectancies of social reward. This may be because people who are perceived as more 'spontaneous' tend to be more liked (Zabelina, Robinson, & Anicha, 2007), which may lead to more expectancies of being liked.

Lack of perseverance, as measured by the UPPS scale, was correlated with higher social threat expectancies. This is contrary to the hypothesis that individuals who exhibit a relative lack of concern with the future (perhaps indexed by a lack of perseverance) may also be relatively unconcerned about the potential to be rejected in future social scenarios. However, it may be that lack of perseverance does not reflect a lack of concern about the future. Lack of perseverance may also arise due to anxiety, lack of confidence in one's ability to complete the task, or fear of failure (Pajares, 2008). The (lack of) perseverance scale of the UPPS may tap this form of the trait more so than lack of perseverance arising from lack of concern. For instance, the UPPS item "Sometimes there are so many little things to be done that I just ignore them all" seems likely to apply more in circumstances where individuals feel overwhelmed or anxious. If lack of perseverance as measured by the UPPS is indeed tapping tendencies that arise from anxiety or lack of self-confidence, this would be consistent with its correlation with LODESTARS-threat scores. In support of this explanation, UPPS lack of perseverance scores were associated with lower Rosenberg self-esteem scores in our sample ($r = -.329$, $p = .014$), as well as greater attachment anxiety ($r = .292$, $p = .029$), ADDI-27 general distress ($r = .302$, $p = .024$), and reactivity to social evaluation ($r = .307$, $p = .023$; see Appendix 3 for full inter-correlations of all variables).

Compulsive tendencies (as measured by the 'rigid personality' sub-scale of the BAPQ) were negatively correlated with reward expectancies and positively correlated with threat expectancies. These associations remain when controlling for the social elements of the BAP (aloof personality and pragmatic language difficulties). Difficulty adjusting to change (rigidity) may occur in many individuals due to fear of change, associated with generally anxious and threat-sensitive dispositions. This explanation is supported by data from the present studies, as shown in Table 4.25.

4.7 Testing the predictions of the proposed model: links between social expectancies and social approach and avoidance motives

This chapter has described the development and validation of the LODESTARS, a self-report scale designed to measure dispositional, generalised expectancies of social threat and reward. It was found that individuals' LODESTARS scores are quite stable over time and are associated with other stable personality traits such as extraversion and autism-like characteristics. Thus it appears that the LODESTARS is a valid measure of dispositional social expectancies.

In this section, the LODESTARS is used to test the hypothesis that individual differences in generalised social expectancies underpin differences in social motivation (as depicted in Fig. 2.6). It is argued that generalised expectancies regarding social interactions comprise an important cognitive component of interpersonal dispositions and personality traits such as extraversion. It is suggested that expectancies are generated as a proximal expression of such traits, dispositions, and tendencies. According to the model proposed in this thesis, expectancies then directly inform motives and goals. If this is the case, one would expect social reward or threat expectancies to mediate associations between broad interpersonal/affective dispositions and more specific social goals or motives. This prediction was examined by testing the hypotheses listed below.

NB: For ease of reference, inter-correlations among the variables considered in this section are shown in Tables 4.28 and 4.29. Full inter-correlations tables can be found in Appendix 3.

Hypotheses

1. That the observed positive association between extraversion and friendship approach goals is mediated by greater social reward expectancies.
2. That the observed negative association between BAP-aloof and friendship approach goals is mediated by lower social reward expectancies.
3. That the observed negative association between avoidant attachment and friendship approach goals is mediated by lower social reward expectancies.
4. That the observed positive association between anxious attachment and friendship avoidance goals is mediated by higher social threat expectancies.

While it is possible to have a significant 'indirect' effect when a direct effect is non-significant (Hayes, 2013), this is not really 'mediation' per se, but rather a significant indirect effect. In the analyses reported in this thesis, testing the predictions of the proposed model, only mediation models will be assessed (so the direct path has to be significant, or approaching significance). This is in line with the recommendations of Mathieu and Taylor (2006).

Table 4.28: Inter-correlations between LODESTARS, and the interpersonal/affective dispositions and social goals variables considered in this section in the Study 1B sample (64 males and 64 females).

Gender		Extraversion	Neuroticism	BAPQ Aloof	BIS	ASQ Anxiety	ASQ Avoidance	LODESTARS Threat	LODESTARS Reward	Friendship Approach Goals
male	Neuroticism	-.231								
	BAPQ Aloof	-.635***	.279*							
	BIS	-.310*	.504***	.349**						
	ASQ Anxiety	-.056	.401**	.261*	.507***					
	ASQ Avoidance	-.217	.322**	.622***	.217	.215				
	LODESTARS Threat	-.430***	.257*	.327**	.372**	.561***	.068			
	LODESTARS Reward	.311*	-.266*	-.463***	-.426***	-.165	-.492***	-.294*		
	Friendship Approach Goals	.303*	-.115	-.549***	-.248*	.098	-.398**	-.190	.540***	
	Friendship Avoidance Goals	.170	.155	-.145	.198	.367**	.035	.258*	-.048	.235
female	Neuroticism	-.414**								
	BAPQ Aloof	-.682***	.440***							
	BIS	-.168	.597***	.152						

		Extraversion	Neuroticism	BAPQ Aloof	BIS	Anx_att	Av_att	LODESTARS Threat	LODESTARS Reward	Friendship Approach Goals
female (cont.)	ASQ Anxiety	-.379**	.633***	.553***	.541***					
	ASQ Avoidance	-.382**	.342**	.629***	.004	.517***				
	LODESTARS Threat	-.465***	.567***	.547***	.522***	.720***	.341**			
	LODESTARS Reward	.576***	-.336**	-.695***	-.064	-.301*	-.347**	-.391**		
	Friendship Approach Goals	.296*	-.193	-.306*	.116	.016	-.152	.014	.455***	
	Friendship Avoidance Goals	.046	.003	-.087	.177	.235	-.041	.310*	.136	.284*

Table 4.29: Inter-correlations between LODESTARS, and the interpersonal/affective dispositions and social goals variables considered in this section in the Autumn 2014 sample (18 males and 150 females).

Gender		Extraversion	Neuroticism	BAPQ Aloof	Anx_att	Av_att	LODESTARS Threat	LODESTARS Reward	Friendship Approach Goals
male	Neuroticism	-.143							
	BAPQ Aloof	-.742***	-.101						
	Anx_att	-.297	.623**	-.108					
	Av_att	-.385	.578*	.208	.832***				

		Extraversion	Neuroticism	BAPQ Aloof	Anx_att	Av_att	LODESTARS Threat	LODESTARS Reward	Friendship Approach Goals
male (cont.)	LODESTARS Threat	-.322	.601**	-.036	.740***	.580*			
	LODESTARS Reward	.098	-.140	.028	-.033	.146	.081		
	Friendship Approach Goals	.056	-.147	.024	.134	.234	.081	.154	
	Friendship Avoidance Goals	-.126	-.123	-.012	.377	.233	.099	-.147	.200
female	Neuroticism	-.412***							
	BAPQ Aloof	-.665***	.500***						
	Anx_att	-.500***	.617***	.493***					
	Av_att	-.405***	.507***	.594***	.635***				
	LODESTARS Threat	-.474***	.525***	.486***	.697***	.468***			
	LODESTARS Reward	.429***	-.359***	-.592***	-.401***	-.504***	-.417***		
	Friendship Approach Goals	.198*	-.081	-.244**	-.039	-.187*	-.082	.400***	
	Friendship Avoidance Goals	.002	.016	-.130	.152	-.014	.152	.064	.251**

4.7.1 Methods

The aforementioned hypotheses were tested using Andrew Hayes' PROCESS macro for SPSS (http://www.processmacro.org/). PROCESS uses a regression-based path analytic framework for estimating direct and indirect effects in mediation models (Hayes, 2013). PROCESS implements bootstrapped confidence intervals for inference about the significance and effect size of indirect effects. Model 4 in PROCESS was used to test each of the 4 predictions. A general representation of the model is shown in Fig. 4.4; this format is then used to present the results of each of the mediation analyses conducted. The path (regression) coefficients are reported in unstandardized form, as this is the preferred metric in causal modelling (Hayes, 2013). The scale of unstandardized coefficients is determined by the scale of measurement of the variables in the model. Therefore the coefficients can be greater than 1.

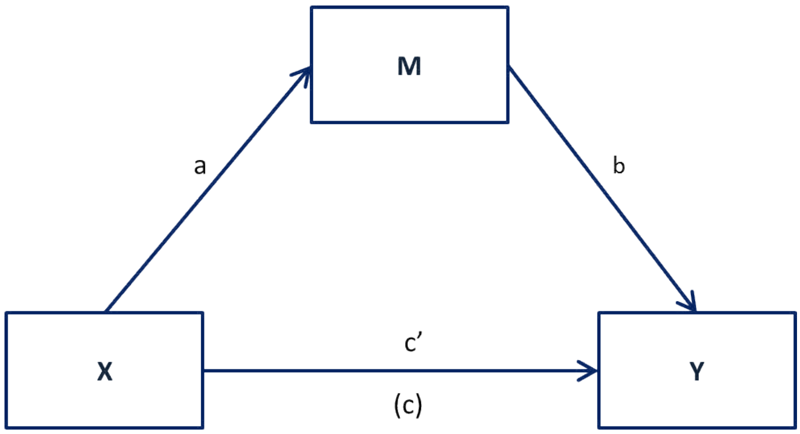

Figure 4.4: Diagrammatic representation of a mediation model. The total effect of *X* on *Y* is represented as *c*. The indirect effect of *X* on *Y* through the mediator $M = a*b$. The direct effect of *X* on *Y* is given by *c'*.

The samples used to test the mediation models were from Study 1B and the Autumn 2014 study. As gender differences were observed in several of the variables used, analyses were conducted separately for males and females from Study 1B. As there were only 18 males in the Autumn 2014 sample, these were not included in the present analyses. This left a sample of 150 female participants from the Autumn 2014 study.

The effect sizes for the mediation analyses are given as percent mediation (P_M) values (Preacher & Kelley, 2011). That is, the percent of the total effect (c) accounted for by the indirect effect (a*b).

4.7.2 Results

4.7.2.1 Prediction 1: That the observed positive association between extraversion and friendship approach goals is mediated by greater social reward expectancies

Study 1B, males: The indirect effect of extraversion on friendship approach goals via reward expectancies was significant, *ab* = 0.23, 95% CI = 0.08, 0.47. The mediator accounted for more than half of the total effect, P_M = .51. Path coefficients from this analysis are shown in Fig. 4.5.

Study 1B, females: The indirect effect of extraversion on friendship approach goals via reward expectancies was significant, *ab* = 0.23, 95% CI = 0.08, 0.44. The mediator accounted for more than 80% of the total effect, P_M = .83. Path coefficients from this analysis are shown in Fig. 4.6.

Autumn 2014 study, females: The indirect effect of extraversion on friendship approach goals via reward expectancies was significant, *ab* = 0.17, 95% CI = 0.07, 0.37. The mediator accounted for more than 80% of the total effect, P_M = .84. Path coefficients from this analysis are shown in Fig. 4.7.

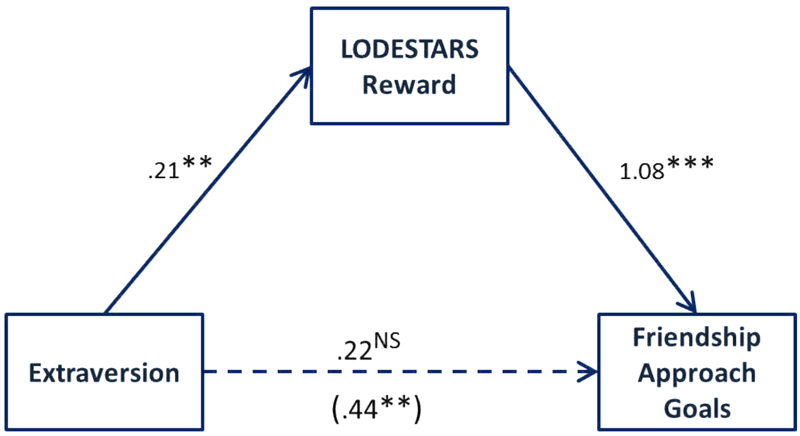

Figure 4.5: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of extraversion on friendship approach goals, and for the indirect effect through social reward expectancies in male participants from Study 1B (n = 64).
*$p < .05$; **$p < .01$; ***$p < .001$

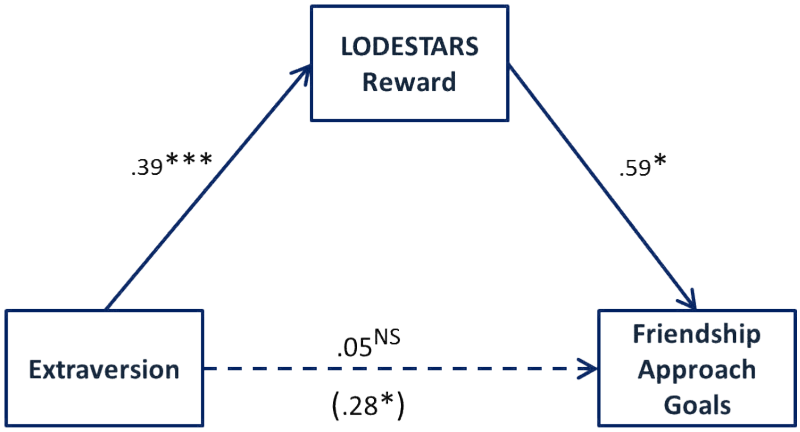

Figure 4.6: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of extraversion on friendship approach goals, and for the indirect effect through social reward expectancies in female participants from Study 1B (n = 64).
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

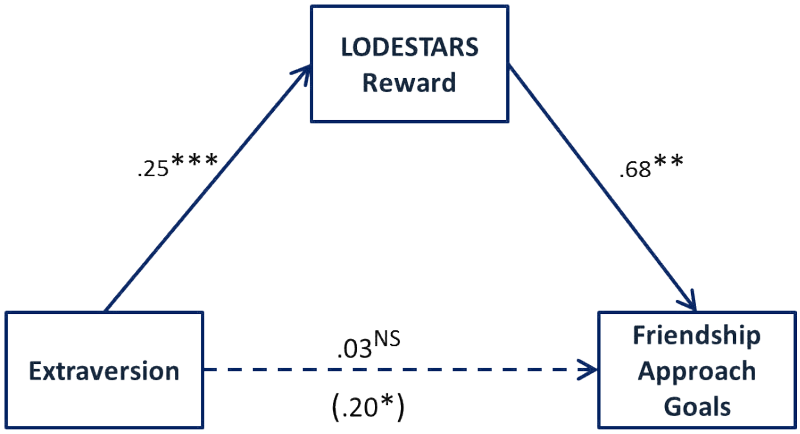

Figure 4.7: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of extraversion on friendship approach goals, and for the indirect effect through social reward expectancies in female participants from the Autumn 2014 study (n = 150).
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

4.7.2.2 Prediction 2: That the observed negative association between BAP-aloof and friendship approach goals is mediated by lower social reward expectancies

Study 1B, males: The indirect effect of BAP-aloof on friendship approach goals via reward expectancies was significant, *ab* = -0.36, 95% CI = -0.85, -0.12. The mediator accounted for more than 30% of the total effect, $P_M = .31$. Path coefficients from this analysis are shown in Fig. 4.8.

Study 1B, females: The indirect effect of BAP-aloof on friendship approach goals via reward expectancies was significant, *ab* = -0.33, 95% CI = -0.60, -0.13. The indirect effect in this case was larger than the total effect ($P_M = 1.06$). Path coefficients from this analysis are shown in Fig. 4.9.

Autumn 2014 study, females: The indirect effect of BAP-aloof on friendship approach goals via reward expectancies was significant, *ab* = -0.28, 95% CI = -0.54, -0.12. The mediator accounted for more than 95% of the total effect, $P_M = .96$. Path coefficients from this analysis are shown in Fig. 4.10.

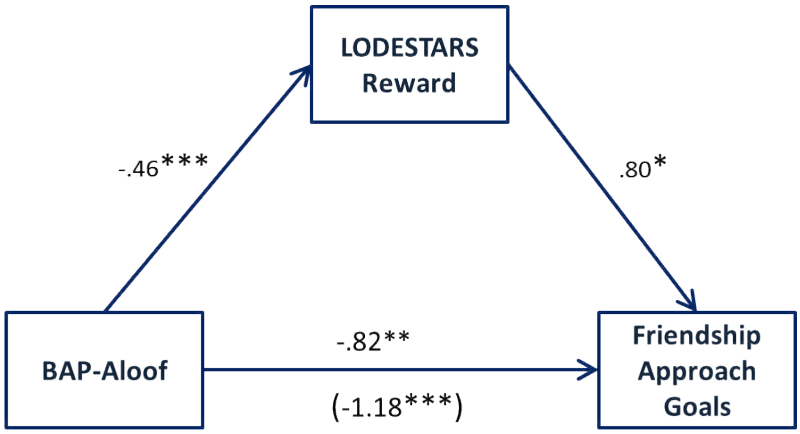

Figure 4.8: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of BAP-aloof on friendship approach goals, and for the indirect effect through social reward expectancies in male participants from Study 1B (n = 64).
*$p < .05$; **$p < .01$; ***$p < .001$

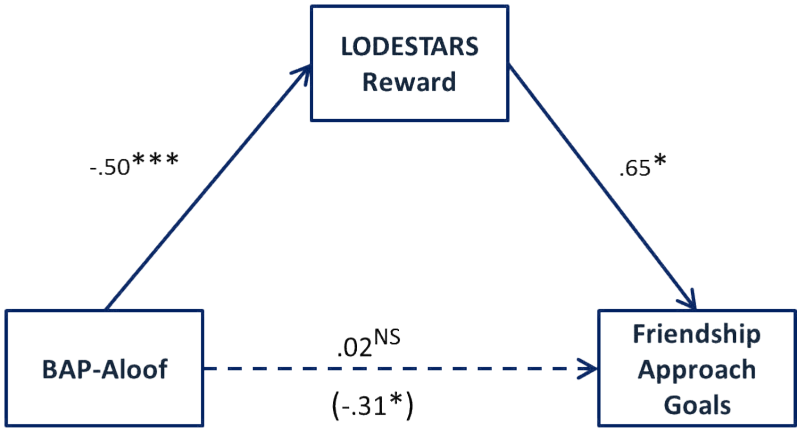

Figure 4.9: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of BAP-aloof on friendship approach goals, and for the indirect effect through social reward expectancies in female participants from Study 1B (n = 64).
$*p < .05$; $**p < .01$; $***p < .001$

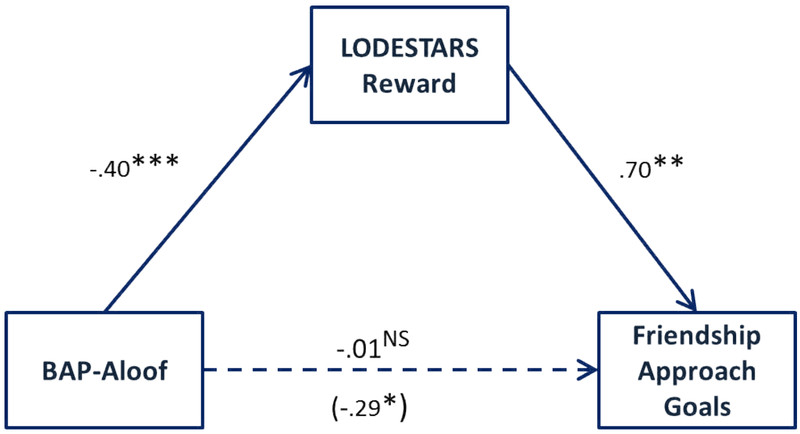

Figure 4.10 : Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of BAP-aloof on friendship approach goals, and for the indirect effect through social reward expectancies in female participants from the Autumn 2014 study (n = 150).
$*p < .05$; $**p < .01$; $***p < .001$

4.7.2.3 *Prediction 3: That the observed negative association between avoidant attachment and friendship approach goals is mediated by lower social reward expectancies*

Study 1B, males: The indirect effect of avoidant attachment on friendship approach goals via reward expectancies was significant, *ab* = -0.44, 95% CI = -0.89, -0.16. The mediator accounted for more than half of the total effect, $P_M = .56$. Path coefficients from this analysis are shown in Fig. 4.11.

Study 1B, females: The mediation model was not assessed as the zero-order correlation between avoidant attachment and friendship approach goals was not significant ($p = .23$).

Autumn 2014 study, females: The indirect effect of avoidant attachment on friendship approach goals via reward expectancies was significant, *ab* = -0.24, 95% CI = -0.50, -0.10. The indirect effect in this case was greater than the total effect ($P_M = 1.10$), which in this analysis was found to be non-significant (despite a zero-order correlation of -.187, $p = .02$). Path coefficients from this analysis are shown in Fig. 4.12.

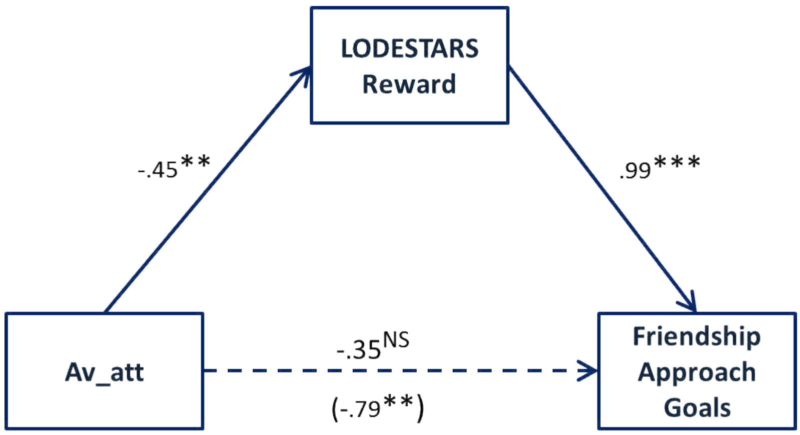

Figure 4.11: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of avoidant attachment on friendship approach goals, and for the indirect effect through social reward expectancies in male participants from Study 1B (n = 64).
$*p < .05$; $**p < .01$; $***p < .001$

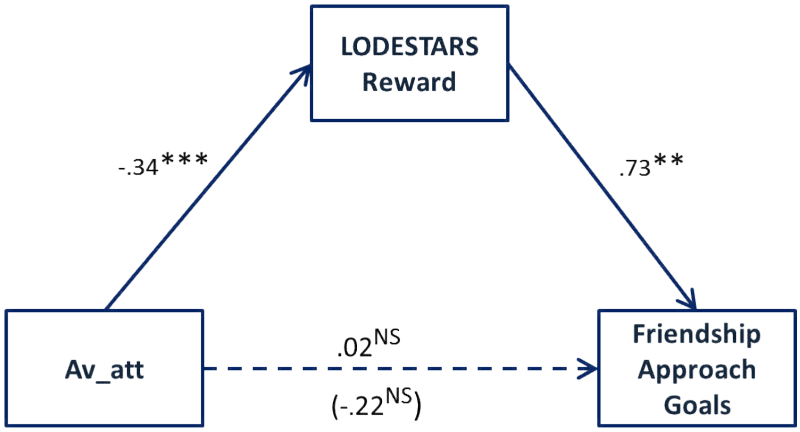

Figure 4.12: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of avoidant attachment on friendship approach goals, and for the indirect effect through social reward expectancies in female participants from the Autumn 2014 study (n = 150).
**p* < .05; ***p* < .01; ****p* < .001

4.7.2.4 Prediction 4: That the observed positive association between anxious attachment and friendship avoidance goals is mediated by greater social threat expectancies

Study 1B, males: The indirect effect of anxious attachment on friendship avoidance goals via threat expectancies was not significant, *ab* = 0.07, 95% CI = -0.18, 0.37. The proposed mediator accounted for less than 15% of the total effect, $P_M = .12$.

Study 1B, females: The mediation model was assessed but it is important to note that the zero-order correlation between anxious attachment and friendship avoidance goals was not significant by the traditional standard of $\alpha = .05$ ($p = .06$). The indirect effect of anxious attachment on friendship avoidance goals via threat expectancies was not significant, ab = 0.25, 95% CI = -0.02, 0.53. The proposed mediator nonetheless accounted for 90% of the total effect, $P_M = .90$.

Autumn 2014 study, females: The mediation model was assessed but again it is important to note that the zero-order correlation between anxious attachment and friendship avoidance goals was not significant by the traditional standard ($p = .06$). The indirect effect of anxious attachment on friendship avoidance goals via threat expectancies was not significant, ab = 0.07, 95% CI = -0.11, 0.26. The proposed mediator accounted for 41% of the total effect, $P_M = .41$.

4.7.3 Discussion

Across all three samples, social reward expectancies were found to fully mediate the link between extraversion and friendship approach goals. Reduced social reward expectancies fully mediated the association between BAP-aloof and lower friendship approach goals in female participants; partial mediation was found in male participants. That is, the indirect effect was significant, but the direct effect of BAP-aloof on friendship goals remained significant when social reward expectancies were accounted for. Reduced social reward expectancies also fully mediated the association between avoidant attachment and lower friendship approach goals in male Study 1B participants and in female participants from the Autumn 2014 study. The indirect effect of avoidant attachment on friendship approach goals was not assessed in female participants from Study 1B as the zero-order correlation between these variables was not significant in this sample.

No support was found for the hypothesis that greater social threat expectancies would mediate the association between anxious attachment and friendship avoidance goals. However, this was only assessed in male participants from Study 1B as the zero-order correlation between anxious attachment and friendship avoidance goals was not significant in either of the female samples available (p = .06 in both cases).

Overall the results reported in this section provide strong support for the hypothesis that social reward expectancies mediate links between interpersonal traits and social (friendship) approach goals. These results underline the crucial importance of reward expectancies in motivating behaviour.

The available data did not yield evidence that social threat expectancies mediate associations between interpersonal traits and social (friendship) avoidance goals. This may have been partly due to a paucity of data to probe for such mediation effects. For instance, I would hypothesise that both neuroticism and BIS may be associated with social (friendship) avoidance goals. A link between BIS and friendship avoidance goals has previously been reported by Gable (2006). However, neither

BIS nor neuroticism were significantly associated with friendship avoidance goals in the present studies.

4.8 Testing the predictions of the proposed model: links between social expectancies and social integration outcomes

In this section, the predictions of the theoretical framework proposed in this thesis are further examined by testing whether individual differences in generalised social expectancies mediate associations between interpersonal/affective dispositions and achieved social integration. Although expectancies and outcomes are separated by two stages (motivation and behaviour) in the model, outcomes are nonetheless proposed to occur downstream of expectancies. It is suggested that dispositional expectancies are a pivotal cognitive component in determining social integration outcomes such as loneliness and satisfaction with social bonds. If this is the case then expectancies would be expected to explain (mediate) – at least partially – links between personality traits and social outcomes. Establishing whether this occurs, and to what extent, seems useful not only theoretically but also in terms of potential strategies for reducing loneliness. Expectancies may be a suitable entry point to target maladaptive social cognition and behaviour (i.e. that contributes to unwanted outcomes such as loneliness) as expectancies are consciously accessible and perhaps can therefore be consciously modified, e.g. by means such as cognitive therapy (Beck, 2010; Labbe & Maisto, 2011).

For ease of reference, inter-correlations among the variables considered in this section are shown in Table 4.30. Full inter-correlations tables can be found in Appendix 3.

The prediction that expectancies mediate – at least partially – links between personality traits and social outcomes was examined by testing the following specific hypotheses:

1. That the observed positive association between extraversion and social integration is mediated by greater social reward expectancies.

2. That the observed negative association between neuroticism and social integration is mediated by greater social threat expectancies.
3. That the observed negative association between BIS and social integration is mediated by greater social threat expectancies.
4. That the observed negative association between BAP-aloof and social integration is mediated by lower social reward expectancies.
5. That the observed negative association between avoidant attachment and social integration is mediated by lower social reward expectancies.
6. That the observed negative association between anxious attachment and social integration is mediated by greater social threat expectancies.

Table 4.30: Inter-correlations between LODESTARS, and the interpersonal/affective dispositions and social integration outcome variables considered in this section in the Study 1B sample (64 males and 64 females for all measures, except the SNI which was completed by 63 males and 26 females in this sample).

Gender		Extraversion	Neuroticism	BIS	BAPQ Aloof	ASQ Anxiety	ASQ Avoidance	LODESTARS Threat	LODESTARS Reward	Number in social network
male	Neuroticism	-.231								
	BIS	-.310*	.504***							
	BAPQ Aloof	-.635***	.279*	.349**						
	ASQ Anxiety	-.056	.401**	.507***	.261*					
	ASQ Avoidance	-.217	.322**	.217	.622***	.215				
	LODESTARS Threat	-.430***	.257*	.372**	.327**	.561***	.068			
	LODESTARS Reward	.311*	-.266*	-.426***	-.463***	-.165	-.492***	-.294*		
	Number in social network	.455***	-.140	-.236	-.395**	-.001	-.152	-.255*	.378**	
	GBS General Belongingness	.395**	-.510***	-.368**	-.536***	-.564***	-.434***	-.403**	.324**	.186

Gender		Extraversion	Neuroticism	BIS	BAPQ Aloof	ASQ Anxiety	ASQ Avoidance	LODESTARS Threat	LODESTARS Reward	Number in social network
female	Neuroticism	-.414**								
	BIS	-.168	.597***							
	BAPQ Aloof	-.682**	.440***	.152						
	ASQ Anxiety	-.379**	.633***	.541***	.553***					
	ASQ Avoidance	-.382**	.342**	.004	.629***	.517***				
	LODESTARS Threat	-.465***	.567***	.522***	.547***	.720***	.341**			
	LODESTARS Reward	.576***	-.336**	-.064	-.695***	-.301*	-.347**	-.391**		
	Number in social network	.394*	.213	.313	-.233	.074	-.048	-.102	.243	
	GBS General Belongingness	.606***	-.584***	-.330**	-.763***	-.752***	-.588***	-.619***	.535***	.022

4.8.1 Methods

The above hypotheses were tested using Andrew Hayes' PROCESS macro for SPSS (http://www.processmacro.org/), using the same procedures as in section 4.7. Data from Study 1B were used for the analyses, which were again conducted separately for male and female participants. Social integration was assessed in terms of sense of belonging (General Belongingness Scale scores) and, where possible, in terms of the number of people in participants' social networks. That is, the number of people with whom participants have regular social contact at least every two weeks. Social Network Index (SNI) scores could only be used to test the models relating extraversion and BAP-aloof to social integration however, as most of the zero-order correlations involving the SNI were not significant.

4.8.2 Results

4.8.2.1 Prediction 1: That the observed positive association between extraversion and social integration is mediated by greater social reward expectancies

Study 1B, males (n = 63 for SNI; full sample of n= 64 for belongingness): The indirect effect of extraversion on SNI-number via reward expectancies was significant, *ab* = 1.22, 95% CI = 0.22, 3.15. The mediator accounted for nearly 20% of the total effect, P_M = .18. Path coefficients from this analysis are shown in Fig. 4.13.

The indirect effect of extraversion on belongingness via reward expectancies was significant, *ab* = 0.07, 95% CI = 0.01, 0.19. The mediator accounted for nearly 20% of the total effect, P_M = .18. Path coefficients from this analysis are shown in Fig. 4.14.

Study 1B, females (n = 26 for SNI; full sample of n= 64 for belongingness): The indirect effect of extraversion on SNI-number via reward expectancies was not significant, *ab* = 0.23, 95% CI = -0.10, 1.08. The proposed mediator accounted for less than 15% of the total effect, P_M = .11.

The indirect effect of extraversion on belongingness via reward expectancies was significant, *ab* = 0.21, 95% CI = 0.03, 0.44. The mediator accounted for more than 25% of the total effect, P_M = .26. Path coefficients from this analysis are shown in Fig. 4.15.

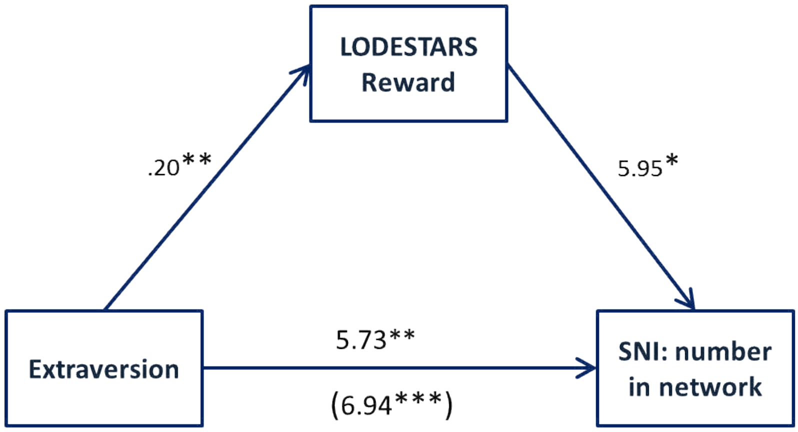

Figure 4.13: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of extraversion on SNI-number, and for the indirect effect through social reward expectancies in male participants from Study 1B (n = 63).
**p* < .05; ***p* < .01; ****p* < .001

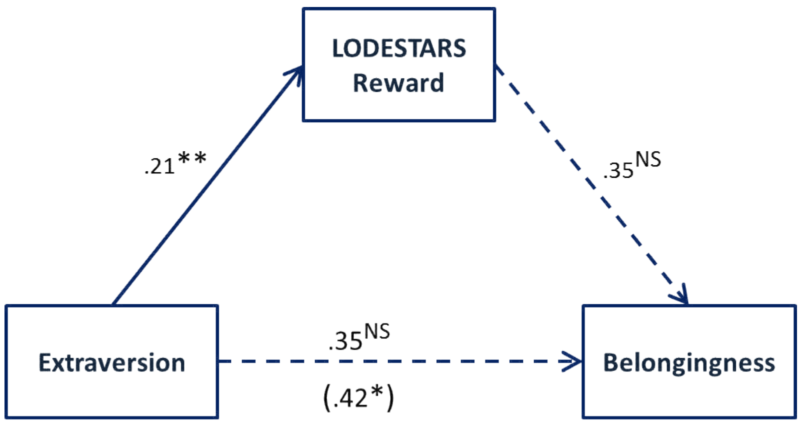

Figure 4.14: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of extraversion on belongingness, and for the indirect effect through social reward expectancies in male participants from Study 1B (n = 64).
**p* < .05; ***p* < .01; ****p* < .001

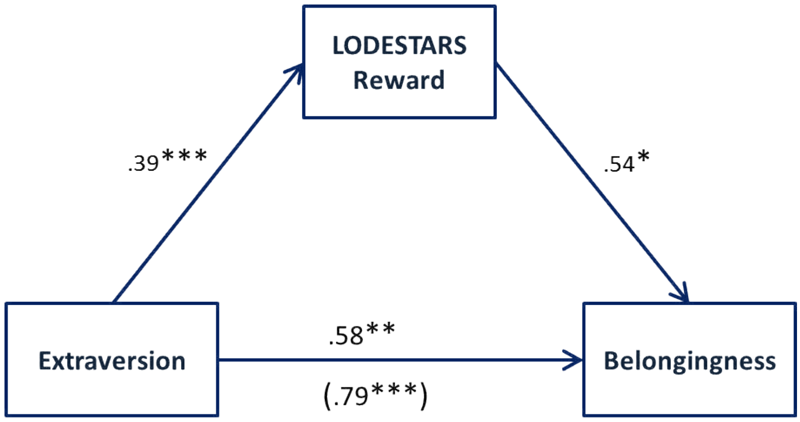

Figure 4.15: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of extraversion on belongingness, and for the indirect effect through social reward expectancies in female participants from Study 1B (n = 64).
*p < .05; **p < .01; ***p < .001

4.8.2.2 Prediction 2: That the observed negative association between neuroticism and social integration is mediated by greater social threat expectancies

Study 1B, males: The indirect effect of neuroticism on belongingness via threat expectancies was significant, *ab* = -0.09, 95% CI = -0.19, -0.01. The mediator accounted for 15% of the total effect, $P_M = .15$. Path coefficients from this analysis are shown in Fig. 4.16.

Study 1B, females: The indirect effect of neuroticism on belongingness via threat expectancies was significant, *ab* = -0.32, 95% CI = -0.61, -0.14. The mediator accounted for more than 40% of the total effect, $P_M = .41$. Path coefficients from this analysis are shown in Fig. 4.17.

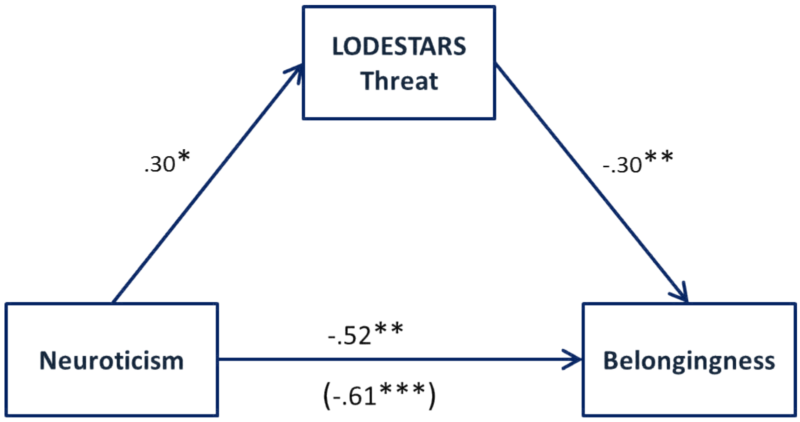

Figure 4.16: Path coefficients for the total and direct (accounting for LODESTARS-threat) effects of neuroticism on belongingness, and for the indirect effect through social threat expectancies in male participants from Study 1B (n = 64).
*p < .05; **p < .01; ***p < .001

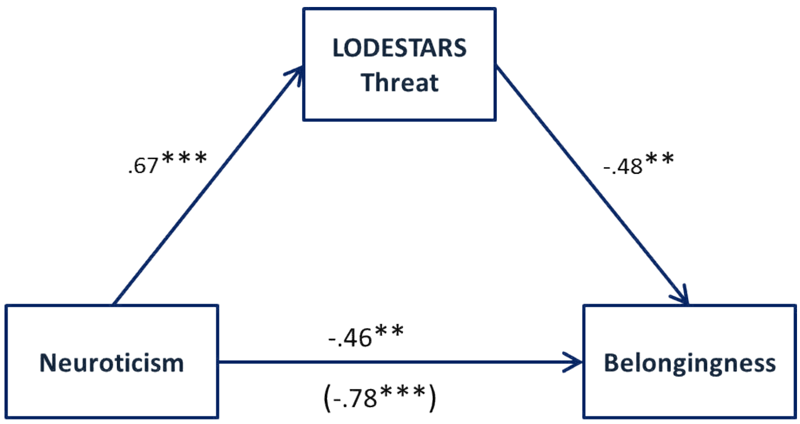

Figure 4.17: Path coefficients for the total and direct (accounting for LODESTARS-threat) effects of neuroticism on belongingness, and for the indirect effect through social threat expectancies in female participants from Study 1B (n = 64).
*p < .05; **p < .01; ***p < .001

4.8.2.3 Prediction 3: That the observed negative association between BIS and social integration is mediated by greater social threat expectancies

Study 1B, males: The indirect effect of BIS on belongingness via threat expectancies was significant, *ab* = -0.19, 95% CI = -1.29, -0.41. The mediator accounted for more than 30% of the total effect, P_M = .31. Path coefficients from this analysis are shown in Fig. 4.18.

Study 1B, females: The indirect effect of BIS on belongingness via threat expectancies was significant, *ab* = -0.77, 95% CI = -0.61, -0.14. The mediator accounted for more than 95% of the total effect, P_M = .97. Path coefficients from this analysis are shown in Fig. 4.19.

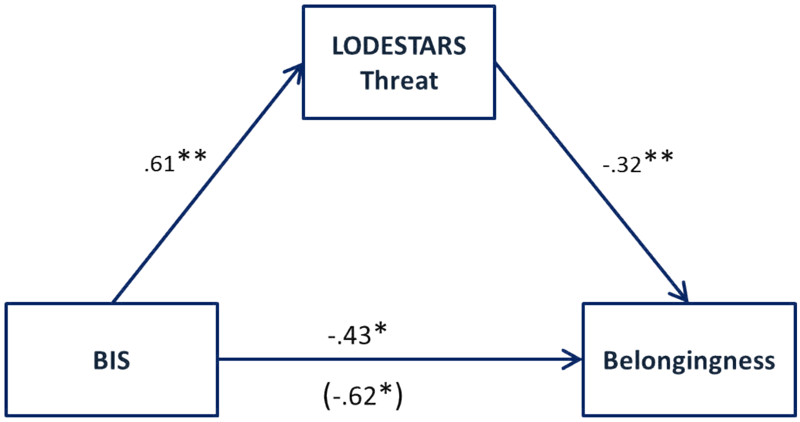

Figure 4.18: Path coefficients for the total and direct (accounting for LODESTARS-threat) effects of BIS on belongingness, and for the indirect effect through social threat expectancies in male participants from Study 1B (n = 64).
*p < .05; **p < .01; ***p < .001

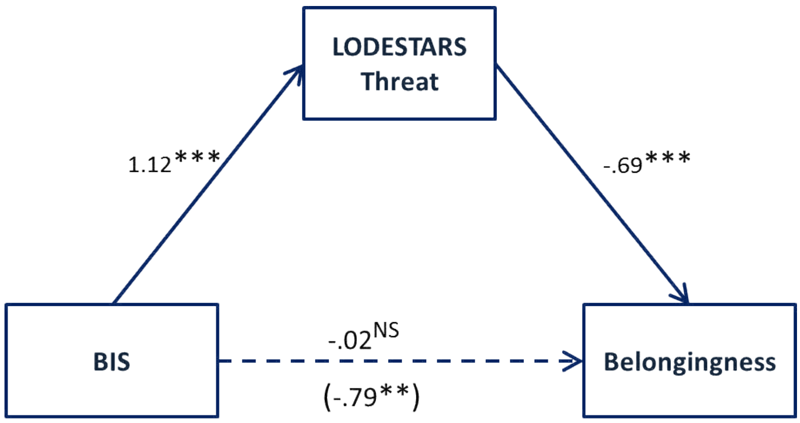

Figure 4.19: Path coefficients for the total and direct (accounting for LODESTARS-threat) effects of BIS on belongingness, and for the indirect effect through social threat expectancies in female participants from Study 1B (n = 64).
*p < .05; **p < .01; ***p < .001

4.8.2.4 Prediction 4: That the observed negative association between BAP-aloof and social integration is mediated by lower social reward expectancies

Study 1B, males (n = 63 for SNI; full sample of n= 64 for belongingness): The indirect effect of BAP-aloof on SNI-number via reward expectancies was significant, *ab* = -2.66, 95% CI = -7.18, -0.35. The mediator accounted for nearly 30% of the total effect, P_M = .29. Path coefficients from this analysis are shown in Fig. 4.20.

The indirect effect of BAP-aloof on belongingness via reward expectancies was not significant, *ab* = -0.07, 95% CI = -0.25, 0.13. The proposed mediator accounted for less than 10% of the total effect, P_M = .08.

Study 1B, females: The indirect effect of BAP-aloof on belongingness via reward expectancies was not significant, *ab* = -0.01, 95% CI = -0.22, 0.20. The proposed mediator accounted for only 1% of the total effect, P_M = .01.

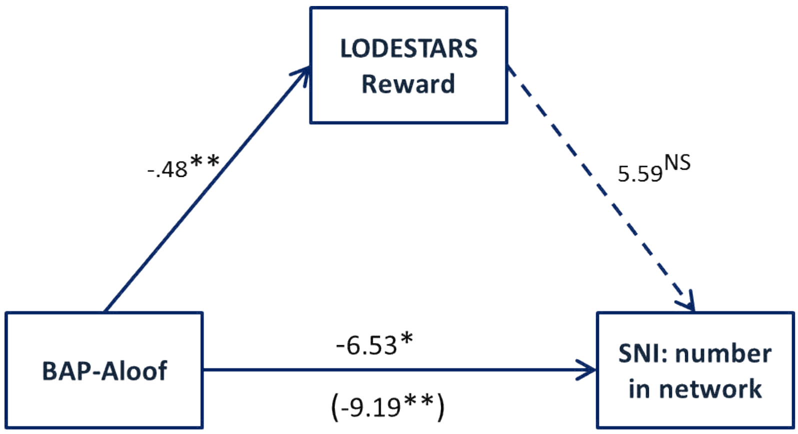

Figure 4.20: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of BAP-aloof on SNI-number, and for the indirect effect through social reward expectancies in male participants from Study 1B (n = 63).
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$

4.8.2.5 *Prediction 5: That the observed negative association between avoidant attachment and social integration is mediated by lower social reward expectancies*

Study 1B, males: The indirect effect of avoidant attachment on belongingness via reward expectancies was not significant, *ab* = -0.10, 95% CI = -0.31, 0.07. The proposed mediator nonetheless accounted for more than 15% of the total effect, $P_M = .17$.

Study 1B, females: The indirect effect of avoidant attachment on belongingness via reward expectancies was significant, *ab* = -0.23, 95% CI = -0.52, -0.06. The mediator accounted for more than 20% of the total effect, $P_M = .22$. Path coefficients from this analysis are shown in Fig. 4.21.

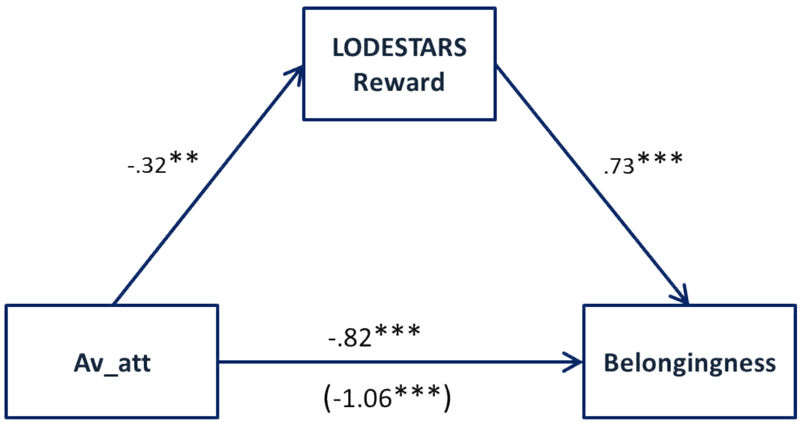

Figure 4.21: Path coefficients for the total and direct (accounting for LODESTARS-reward) effects of avoidant attachment on belongingness, and for the indirect effect through social reward expectancies in female participants from Study 1B (n = 64).
*$p < .05$; **$p < .01$; ***$p < .001$

4.8.2.6 *Prediction 6: That the observed negative association between anxious attachment and social integration is mediated by greater social threat expectancies*

Study 1B, males: The indirect effect of anxious attachment on belongingness via threat expectancies was not significant, *ab* = -0.09, 95% CI = -0.25, 0.06. The proposed mediator accounted for less than 15% of the total effect, $P_M = .12$.

Study 1B, females: The indirect effect of anxious attachment on belongingness via threat expectancies was not significant, *ab* = -0.16, 95% CI = -0.45, 0.06. The proposed mediator accounted for 15% of the total effect, $P_M = .15$.

4.8.3 Discussion

Social reward expectancies were found to mediate the link between extraversion and social integration, both in terms of SNI-number and sense of belonging. Conversely, social threat expectancies partially mediated the link between neuroticism and reduced belongingness. Similarly, the link between BIS and reduced belongingness was partially mediated by threat expectancies in males, and fully mediated by threat expectancies in females in the present sample.

Less support was found for the hypothesis that the link between BAP-aloof and social integration would be mediated by lower social reward expectancies. Partial mediation by reward expectancies was found for the link between BAP-aloof and SNI-number, but there was no significant indirect effect via reward expectancies for belongingness.

Little support was found for the hypotheses that links between attachment style and social integration may be mediated by expectancies. Reduced social reward expectancies partially mediated the link between avoidant attachment and reduced sense of belonging in female participants; this effect was not significant in males. No support was found for the hypothesis that greater social threat expectancies would mediate the association between anxious attachment and reduced belongingness.

The results reported in this section indicate that links between broad affective dispositions (extraversion, neuroticism and BIS) and social integration are partially explained by associated individual differences in valenced social expectancies. It appears that more specifically social/interpersonal traits (BAP-aloof, attachment style) exert most of their influence upon social integration via pathways that are not captured by expectancies. The amount of the total effect of these variables upon integration explained by expectancies was generally about 15% in the models tested here.

4.9 Conclusion

Having ascertained that the LODESTARS represents an internally consistent and reliable measure of dispositional social reward and threat expectancies, this chapter proceeded to describe work examining the construct validity of the LODESTARS. The strong and consistent patterns of results found in the studies reported here demonstrate that the LODESTARS has good psychometric properties and represents a valid instrument for studying individual differences in dispositional social expectancies.

Most of the inter-correlations between LODESTARS scores and constructs relating to self-concept, affective dispositions and attachment are consistent with those found by MacDonald et al. (2011), using their original STARS measure. As noted in section 4.3.3, Study 1A failed to replicate MacDonald et al.'s finding of a negative correlation between STARS-reward and attachment avoidance. However subsequent studies (1B, Imaging and Autumn 2014) all demonstrate negative correlations between LODESTARS-reward and attachment avoidance, so it seems the early non-significant result may have been an anomaly of the Study 1A data.

Across all studies conducted to date, LODESTARS-reward scores have been found to correlate with LODESTARS-threat scores. This represents a point of psychometric divergence of the LODESTARS measure from the STARS. It is speculated that this has arisen due to the different form of the anticipated social interaction. Compared with the STARS procedure, participants responding to the LODESTARS may be relatively more invested in the social outcomes of the anticipated interactions. Respondents completing the LODESTARS are asked to imagine interacting with members of a club or society that they have chosen to join. In this scenario a failure to bond (i.e. lack of social reward) may be experienced as threatening or painful – even in the absence of actual rejection. Low expectancies of social reward may thus be tied to higher expectancies of social threat and perhaps vice versa, which would result in the observed LODESTARS threat-reward correlations.

While linked with other constructs, it appears the expectancies measured by the LODESTARS are not reducible to constructs like attachment style, nor to Big Five personality dimensions such as extraversion or neuroticism. Correlations between the LODESTARS variables and these other constructs are moderate to strong (Evans, 1996), rather than very strong or indicative of singularity or redundancy. Further, the mediation models estimated in sections 4.7 and 4.8 demonstrate the usefulness of expectancies in predicting motivation and behaviour, and of the LODESTARS as a measure of these expectancies. Given that a great deal of human behaviour may be predicted by individual differences in social expectancies, levels of dispositional expectancies of social threat and reward represent important constructs for further investigation. Understanding the mechanisms, including the biological mechanisms, by which expectancies are linked to differences in motivation, behaviour and ultimately outcomes, is an important avenue for further investigation. This is explored in Chapter 5.

Chapter 5

Relating individual differences in social threat and reward expectancies to human brain structure

5.1 Introduction

In the previous chapter I described a measure of social threat and reward expectancies, the LODESTARS. The results presented in Chapter 4 demonstrate that these expectancies have independent, although functionally related, associations with a host of individual difference and personality variables such as attachment style, personality and self-esteem. Further, LODESTARS scores are strongly associated with individuals' social integration, in terms of social network size and complexity, as well as individuals' own perceptions of how socially integrated they are – how well they feel they belong (see Table 4.21).

Individuals' social reward and threat expectancies are quite stable over time (Table 4.9; Fig. 4.2) and are associated with other stable traits such as self-esteem and autism-like characteristics. Given this stability it seems likely that these expectancies would be associated with stable, structural aspects of the brain. In this chapter I assess whether social reward and threat expectancies have distinct neural correlates by examining associations between LODESTARS scores and individual differences in brain structure. I examine regional grey matter volume (GMvol) across the brains of 100 participants and test whether there are regions in which individual differences in GMvol correlate with LODESTARS scores.

Little is known about the biological bases of generalized social expectancies, per se. Previous brain-imaging work, constituting mainly functional MRI (fMRI) studies (e.g. Gossen et al., 2014; Rademacher et al., 2010; Spreckelmeyer et al., 2009), has tended to focus on short-term *anticipation* of social reward *in the presence of external cues.*

The most consistent and robust finding from this work is that the ventral striatum (VS), and particularly a sub-region of it called the nucleus accumbens (NAcc), is activated during cued anticipation of social rewards (Baez-Mendoza & Schultz, 2013; Gossen et al., 2014; Rademacher et al., 2010; Spreckelmeyer et al., 2009). VS/NAcc activation is not specific to anticipation of social reward; an extensive literature demonstrates that this region is recruited by cued anticipation of many different types of reward (Haber, 2011; Haber & Knutson, 2009; Kirsch et al., 2003; Knutson, Adams, Fong, & Hommer, 2001; Knutson, Fong, Adams, Varner, & Hommer, 2001; Knutson & Greer, 2008; Rademacher et al., 2010; Spreckelmeyer et al., 2009). The extent of anticipation-related activation in the NAcc has been found to correlate positively with expected reward value (Knutson, Adams, et al., 2001; Spreckelmeyer et al., 2009) and to vary with individuals' subjective preferences (Clithero, Reeck, Carter, Smith, & Huettel, 2011; Kim, Adolphs, O'Doherty, & Shimojo, 2007; O'Doherty, Buchanan, Seymour, & Dolan, 2006). NAcc activation during the anticipatory phase of cued reward paradigms therefore appears to signal motivational salience, possibly in terms of the individual's positive anticipatory affect at the prospect of gaining the reward in question (Gossen et al., 2014; Knutson & Greer, 2008).

There is extensive evidence that the VS/NAcc encodes the motivational value of stimuli, in terms of a 'final common currency' which can then be used in initiating or adjusting goal-directed behaviours (Sescousse, Li, & Dreher, 2014). The term 'motivation,' taken literally, describes "an impulse to movement – as when the expectation [anticipation] of a desired outcome mobilizes someone into action" (Clithero et al., 2011, p.1). This is a very good account of the probable role of the VS in goal-directed (motivated) behaviour. The VS receives inputs from all components of the valuation system (Haber, 2011; see also Chikama, McFarland, Amaral, & Haber, 1997; Maioli, Squatrito, Battaglini, Rossi, & Galletti, 1983). The striatum is a component of the basal ganglia, a set of subcortical structures necessary for the control of voluntary movement (Baez-Mendoza & Schultz, 2013; Nolte, 2008). The motivational values encoded by the VS/NAcc are computed irrespective of the specific features of potential rewards (Sescousse et al., 2014) and are not directly accessible to conscious awareness (Ochsner & Gross, 2014). The core-level valuations that are computed by the VS are mainly useful for guiding habitual behaviour (Sescousse et al., 2014). Beyond being a 'reward centre' the striatum may play a more general role in mediating habitual action responses (Denny, Silvers, & Ochsner, 2009; Fernandez-Ruiz, Wang, Aigner, & Mishkin, 2001).

The VS/NAcc is thus a key region for motivation, but not for expectancies. At least, not for contextual or conceptual expectancies that are consciously accessible and reportable. Forming a conscious valenced expectancy – as of social threat and/or reward – involves performing a valuation of the concept (social scenario) and expected outcome(s), such as meeting new people. Appraisal of value takes place at many levels within the brain (Ochsner & Gross, 2014) and can occur in response to internally or externally generated stimuli. Ochsner and Gross (2014) propose that a given stimulus may give rise to multiple valuations, which vary along a continuum of representational complexity.

Generating valuations and LODESTARS expectancies may be relatively transient and situation-specific; however there is a component of them that is influenced by individuals' dispositional affective tendencies and stable working models of self and others. The stable component is probably more tapped by the LODESTARS than the original STARS, as the LODESTARS was specifically designed to probe participants' expectancies for interactions with relatively generic others (with whom the participant is motivated to interact) in a generic social event context.

The stable component of individual differences in social threat and reward expectancies seems likely to reflect affective/emotional biases in valuations associated with social scenarios. Thus brain regions implicated in the computation of subjective value may be involved in the generation of valenced social expectancies.

5.1.1 Brain regions involved in valuation.

According to Ochsner and Gross's (2014) framework, the continuum of interacting valuations ranges from core level valuations comprising relatively direct links between stimuli and basic physiological and action responses, to contextual level valuations that place stimuli and core valuations within the present context, to conceptual level valuations that represent stimulus values in belief-desire terms that may be verbalisable and consciously reportable.

Core valuations recruit primarily subcortical brain regions (VS and amygdala) as well as the anterior insula (Ochsner & Gross, 2014; see Fig. 5.1). Contextual valuations assess stimuli (which may include core and conceptual valuations) in combination with the individual's previous experience (historical context) and their current social and motivational contexts. Ochsner and Gross postulate that these valuation processes engage the orbitofrontal cortex (OFC), ventromedial prefrontal cortex (vmPFC), the superior temporal sulcus/temporoparietal junction (STS/TPJ), and the anterior insula (see Fig. 5.1). The OFC and vmPFC receive inputs from the brain structures involved in core valuation, as well as from the medial temporal lobe (MTL) and cortical association areas involved in memory. The inputs from MTL and association cortices provide information on the historical and current temporal and spatial contexts (Davachi, 2006; Murray et al., 2007, as cited in Ochsner & Gross, 2014). The vmPFC/OFC can integrate this information in appraising the value of stimuli in the context of the individual's current state and situation. Bechara, Damasio, Tranel, and Damasio (1997) proposed a similar role for the vmPFC in linking emotional and cognitive processes in decision-making, by accessing and integrating records of previous individual experiences shaped by reward, punishment, and the emotional states attending them.

The anterior insula connects with all the other brain regions involved in core and contextual valuations (Augustine, 1996; Chikama et al., 1997); its role in contextual valuations is to assimilate and make available to awareness information about current body states, particularly in relation to one's current affective state (Ochsner & Gross, 2014). The posterior STS/TPJ is a multisensory association region (Bonner, Peelle, Cook, & Grossman, 2013; Bzdok et al., 2013) which plays a central role in modulating social attention (Nummenmaa & Calder, 2008). This region compares expectancies with feedback, and adjusts attention accordingly (Ochsner & Gross, 2014). This includes situations in which expectations about the beliefs, intentions and actions of others must be updated (Behrens, Hunt, & Rushworth, 2009; Behrens, Hunt, Woolrich, & Rushworth, 2008; Hampton, Bossaerts, & O'Doherty, 2008).

Contextual valuations indicate whether an object or situation is desirable or undesirable in the present context, so whether it should be approached or avoided at the current time (Ochsner & Gross, 2014). Valuations at this level are important for affective learning, in determining if and how the value of a stimulus changes across different contexts. One form of contextual valuation that has received a great deal of research interest is fear extinction. In this paradigm, an organism learns that a stimulus that was previously associated with an aversive outcome no longer is – and can therefore now be valued less negatively. Impairments in fear extinction – i.e. problems with adaptively changing or updating threat expectancies – may result in excessive or disproportionate fear, perhaps of the sort that characterises clinical anxiety. Indeed, individuals higher in self-reported rejection sensitivity have been found to be relatively resistant to fear extinction learning for social threat stimuli (Olsson, Carmona, Downey, Bolger, & Ochsner, 2013). One component of increased rejection sensitivity is heightened social threat expectancies (along with tendencies to more readily perceive social rejection and to react strongly to it). Individual differences in neural systems subserving fear extinction may therefore be instrumental in maintaining dispositional levels of generalised social threat expectancies.

Successful fear extinction (i.e. resulting in diminished negative affect) has consistently been found to engage the vmPFC (Buhle et al., 2014; Diekhof, Geier, Falkai, & Gruber, 2011). In addition, brain structure studies have linked the size (amount of grey matter) of the vmPFC to individual differences in fear extinction learning. Greater GMvol and/or cortical thickness in this region is associated with stronger fear extinction learning and retention (Hartley, Fischl, & Phelps, 2011; Milad et al., 2005). That is, individuals with relatively larger vmPFCs are generally more proficient at flexibly updating acquired expectations of threat and modulating fear/anxiety accordingly. I hypothesise, therefore, that greater GMvol in the vmPFC region may be correlated with lower social threat expectancies as measured by the LODESTARS. More generally, it seems that contextual valuations are strongly interlinked with expectancies. I hypothesise that GMvol variation in brain regions involved in the computation of contextual values may be correlated with individual differences in the LODESTARS measures of social expectancies.

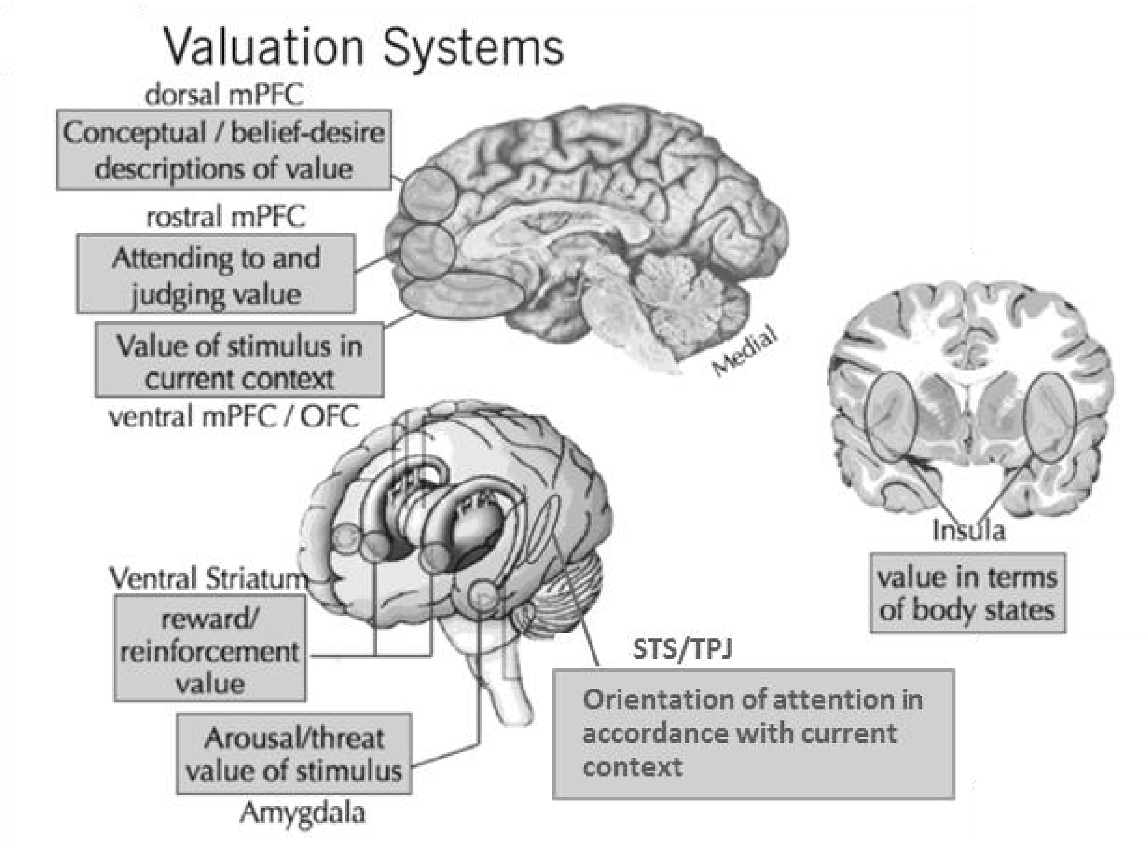

Figure 5.1: Brain regions involved in valuation.
Adapted from Ochsner & Gross (2014), p 26.

At the highest level of the continuum proposed by Ochsner and Gross (2014) are conceptual level valuations. These are representations of stimulus values and affective states that are generalised across exemplars and contexts and are available to conscious awareness in language-like mental representations of beliefs and desires. Conceptual valuations can be verbalised using ‘belief-desire’ language. For example, a conceptual valuation of ‘public speaking’ may in some individuals activate a conceptual representation of ‘fear,’ which can then be reported using that word.

Dorsal and rostral regions of the medial prefrontal cortex (mPFC) are critical to the formation of conceptual valuations, according to Ochsner and Gross's (2014) framework (see Fig. 5.1). The mPFC has been strongly implicated in making judgements about the affective meaning of stimuli, including internal mental states (Denny et al., 2009). The mPFC has been found to be strongly engaged when participants make self-referential judgements (Gusnard, Akbudak, Shulman, & Raichle, 2001), although it is also consistently activated when making judgements about others (Denny, Kober, Wager, & Ochsner, 2012; Mitchell, Banaji, & Macrae, 2005; Saxe & Powell, 2006). It appears that rostral and dorsal mPFC regions process explicit conceptual representations of socially or emotionally relevant information about oneself and others (Denny et al., 2009; Mitchell et al., 2005; Saxe & Powell, 2006; Van Overwalle, 2009). Such explicit conceptual representations, in the form of expectations and associated anticipatory affect, are measured by the LODESTARS. I therefore hypothesise that GMvol variation in rostral and dorsal mPFC regions may be correlated with individual differences in LODESTARS social expectancy scores.

5.1.2 Separate neural systems for reward and threat?

Up to this point, this chapter has primarily focused on brain regions implicated in valuation, with little discussion of whether different regions may be specifically involved in valuation of positive versus negative stimuli. Yet the concepts of a specialised ‘reward system’ (Haber, 2011; Kohls, Chevallier, Troiani, & Schultz, 2012) and, to a lesser extent, an ‘aversion system’ (Hayes & Northoff, 2011) are widespread in the neuroimaging literature, and have received a great deal of empirical support.

At the level of core valuations and behavioural mobilisation/adjustment, it makes sense that neural circuits motivating approach and avoidance would be distinct. One cannot approach and avoid a stimulus at the same time, and behaviour is thought to result from the relative strengths of competing signals. Thus there may be a 'push-pull' mechanism between activity in a reward-sensitive system motivating social approach, versus a threat-sensitive system motivating social aversion (Vrtička & Vuilleumier, 2012). Core valuations subserving rapid or automatic processing of information in terms of 'desirable/wanted' or 'threatening/dangerous,' may be intrinsically connected to behavioural approach or avoidance systems, respectively. In support of this, a vast body of evidence supports the role of the VS/NAcc in reward processing (Diekhof, Kaps, Falkai, & Gruber, 2012; Haber, 2011) and of the amygdala in threat processing (Bishop, 2007; Hayes & Northoff, 2011; Nitschke, Sarinopoulos, Mackiewicz, Schaefer, & Davidson, 2006).

Beyond the level of core valuations however, the support for valence-specialised brain regions becomes less consistent. The medial orbitofrontal cortex (mOFC) is often associated with reward (Diekhof et al., 2012; Rolls, 2000; Sescousse, Redouté, & Dreher, 2010). However, the mOFC is also implicated in a regulatory capacity in the context of aversion processing, for instance in fear extinction, as described earlier. Similarly, the anterior insula and dorsal anterior cingulate cortex (dACC) are commonly associated with aversion and negative affect (Hayes & Northoff, 2011), including rejection-related distress (DeWall et al., 2012; DeWall & Bushman, 2011; Eisenberger, Lieberman, & Williams, 2003). But these regions have also been found to activate during the induction of happiness (Damasio et al., 2000). Recruitment of both dACC and insula are frequently reported for a variety of emotional tasks including emotion regulation tasks. Damasio et al. (2000) suggest that these regions monitor the ongoing internal affective state of the organism. This is elaborated by Ochsner and Gross (2014) who posit that the insula represents information about body states and that the dACC monitors conflicts between competing responses, regardless of whether these are affective or cognitive (Denny et al., 2009).

Thus the notion that there is a dedicated 'reward network' and a separate 'aversion network' comprising distinct neural structures seems not to reflect the data (Lindquist, Satpute, Wager, Weber, & Barrett, 2015), with the possible exception of core valuations in the VS/NAcc and amygdala. However, even these brain regions have been implicated in processing both rewarding and aversive stimuli (Hayes, Duncan, Xu, & Northoff, 2014). Indeed, Bickart, Dickerson, and Feldman Barrett (2014) argue that the amygdala functions as a hub within neural networks supporting both social aversion and affiliation. It is likely that different sub-regions of the amygdala, and of all the macro-anatomical regions implicated in valuation, are involved in processing both rewarding and aversive stimuli (Hayes et al., 2014; Lindquist et al., 2015; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001; John O'Doherty, Critchley, Deichmann, & Dolan, 2003).

On the basis of a meta-analysis of 72 human brain imaging studies in tandem with targeted review of functional neuroanatomy in other mammals (rodents and non-human primates), Hayes et al. (2014) concluded that appetitive and aversion-related valuation processes are dissociable but interconnected. That is, valuation systems are distributed across many cortical and subcortical brain regions, each of which contains dissociable, but interconnected, circuits for appetitive and aversion-related processes. It may be that some brain regions (e.g. the dACC) contain relatively more aversion-related circuits, while others (e.g. VS) have relatively more reward-related circuits. These relative biases of brain valuation regions towards reward or threat processing may be what is most commonly detected in human neuroimaging studies. This hypothesis is supported by the findings of Lindquist et al. (2015), who conducted a meta-analysis of 397 human functional neuroimaging studies on valence. Their results suggested that, at the level of brain activity measurable by fMRI/ positron emission tomography (PET), valence is flexibly encoded across instances by a set of valence-general brain regions. Of these, the vmPFC appeared to have a slight relative preference for positive valence, while left amygdala and left anterior insula demonstrated relatively more consistent increases during negativity than during positivity (Lindquist et al., 2015).

It would not be surprising, given previous findings, if higher social reward and threat expectancies were found to be associated with greater GMvol in regions typically associated with reward and aversion, respectively. However, given the more nuanced picture of neural valuation networks that is emerging, I did not have strong directional hypotheses regarding this.

5.1.3 Modulation of valenced social expectations by dispositional affective biases and attachment style

As discussed, forming expectancies will involve evaluation of the anticipated future scenario. Social expectancies will also be based upon one's stable representations (working models) of oneself and others. In this way, individuals' valenced expectancy biases will be influenced by their attachment style.

As described in Chapter 4, attachment style is systematically associated with social reward and threat expectancies. Avoidant attachment is related to lower expectations of social reward, whereas anxious attachment is linked to higher social threat expectancies. Corroborating this at the level of the brain, Vrtička, Andersson, Grandjean, Sander, and Vuilleumier (2008) found that reward-related activity in the VS and ventral tegmental area in response to positive social feedback (praise) was relatively weak or even absent in individuals high in attachment avoidance (see Fig. 5.2). Further, amygdala activity associated with negative social feedback correlated positively with anxious attachment (shown in Fig. 5.2), suggesting increased sensitivity to social punishment. Similarly, DeWall et al. (2012) used the Cyberball paradigm (Williams & Jarvis, 2006) to investigate whether neural responses to social rejection are modulated by attachment style. They observed heightened activation in anterior insula and dACC in individuals higher in anxious attachment. Perhaps of particular relevance to the LODESTARS, Gillath, Bunge, Shaver, Wendelken, and Mikulincer (2005) conducted an fMRI study in which they examined brain activity associated with imagined social rejection and interpersonal conflict. In individuals higher in anxious attachment, they found greater responses in brain regions typically involved in negative affect and stress (namely anterior temporal pole, dACC and hippocampus), and lower OFC activation, which they interpret as indicating reduced emotion regulation (Gillath et al., 2005). These findings regarding the correlation of attachment anxiety with relative degree of neural activation while thinking negative thoughts held even when neuroticism, trait anxiety, and attachment avoidance were controlled for. Overall, the available data from functional neuroimaging research provides compelling evidence that attachment anxiety is associated with enhanced recruitment of social threat circuits in response to negative social cues (Vrtička & Vuilleumier, 2012). This accords with previous work indicating heightened vigilance to social-emotional cues in individuals higher in anxious attachment (Mikulincer & Shaver, 2007; Vrtička & Vuilleumier, 2012).

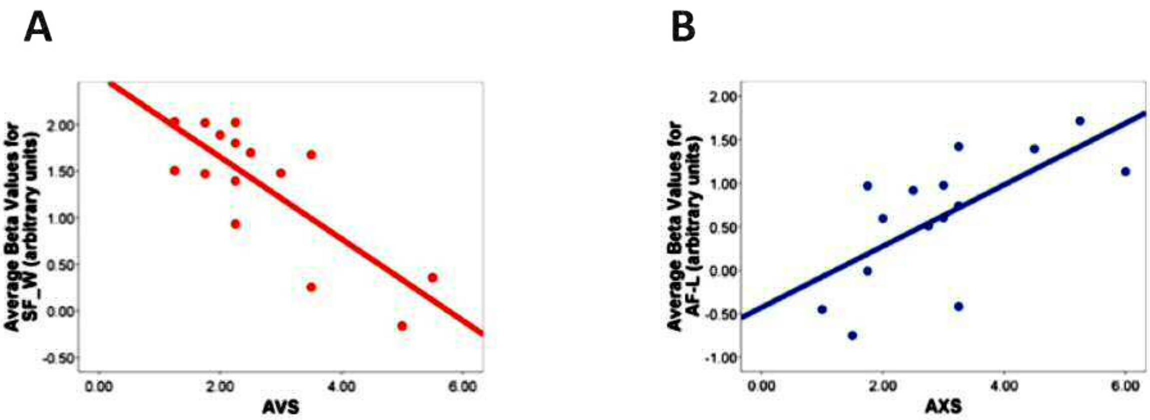

Figure 5.2: A. Negative correlation between avoidant attachment style (AVS) scores and ventral striatum response during perception of positive social feedback.
B. Positive correlation between anxious attachment style (AXS) scores and amygdala response during perception of social punishment.
From Vrtička & Vuilleumier (2012), p 7.

As far as I am aware, only two studies have investigated brain structural correlates of individual differences in attachment style. Quirin, Gillath, Pruessner, and Eggert (2009) found that both attachment anxiety and avoidance were related to a reduced grey matter in the hippocampus. This finding is compatible with the function of the hippocampus in stress responses (Lucassen et al., 2013) and with evidence of greater stress reactivity and/or less effective stress regulation in insecurely attached individuals (Mikulincer & Shaver, 2007).

Benetti et al. (2010) found that high attachment anxiety was associated with reduced grey matter in right anterior temporal cortex (ATC) and increased grey matter in left lateral orbitofrontal cortex. This concurs with previous work linking decreased right ATC volume to self-defeating core beliefs in young adults who reported that their emotional needs were not met by their mothers during childhood (Van der Veek, Van der Leij, Van der Leij, & Scholte, 2011). The lateral OFC is involved in regulating both positive and negative emotions (Mak, Hu, Zhang, Xiao, & Lee, 2009); hyperactivation of this region has been implicated in anxiety disorders (Busatto et al., 2000; Stein, Arya, Pietrini, Rapoport, & Swedo, 2006). Benetti et al. found no regions that were positively or negatively associated with attachment-avoidance that survived correction for multiple comparisons across the whole brain. At a lowered statistical threshold of $p < 0.001$ (uncorrected for multiple comparisons), they detected a trend-level positive correlation in the left superior temporal gyrus. Benetti et al. interpret their findings as indicating that differences in attachment style are associated with differences in the neural structure of regions implicated in emotion regulation.

In an analysis of brain structural correlates of generalized anxiety disorder (GAD) Strawn et al. (2013) found reduced GM volume in left mOFC in a sample of 15 adolescents with GAD (4 of whom had comorbid social phobia). Similarly in adults, Kühn, Schubert, and Gallinat, (2011) found a negative correlation of self-reported trait anxiety with cortical thickness in the right mOFC and a positive correlation with the bilateral volume of NAcc. Cortical thickness measures extracted from mOFC were negatively associated with the volume of left NAcc. Although these studies were of generalised, rather than attachment-specific, anxiety, these results are again suggestive of a relative impairment in emotion regulation in more anxious individuals, perhaps resulting in heightened subjective salience of emotional stimuli and heightened arousal. Interestingly these authors found no association of amygdala volume with trait anxiety/GAD.

5.1.4 Differential susceptibility and subjective salience

The functional and structural findings described above converge with behavioural evidence that individuals higher in attachment avoidance rate positive social information as less pleasant (Vrtička, Sander, & Vuilleumier, 2012) and less arousing (Rognoni, Galati, Costa, & Crini, 2008), while anxious attachment is associated with higher arousal ratings for negative social images and video-clips (Rognoni et al., 2008; Vrtička et al., 2012). In Vrtička et al.'s (2012) study, the higher arousal ratings reported by more anxiously attached individuals were not specific for negative social images; these individuals registered higher arousal ratings for all stimulus categories (which comprised social-positive, plus non-social-positive and non-social-negative in addition to social-negative).

It may be, therefore, that while some mechanisms mediating social reward sensitivity are independent of mechanisms underpinning social threat sensitivity, others may mediate heightened (or reduced) sensitivity to both. This is supported by evidence from psychological genetic studies that alleles associated with greater sensitivity to social stressors such as rejection may also confer greater sensitivity to positive stimuli such as social reward or support (Falk, Way, & Jasinska, 2012). It is possible that, in addition to sub-regions containing circuits dedicated to social-reward processing, social-threat processing and social-pain processing, brain regions involved in valuation may also contain circuits dedicated to salience (Falk et al., 2012). Incorporating both social threat and reward in the same design, as was done throughout this my PhD research, better enables us to distinguish brain regions in which structure or function varies with reward specifically, threat specifically, or with salience. See section 5.2.2.3 and Fig. 5.3 for further elaboration on this.

5.1.5 Summary of hypotheses

As far as I am aware, this is the first study to investigate the brain structural correlates of social expectancies. I hypothesised that individual differences in social threat and reward expectancies would be reflected in the regional GM anatomy supporting the formation and elaboration of subjective value. I hypothesised that individual differences in GMvol associated with LODESTARS scores would be more manifest in regions mediating contextual and conceptual level valuations, rather than core level valuation systems.

One of the most consistent findings from related work conducted thus far is that the vmPFC/mOFC region is implicated in regulating social (and non-social) anxiety. I hypothesised that lower social threat expectancies would correlate with greater GMvol in this brain region.

Conversely, higher social threat expectancies may be associated with greater GMvol in brain regions in which structure and/or functional activation has previously been found to be positively correlated with attachment anxiety. These include lateral orbitofrontal cortex and anterior insula.

5.2 Methods

5.2.1 Participants

100 participants gave written informed consent to take part in the experiment. Their demographic details are displayed in Table 5.1.

Number	Gender	Age
100	26 M 74 F	Mean: 24.25 Range: 18 - 54

Table 5.1 Demographic details for the sample of individuals who participated in the LODESTARS VBM study.

5.2.2 Voxel-based morphometry methods

VBM is a method which enables researchers to identify local individual differences in brain tissue composition, while discounting large-scale differences in gross anatomy and position (Mechelli, Price, Friston, & Ashburner, 2005). VBM analysis yields a quantitative measure, for each participant at each voxel, of the tissue volume (e.g. GMvol) per unit volume of the spatially normalised brain image. These values can then be analysed to identify regions in the brain where GMvol significantly differs between groups or co-varies with a predictor of interest. In the present analysis, the predictor variables of interest are social threat and reward expectancies as measured by the LODESTARS.

5.2.2.1 *Image acquisition*

High-resolution T1-weighted anatomical images for each participant were acquired using a 3-Tesla HDx MRI scanner (manufactured by General Electric) at Cardiff University Brain Research Imaging Centre (CUBRIC), School of Psychology, Cardiff University. The three-dimensional T1-weighted whole-brain images were acquired using a fast spoiled gradient echo sequence (FSPGR) with $1 \times 1 \times 1$ mm^3 voxel size and between 168 and 182[1] contiguous slices. In all cases, the image acquisition parameters were as follows: repetition time (TR) = 7.8 ms echo time (TE) = 2.984 ms; inversion time = 450 ms; flip angle = 15°; data matrix = 256 × 192. These data were acquired between July and December 2013, usually within one week[2] of the participant completing the LODESTARS.

5.2.2.2 *Image analysis*

The VBM analysis was performed using SPM12 (Wellcome Trust Centre for Neuroimaging, http://www.fil.ion.ucl.ac.uk/spm/software/spm12/) implemented in MATLAB version R2012b (The MathWorks). The analysis proceeds by segmenting each participant's structural T1-weighted MR images into grey matter, white matter and cerebrospinal fluid; normalising all the image segments of interest (in this case, the grey matter segments) to the same stereotaxic[3] space, spatially smoothing these grey matter images, and finally performing statistical analyses. The outputs are statistical parametric maps (SPMs) showing regions where grey matter volume significantly co-varies with the predictors of interest. The details of these steps as implemented in the present analysis are outlined next.

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[1] 75 participants had scans of 168 slices; 15 had 172 slices; 2 had 176 slices; 5 had 178 slices; 3 had 182 slices.

[2] 32 participants were not scanned within one week of completing the LODESTARS. The longest gap between LODESTARS completion and structural MRI scan was 164 weeks.

[3] **Stereotaxis** (*n.*): A method in neurosurgery and neurological research for locating points within the brain using an external, three-dimensional frame of reference (The American Heritage Dictionary, 2014).
Stereotaxic (*adj.*): Of or pertaining to precise measurements in three dimensions of a place in the brain (Random House Webster's College Dictionary, 2010).

Segmentation

Classification (i.e. segmentation) of brain tissue into grey matter, white matter and cerebrospinal fluid was carried out for each image using the 'unified segmentation' set of algorithms in SPM12. For the grey matter (GM) and white matter (WM) segments, images in native space at the resolution of the original scans were produced, along with some lower resolution ($1.5 \times 1.5 \times 1.5$ mm^3 voxel size) roughly aligned versions to be used in the spatial registration step that follows.

Spatial normalisation and smoothing

Spatial normalisation is the procedure whereby the individual GM segments are brought into a common space via registration to a standard stereotactic atlas. This ensures voxel-wise correspondence across different brains. The normalised grey matter maps for the present VBM were created using the diffeomorphic anatomical registration through exponentiated lie-algebra (DARTEL) registration method in SPM12 (Ashburner, 2007). Before registering the participants' brain scans to a standard atlas, DARTEL first creates an average template of the brains. The purpose of this is to increase the accuracy of inter-participant alignment by modelling the shape of each brain using millions of parameters (three parameters for each voxel). DARTEL then estimates the nonlinear deformations that will best align all these brains together. This is achieved by aligning GM among the brain images, while simultaneously aligning WM, using the roughly aligned tissue class images produced during the segmentation step. By this method, DARTEL generates its own increasingly crisp average template data, to which the tissue segments are iteratively aligned. DARTEL alternates between building a template, then registering the tissue class images with the template, then building an improved template. During this iterative process, DARTEL creates a 'flow-field' (deformation matrix) for each participant, which specifies how the individual GM and WM images should be warped to best match the average shape of the template. The final template that is generated reflects the 'common average' of the brains in the experimental cohort, but it may not be well-aligned to a standard neurological space. In order for the results of a study to be generalizable, the data need to be in a standard 3D space. In SPM this is accomplished by ‘normalising’ the images into the space defined by the Montreal Neurological Institute (MNI) template.

DARTEL’s ‘Normalise to MNI Space’ module incorporates an affine transform that registers the cohort-specific average template to MNI space. The native-space GM images produced during segmentation are then converted to MNI space using this affine transform[4] and the DARTEL flow-fields. Spatial normalization introduces local volume changes to the tissue segments (some regions must be expanded, and others compressed, in order to fit the template). The original anatomical differences are, however, encoded by the deformation matrices recorded by DARTEL. By using this information and applying a ‘modulation’ (multiplying the normalised grey matter segments by corresponding Jacobian determinants[5] from the participants’ deformation matrices), the induced volume changes will be corrected and the original local GM volumes within each voxel will be preserved, even in the new space. For example, if one participant's amygdala is much larger than the group average, the large deformations required to warp this structure to the common template will multiply the GMvol voxel values of this region. Thus the voxel values from any region following modulation can be interpreted as the tissue volume per unit of spatially normalised image (Ashburner & Friston, 2000). So in effect, analysis of modulated VBM data tests for regional individual differences in the absolute volume of grey matter (Ashburner & Friston, 2000).

Spatial smoothing is also applied during DARTEL’s ‘Normalise to MNI’ step. That is, the normalised tissue segments are convolved with a Gaussian function. This ensures that any random errors in the data have a normal (Gaussian) distribution, which is a prerequisite for parametric tests. Smoothing compensates for any small inaccuracies in spatial normalisation (even high-dimensional DARTEL does not yield images with perfect voxel-wise correspondence) by ‘blurring’ the effects (volume indices) across neighbouring voxels. Smoothing determines the spatial scale at which

[4] An affine transformation maps variables (e.g. voxels) located, for example, at positions in an input image into a new variable (e.g. in an output image) by applying a combination of translation, rotation and scaling and/or shearing (i.e. non-uniform scaling in some directions) operations.

[5] When one changes co-ordinate systems, one’s data is stretched and warped. Jacobian determinants keep a record of the stretching and warping that has occurred.

effects are most sensitively detected in order to discriminate true effects from random noise; therefore the size of the smoothing kernel should be similar to the size of expected effects. We employed a Gaussian kernel of 8 mm full width at half maximum. An 8 mm smoothing kernel is optimal for detecting morpho- metric differences in both large and small neural structures (Honea, Crow, Passingham, & Mackay, 2005). Larger smoothing kernels (10–12 mm) are likely to miss group differences in small structures, whereas smaller kernels (4–6 mm) can produce false positive findings (Honea, Crow, Passingham, & Mackay, 2005). The spatially normalised, modulated and smoothed grey matter segments constitute the input for the voxel-wise statistical analyses.

5.2.2.3 Statistical analyses

Statistical analysis was conducted using a general linear model (GLM) framework. The pre-processed GM images (one per participant) were entered as the dependent variables into multiple regression models in SPM12. These models were then estimated for each voxel in the brain to determine brain regions in which GMvol showed significant co-variation with LODESTARS-threat and/or LODESTARS-reward scores. In addition to the regressors of interest, it is important to include within the GLM covariates of no interest (for the present study) that may affect the interpretation of differences in regional GMvol (Barnes et al., 2010). Overall differences in brain volume were accounted for by applying proportional scaling. This scales each voxel's GMvol value so that it is proportional to the fraction of that participant's total brain volume accounted for by that piece of grey matter (Ashburner, 2010). The resulting voxel values are proportions of total GM volume.

It is known that men generally have larger overall brain volumes and global GM proportions than women (Luders, Gaser, Narr, & Toga, 2009). Further, there are systematic regional GMvol differences between the genders: a number of regions have been identified in which women typically have larger proportional GM volumes than men, and vice versa (Gur, Gunning-Dixon, Bilker, & Gur, 2002; Luders et al., 2009; Ruigrok et al., 2014; Schlaepfer et al., 1995). In the regression models used in the present analyses, a covariate indicating gender was included to account for such effects. Regional GMvol also varies with age, and this interacts with gender: some brain regions show age-associated volume reduction in adults and there is evidence that this occurs faster in men than women, especially for certain cortical regions (Good et al., 2001; Gur, Gunning-Dixon, Turetsky, Bilker, & Gur, 2002). Age was therefore included as a covariate in the GLMs for the present analyses.

A binary MNI brain mask (SPM8 brainmask.nii) was used to restrict the analysed volume to voxels within the brain. T-statistic maps (SPMs) were created to show the correlations between regional GMvol and each regressor of interest.

Inference as to whether regional GMvol significantly correlates with one or both regressors of interest requires that both LODESTARS-reward and threat scores be included within the same model. If we were interested solely in identifying brain regions in which GMvol is associated with either reward or threat expectancies, a reasonable approach would be to run two models, one with LODESTARS-reward as the only regressor of interest, and one with LODESTARS-threat as the only regressor of interest:

$$GMvol = \alpha + b_0\ LODESTARS\_reward + b_1\ age + b_2\ gender$$

$$GMvol = \alpha + b_0\ LODESTARS\_threat + b_1\ age + b_2\ gender$$

This approach would yield information about where in the brain individual differences in social threat expectancies are correlated with GMvol and, independently, where in the brain social reward expectancies are correlated with GMvol. However, this method causes problems for distinguishing between brain regions in which GMvol specifically correlates with threat <u>or</u> reward expectancies, versus regions in which GMvol correlates with individual differences in arousal, or subjective salience, associated with anticipated social scenarios. It is difficult to disambiguate these patterns using models which only involve reward or threat, as the predictions of the different hypothesised patterns overlap in such models (Bartra, McGuire, & Kable, 2013; see Fig. 5.3). That is, brain regions involved in expectancies may process expectancy information specifically for reward (e.g. reward magnitude), specifically for threat (e.g. likelihood of threat outcome), or they may encode attributes such as the salience of the anticipated outcome, irrespective of its valence (Bartra et al., 2013).

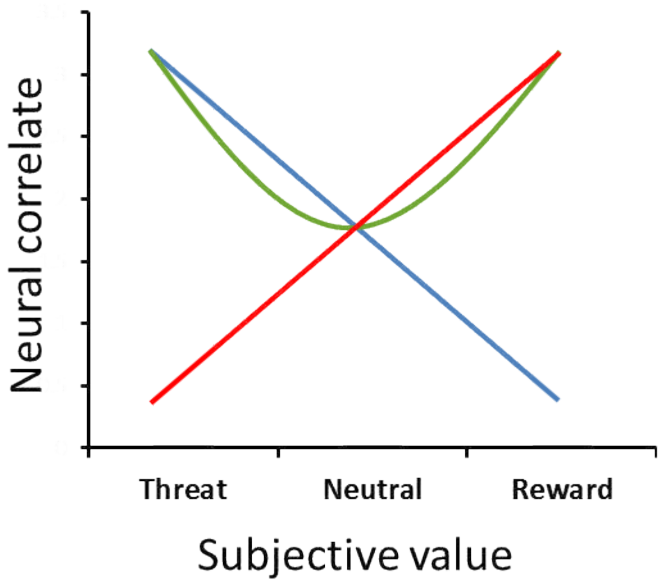


Figure 5.3: Three hypothetical profiles for neural correlates of subjective value (SV). The red line represents monotonically increasing neural response/GMvol correlated with more rewarding expected outcomes, while the blue line represents the opposite linear pattern: greater response/GMvol associated with more threatening potential outcomes. The green line represents a greater response to more extreme potential outcomes, either rewards or threats.

Modified from Bartra et al., 2013

As there are both threat- and reward-expectancy data from the present study, the statistical parametric maps (SPMs) resulting from the above two regression models could be overlaid. This would indicate voxels in which GMvol is significantly correlated (positively or negatively) with threat and reward expectancies. This was done – see Table 5.8 and Fig. 5.13 for results. This overlapping regions approach does not, however, tell us very much about which GMvol – expectancy correlations are unique to threat or reward, versus those that include some shared variance. To interrogate this, it is necessary to include both LODESTARS-reward and threat in the same GLM.

I would not expect reward and threat expectancies to be uncorrelated either behaviourally nor necessarily in the brain. However, it is informative to clarify the effects on GMvol that are uniquely attributable to each of these two regressors. Entering both into a GLM will automatically achieve this: an essential property of the GLM is that only the variability unique to each regressor drives the parameter estimate for it, so that each effect is adjusted for all others (Mumford, Poline, & Poldrack, 2015; Poldrack, Mumford, & Nichols, 2011). Only assessing the GMvol associations of variance that is unique to threat and to reward carries its own problems however. These are due to the fact that the standard process of GLM parameter estimation removes the effects of shared variability (Mumford et al., 2015). When two regressors are highly correlated, their shared variability is large and the unique component for each is correspondingly small. This results in a loss of statistical power. Further, in this case, it is interesting to explore not only the regional GMvol differences uniquely associated with threat or reward expectancies, but also those present when the shared variance is included within the model.

The correlation between LODESTARS-threat and reward scores in the VBM participants (n = 100) was -.361, $p = 0.0002$ (see Fig. 5.4). Thus, as would be expected, there is certainly some shared variance between these two regressors. In order to construct GLMs that incorporate the shared variance component, I created (using SPSS) two new variables: LODESTARS-threat orthogonalised with respect to reward (LODESTARS_threat_orth) and LODESTARS-reward orthogonalised with respect to threat (LODESTARS_reward_orth). These variables are simply the residuals that result from regressing threat on reward and vice versa. That is, I conducted a simple linear regression with LODESTARS-threat as the dependent variable and LODESTARS-reward as the independent variable. By definition, the residuals from this analysis constitute the portion of the LODESTARS-threat scores that are not predicted by the LODESTARS-reward scores, i.e. the variance that is unique to threat and not shared with reward. These residuals are therefore the threat scores that remain once the shared variance has been removed. Thus using these will allow all the shared variance to be attributed to LODESTARS-reward. So these residuals are the

LODESTARS_threat_orth variable that I used. It was then possible to run two GLMs, which between them allowed assessment of individual differences in GMvol uniquely attributable to variance in LODESTARS-threat or reward, as well as GMvol associations present when the shared variance was included but attributed exclusively to threat or reward. In other words, the effects of reward expectancies adjusted for threat and unadjusted for threat, plus the effects of threat adjusted and unadjusted for reward. The two models are specified below. See Fig. 5.5 for a diagrammatic representation of the assignation of (shared) variance that results from orthogonalisation.

Model = Threat orthogonalised with respect to reward. All shared variance assigned to reward.
GMvol = $\alpha + b_0$ LODESTARS_reward + b_1 LODESTARS_threat_orth + b_2 age + b_3 gender

Model = Reward orthogonalised with respect to threat. All shared variance assigned to threat.
GMvol = $\alpha + b_0$ LODESTARS_reward_orth + b_1 LODESTARS_threat + b_2 age + b_3 gender

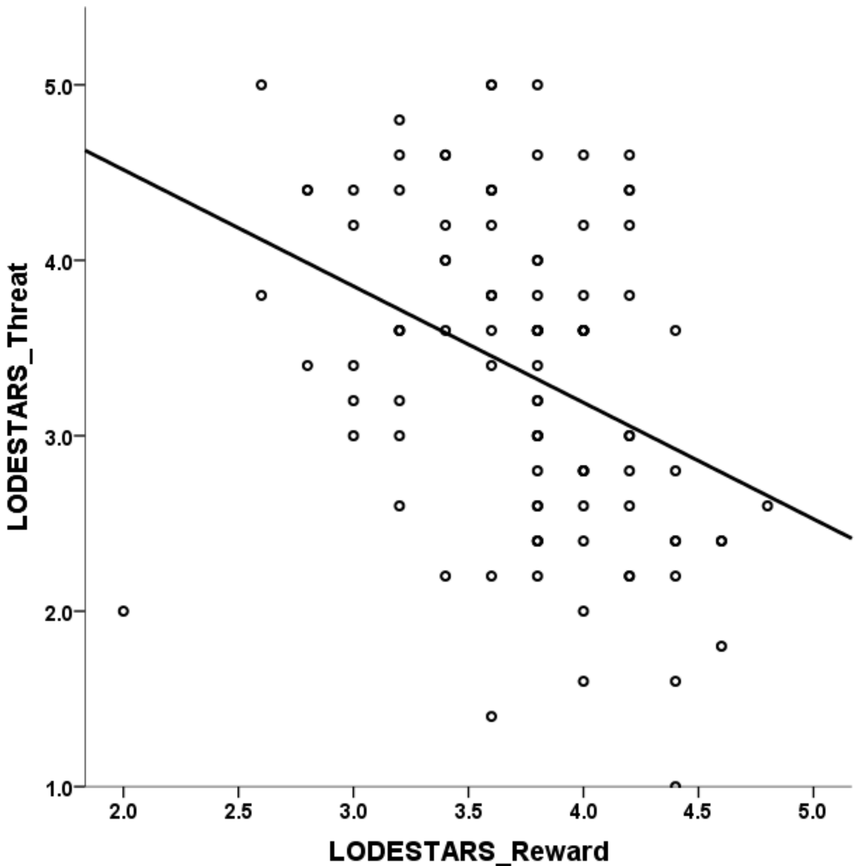


Figure 5.4: Scatterplot showing the relationship between LODESTARS-threat and LODESTARS-reward scores (n = 100).

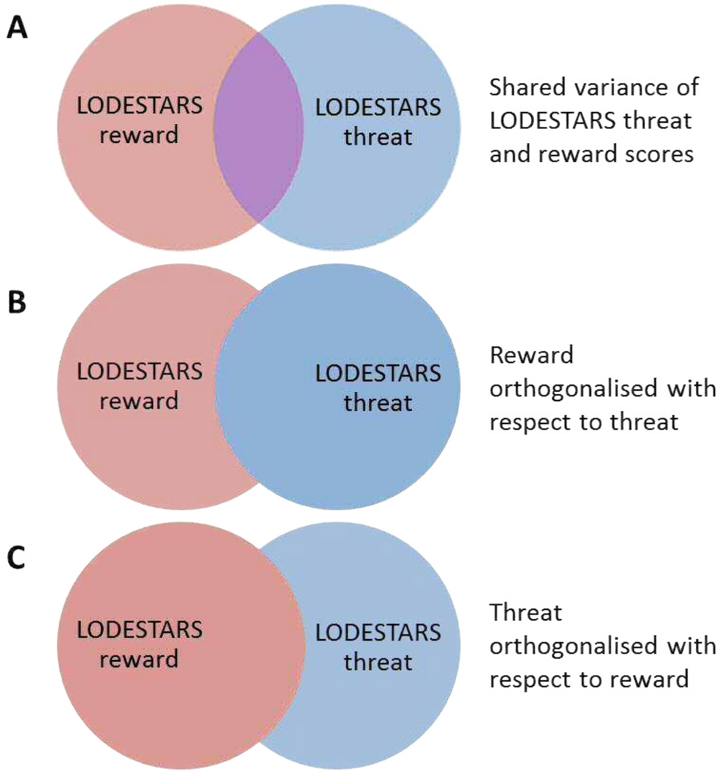


Figure 5.5: Venn diagrams illustrating how the variability is distributed across the 2 LODESTARS regressors where red is unique to reward, blue is unique to threat and purple is shared. A depicts 'raw' LODESTARS-threat and reward scores, which exhibit some overlapping variance. B and C depict the two regression models run, demonstrating the effects of variable orthogonalisation. In B, all the shared variance is assigned to LODESTARS-threat while in C, all shared variance is assigned to LODESTARS-reward.

5.2.2.4 Correction for multiple comparisons

Conducting voxel-wise statistics necessitates a correction for multiple comparisons. However, dividing the critical p value (α) by the total number of tests (i.e. voxels), as in Bonferroni correction, is inappropriate in the context of neuroimaging data analysis. This is because adjacent voxels are not independent of one another and so to treat the multiple statistical tests as if they are independent is excessively stringent. Spurious effects resulting from random noise would be expected to manifest as significant voxels that are scattered throughout the brain (Ward, 2010). By contrast, genuine (biologically meaningful) grey matter effects will manifest as significant voxels that are interconnected to form spatially continuous 'clusters'. Thus, a correction based on the spatial extent of the significant findings (i.e., a correction on cluster level) may yield more appropriate results than a voxel level correction (Kurth, Gaser, & Luders, 2015). Cluster-based statistics define significant regions based on both their peak statistical values (e.g. *t*-values) and spatial extent. However, during the development of VBM, it was observed that standard applications of cluster-based inference (developed for fMRI data) produce an excessive number of false positives (Ashburner & Friston, 2000), due to the violation of the assumption of `stationarity' of smoothness upon which expected cluster spatial extents are based. Accurate calculation of the expected number of connected voxels per cluster requires the smoothness of the image to be spatially invariant. In fMRI, the assumption of such `stationarity' of smoothness across the whole image is usually a good approximation of reality. However, SPMs generated from tissue probability data violate the stationarity assumption on account of the highly nonstationary nature of the underlying neuroanatomy (Ashburner & Friston, 2000; Hayasaka, Phan, Liberzon, Worsley, & Nichols, 2004).

Large clusters will occur in regions where the images are very smooth, and small clusters in regions where the image is very rough. This will result in more false positive clusters in smooth regions. Moreover, true positive clusters in rough regions could be missed because their spatial extent may not be sufficient to exceed the critical extent threshold for the whole brain (Worsley, Andermann, Koulis, MacDonald, & Evans, 1999). To be valid, cluster-based statistical inference for VBM data therefore requires correction for non-stationarity of smoothness (Ashburner & Friston, 2000; Hayasaka et al., 2004).

To correct for multiple comparisons across the whole brain, I therefore applied non-stationary cluster extent correction. This was implemented using the VBM8 toolbox (http://dbm.neuro.uni-jena.de/vbm/) running in SPM12. This procedure corrects the size of each cluster according to the local smoothness values, such that comparison of the extent of each cluster with the overall expected voxels-per-cluster threshold calculated for the whole brain is valid.

5.2.2.5 Mitigation of Type II errors

In recent years, some researchers have voiced concerns about Type II (false negative) errors in neuroimaging data analyses resulting from over-zealous correction for multiple comparisons (e.g. Gonzalez-Castillo et al., 2012; Lieberman & Cunningham, 2009). The problem is that, while the underlying results (e.g. t-statistics) remain the same, the choice of significance threshold alters the SPMs that are used for statistical inference and display (see Fig. 5.6). Statistical thresholds effectively hide the underlying (sub-threshold) data from scrutiny. If the threshold is overly conservative, this will result in Type II errors. In the case of brain-imaging studies, this can result in a flawed view of the nature of the neural system(s) underlying the cognitive process(es) under investigation. Complex cognitive functions – such as forming social expectations – do not arise from the solitary actions of isolated brain regions. Rather, they require multiple interrelated and complementary processes to be performed by a system, or network, of functionally related brain regions (Bressler, 1995; Fuster, 2003). Thus if we inadvertently set our thresholds too high we run the risk of missing the network view by only reporting the peaks (like the tips of icebergs) in our data, but missing the interconnected 'ice' (networks of brain regions) beneath this surface.

In the case of an exploratory study such as this, it is particularly important to mitigate against false negatives. A major aim of the study is to look for promising leads – results that can be followed up in subsequent studies, or that may generate new hypotheses. In this situation, excessive Type II errors might impede the development of potentially fruitful lines of further research (Fiedler, Kutzner, & Krueger, 2012; Streiner & Norman, 2011). Streiner and Norman (2011) advise against correcting for multiple comparisons in these circumstances, but with the caution that any positive results should be seen as preliminary, for the purpose of hypothesis generation, rather than as definitive findings. With this caveat in mind therefore, uncorrected (unc.) results will be reported in this chapter in addition to cluster-extent corrected results.

Regarding the choice of unc. threshold, Lieberman and Cunningham (2009) recommend that reporting clusters for which $p < 0.005$, with a 10-voxel extent threshold, will result in a desirable balance between Type I and Type II error rates. On the basis of one million simulations, this level of thresholding was found to produce high but acceptable Type II error rates, with a false discovery rate (FDR) comparable to the effective FDR in typical behavioural science research[6] (Lieberman & Cunningham, 2009). In accordance with these recommendations, I will report all clusters spanning 10 or more voxels that survive thresholding at $p<0.005$, unc.

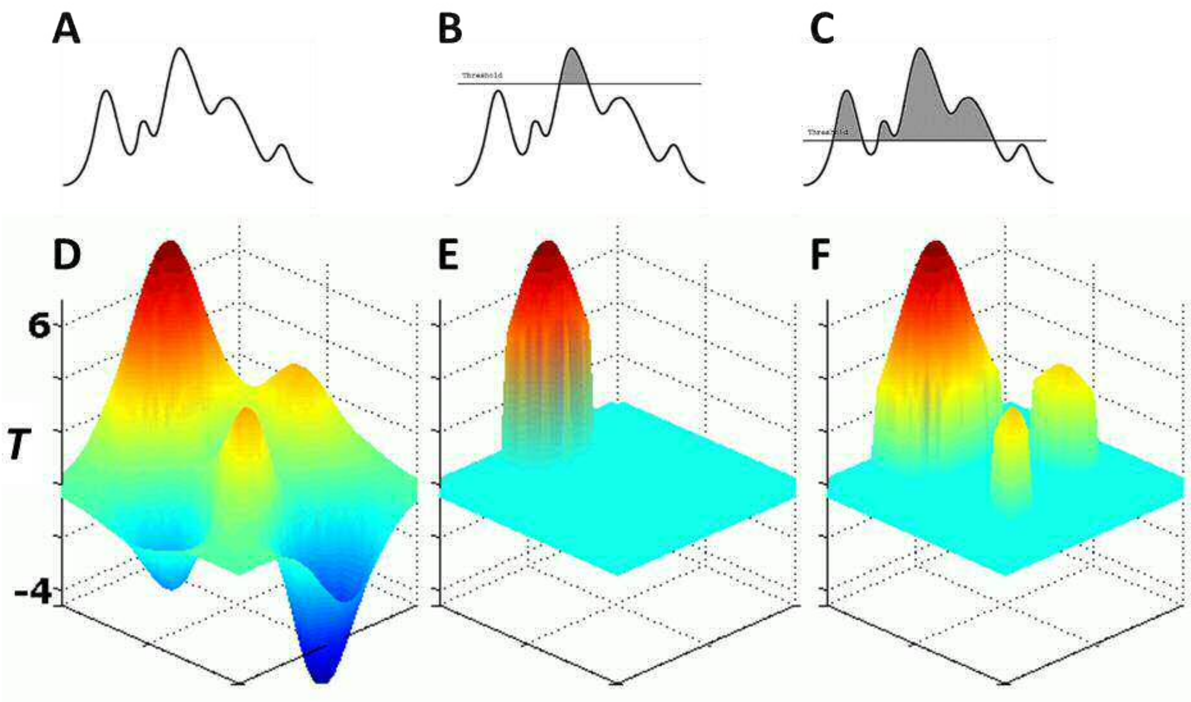


Figure 5.6: Illustration of how the choice of significance threshold can alter the statistical parametric maps (SPMs) that result from neuroimaging data analyses.

Images **A-C** (taken from http://svi.nl/SeedAndThreshold) show how changing a threshold can alter our perception of not only the extent of significant regions but also whether they are connected or not. The first image (**A**) shows the raw data, while the second (**B**) shows a high threshold which defines one significant region with a single peak. By contrast, a lower threshold (**C**) reveals two distinct regions: one that has three peaks, and another with a single peak. These two regions, defined with this threshold, are not spatially connected. (Although we can see that if we reduce the threshold a little more the selection will be expanded such that the two regions will appear connected, as one single multi-peak region).

Images **D-F** (adapted from http://www.mccauslandcenter.sc.edu/mricro/mricron/stats.html) show how changing a threshold can change the appearance of an SPM. The raw statistical map is shown in panel **D**, while the middle panel (**E**) has been thresholded to only show voxels with T-scores greater than 4.5 (with only a single peak surviving), and the right panel shows a more liberal threshold of T > 2.5 – with three regions surviving this threshold.

[6] as gauged from a randomly selected issue of the *Journal of Personality and Social Psychology*.

5.3 Results

The mean LODESTARS-reward score in this sample was 3.37 (std. dev. = .92) and the mean LODESTARS-threat score was 3.73 (std. dev. = .50). There were no significant gender differences in the LODESTARS scores.

I examined for correlations between grey matter volume (GMvol) and two psychological variables: social reward expectancy and social threat expectancy, both measured by the LODESTARS. I accounted for the potentially confounding variables of age and gender (Gur, Gunning-Dixon, Turetsky, et al., 2002) by entering them into the general linear models as 'regressors of no interest'. Participants' overall brain volumes were also accounted for by the SPM software, which scaled the values in the GMvol data so that they were proportional to the fraction of brain volume accounted for by that piece of grey matter (Ashburner, 2010). Non-stationary cluster size correction for multiple comparisons was applied. The results that survived this correction are described in section 5.3.1 and details of the clusters are given in Table 5.2 (shared variance between threat and reward included) and Table 5.3 (unique variance only). See Fig 5.7 for a summary of the *x*, *y*, and *z* axes used for defining the spatial co-ordinates of voxels within the brain, along with the terms used to describe neuroanatomical locations.

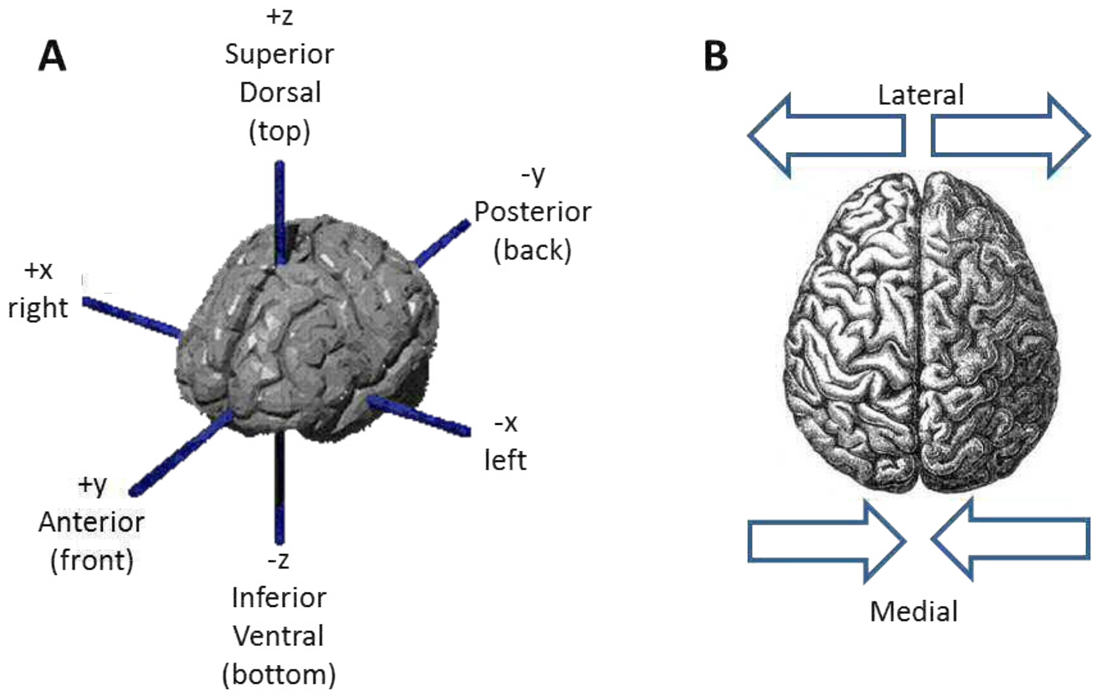


Figure 5.7: A. Summary of the axes used in the MNI coordinate system.

- The origin of the MNI coordinate system is in the anterior commissure, a small, sharply defined bundle of nerve fibres which connects the two cerebral hemispheres.
- The x-axis extends from the left side of the brain to the right.
- The y-axis extends from posterior to anterior.
- The z-axis extends from inferior to superior.

B. Medial and lateral: the left and right hemispheres of the brain are almost mirror images, so it is useful to specify not only whether a given region is on the left or right, but also whether it is medial (towards the middle of the x-axis, on either side), or lateral (towards the ends of the x-axis on either side).

Image A adapted from http://www.grahamwideman.com/gw/brain/orientation/orientterms.htm.

5.3.1 Results that survived nonstationary cluster extent correction

A positive correlation between expectancies of social reward and GMvol was found in a dorsomedial region of left prefrontal cortex (PFC, see Fig. 5.8). This result was significant only in the model in which the shared variance was allocated to reward however; it did not remain significant (at the cluster-size-corrected level) in the model in which the shared variance is allocated to LODESTARS-threat, indicating that this GMvol-expectancy association is partially attributable to shared variance between reward and threat expectancies. No other correlations (positive or negative) of GMvol with LODESTARS-reward survived cluster extent correction.

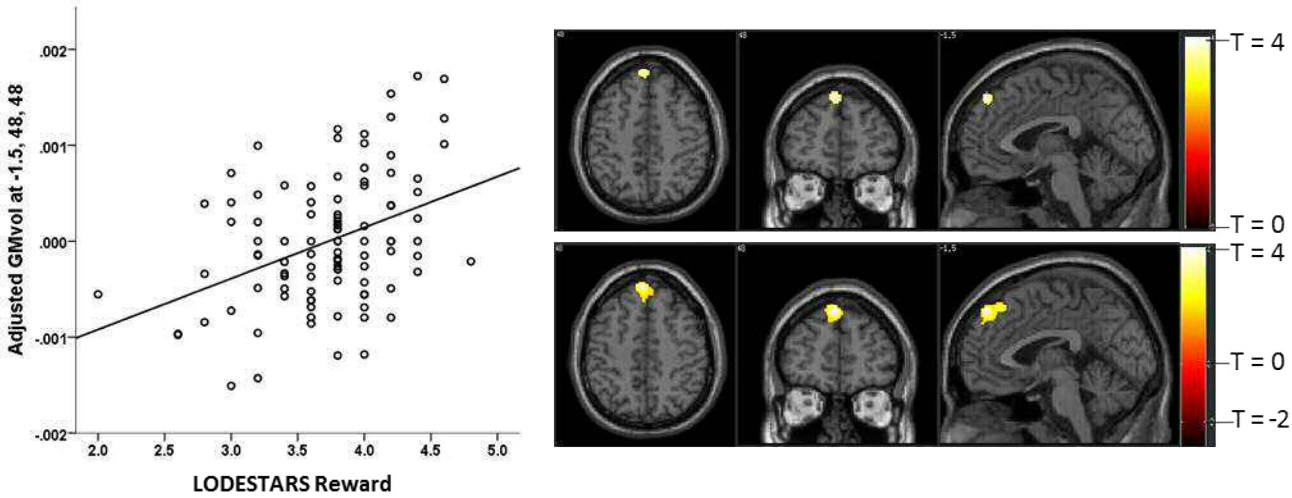


Figure 5.8: Greater GMvol in left dorsomedial prefrontal cortex (dmPFC) associated with higher expectations of social reward.

Upper panel: cluster-extent corrected. Lower panel: extent of the cluster at $p < 0.005$, unc.

Scatterplot shows the relationship between adjusted* GMvol at the peak voxel in this cluster with LODESTARS-reward scores.

*Adjusted for confounds (such as total brain volume) and all other covariates in the model.

Correlation plot is for illustrative purposes only.

Greater GMvol in the right posterior middle temporal gyrus (pMTG) and superior temporal sulcus (pSTS) was associated with higher social threat expectancies (Fig. 5.9), while GMvol in three brain regions was found to be negatively correlated with LODESTARS-threat scores. That is, individuals who reported lower expectations of social threat generally had greater GM volumes in right ventromedial PFC (Fig. 5.10), left lateral occipital lobe (Fig. 5.11), and in the right postcentral gyrus (somatosensory cortex, Fig. 5.12).

Table 5.2 Clusters that survived nonstationary cluster extent correction: shared variance between threat and reward included.

Model	Regressor and direction of correlation with GMvol	Anatomical region	Cluster size (voxels)	MNI coordinates			T-score
				x	*y*	*z*	
Threat orth. w.r.t. Reward	**LODESTARS_reward, positive**	**left dorsomedial PFC (sup. frontal gyrus)**	**171**	**-1.5**	**48**	**48**	**4.03**
Threat orth. w.r.t. Reward	LODESTARS_reward, negative	[no clusters survive threshold]	-		-		-
Reward orth. w.r.t. Threat	**LODESTARS_threat, positive**	**right posterior middle temporal gyrus & superior temporal sulcus (pMTG/STS)**	**212**	**45**	**-58.5**	**10.5**	**4.24**
		right ventromedial PFC/frontal pole	**282**	**3**	**69**	**-4.5**	**4.01**
Reward orth. w.r.t. Threat	**LODESTARS_threat, negative**	**left lateral occipital lobe**	**90**	**-28.5**	**-90**	**-6**	**3.80**
		right postcentral gyrus (somatosensory cortex)	**187**	**60**	**-12**	**30**	**3.58**

Table 5.3 Clusters that survived nonstationary cluster extent correction: unique variance of threat/reward only.

Model	Regressor and direction of correlation with GMvol	Anatomical region	Cluster size (voxels)	MNI coordinates			T-score
				x	*y*	*z*	
Reward orth. w.r.t. Threat	LODESTARS_reward, positive	[no clusters survive threshold]	-		-		-
Reward orth. w.r.t. Threat	LODESTARS_reward, negative	[no clusters survive threshold]	-		-		-
Threat orth. w.r.t. Reward	**LODESTARS_threat, positive**	**right posterior middle temporal gyrus & superior temporal sulcus**	**110**	**45**	**-58.5**	**10.5**	**3.80**
Threat orth. w.r.t. Reward	**LODESTARS_threat, negative**	**left lateral occipital lobe**	**97**	**-28.5**	**-90**	**-6**	**4.01**

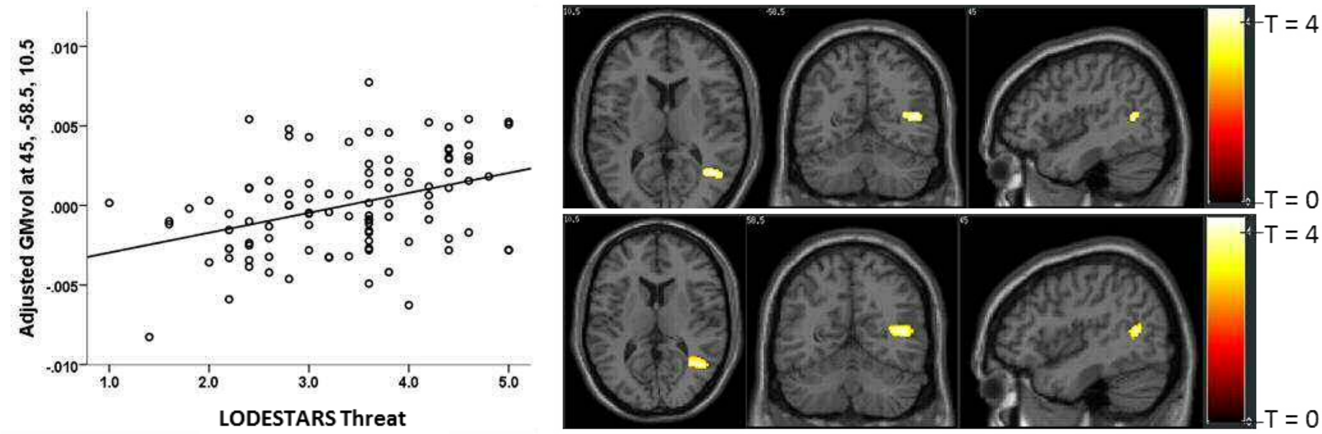


Figure 5.9: Greater GMvol in right posterior middle temporal gyrus and superior temporal sulcus (pMTG/STS) associated with higher expectations of social threat.

Upper panel: cluster-extent corrected. Lower panel: extent of the cluster at p < 0.005, unc.

Scatterplot shows the relationship between adjusted GMvol at the peak voxel in this cluster with LODESTARS-threat scores.

Correlation plot is for illustrative purposes only.

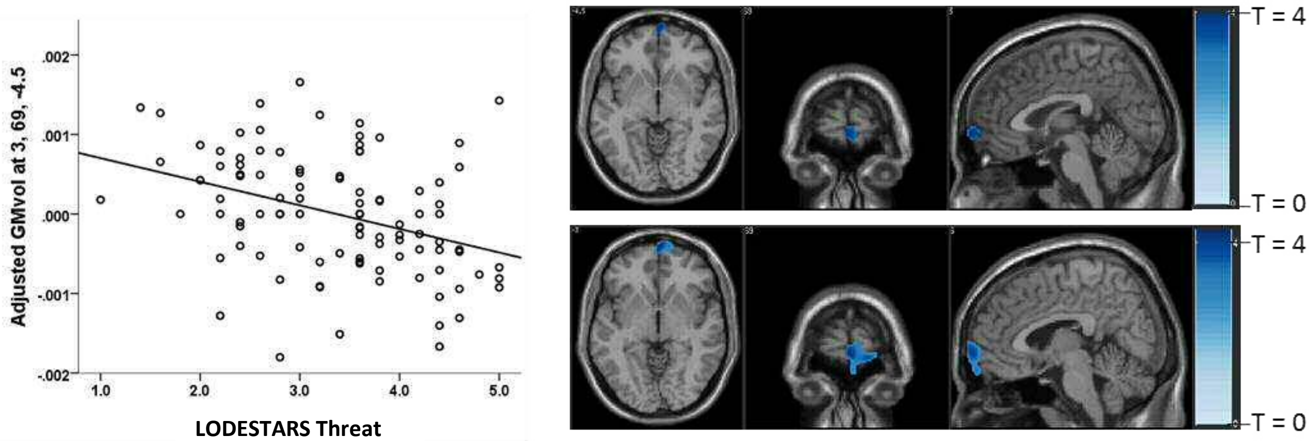


Figure 5.10: Greater GMvol in right ventromedial PFC was associated with lower expectations of social threat.

Upper panel: cluster-extent corrected. Lower panel: extent of the cluster at p < 0.005, unc.

Scatterplot shows the relationship between adjusted GMvol at the peak voxel in this cluster with LODESTARS-threat scores.

Correlation plot is for illustrative purposes only.

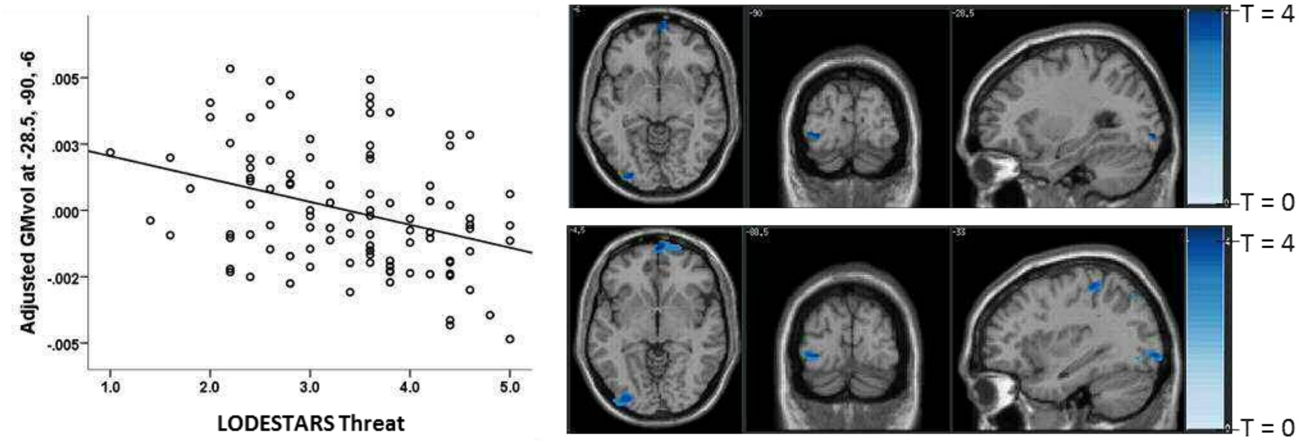


Figure 5.11: Greater GMvol in left lateral occipital cortex associated with lower expectations of social threat.

Upper panel: cluster-extent corrected. Lower panel: extent of the cluster at p < 0.005, unc.

Scatterplot shows the relationship between adjusted GMvol at the peak voxel in this cluster with LODESTARS-threat scores.

Correlation plot is for illustrative purposes only.

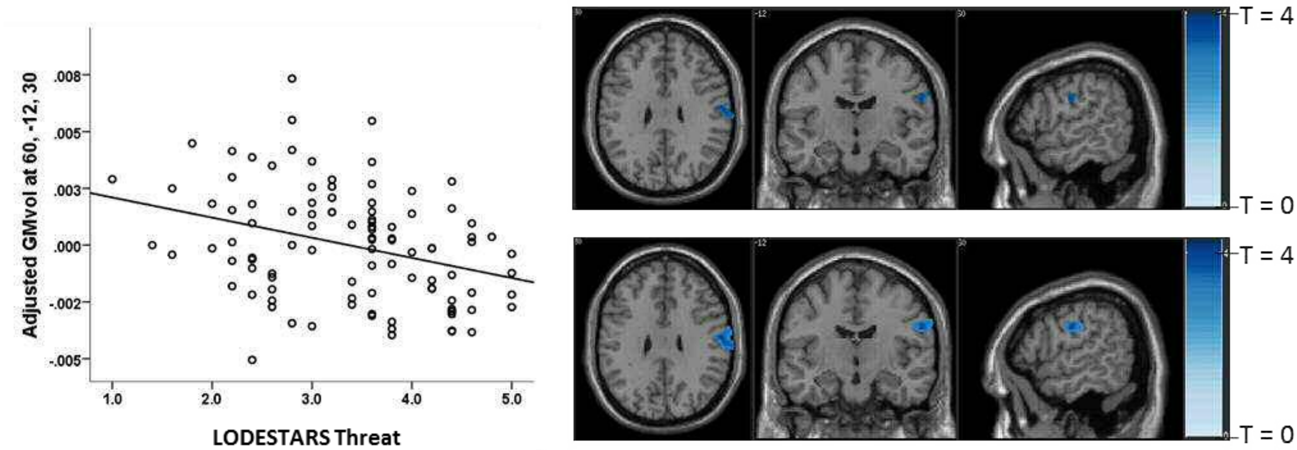


Figure 5.12: Greater GMvol in right postcentral gyrus (somatosensory cortex) associated with lower expectations of social threat.

Upper panel: cluster-extent corrected. Lower panel: extent of the cluster at p < 0.005, unc.

Scatterplot shows the relationship between adjusted GMvol at the peak voxel in this cluster with LODESTARS-threat scores.

Correlation plot is for illustrative purposes only.

5.3.2 Results that survived significance thresholding at p < 0.005, uncorrected for multiple comparisons, and a 10 voxel cluster-extent threshold

To mitigate against Type II errors, details of all clusters spanning 10 or more voxels that survived the threshold of $p < 0.005$, unc., are given in Tables 5.4 and 5.6 (shared variance between threat and reward included) and Tables 5.5 and 5.7 (unique variance only).

Table 5.4 Clusters that survived p < 0.005, 10 voxel extent threshold: shared variance between threat and reward included.
Model = Threat orth. w.r.t. Rew. All shared variance assigned to reward.

Regressor and direction of correlation	Anatomical region	Extent (voxels)	MNI coordinates			T-score
			x	*y*	*z*	
LODESTARS_reward, positive	left dorsomedial PFC	1158	-1.5	48	48	4.03
	right fusiform gyrus	405	33	-15	-46.5	3.56
	left lateral orbitofrontal cortex	539	-40.5	42	-19.5	3.54
	right inferior temporal gyrus	128	63	-15	-37.5	3.39
	right dorsal anterior insula	81	34.5	9	-16.5	3.35
	right medial orbitofrontal cortex	306	12	46.5	-22.5	3.28
	left dorsolateral PFC	45	-37.5	40.5	37.5	3.25
	left cerebellum	47	-24	-40.5	-60	3.20
	right cerebellum	48	25.5	-25.5	-33	3.14
	left subgenual cingulate/subcallosal cortex/straight gyrus	41	-1.5	9	-16.5	3.06
	left frontal pole	43	-22.5	67.5	6	3.00
	right dorsomedial PFC	23	30	22.5	60	2.91
	left precuneus	17	-12	-69	66	2.88

	left inferior temporal gyrus	38	-31.5	-12	-51	2.86
	right cerebellum	70	12	-57	-64.5	2.85
	right postcentral gyrus (somatosensory cortex)	25	64.5	-1.5	27	2.75
	left ventromedial frontal pole	24	-7.5	63	-19.5	2.74
LODESTARS_reward, negative	right posterior middle temporal gyrus	20	37.5	-57	6	2.80

Table 5.5 Clusters that survived p < 0.005, 10 voxel extent threshold: unique variance of threat only.
Model = Threat orth. w.r.t. Rew. All shared variance assigned to reward.

Regressor and direction of correlation	Anatomical region	Extent (voxels)	MNI coordinates			T-score
			x	*y*	*z*	
LODESTARS_threat, positive	right posterior middle temporal gyrus & superior temporal sulcus	296	45	-58.5	10.5	3.80
	right lateral orbitofrontal cortex	63	45	30	-6	3.32
	left amygdala	57	-28.5	-12	-7.5	2.98
	right cerebellum	66	6	-66	-15	2.96
	left cerebellum	98	-51	-45	-36	2.96

	right dorsal anterior insula	69	39	15	13.5	2.92
	right supramarginal gyrus	23	45	-28.5	30	2.85
	right superior frontal gyrus	20	19.5	25.5	37.5	2.82
	right orbitofrontal cortex	45	21	10.5	-21	2.82
	right temporal pole	13	28.5	18	-28.5	2.75
LODESTARS_threat, negative	left lateral occipital gyrus	317	-28.5	-90	-6	4.01
	left postcentral gyrus (somatosensory cortex)	257	-33	-34.5	57	3.80
	right ventromedial PFC/frontal pole	302	3	70.5	-4.5	3.54
	left medial orbitofrontal cortex	197	-9	45	-21	3.34
	right postcentral gyrus & supramarginal gyrus	401	69	-19.5	28.5	3.34
	right superior parietal lobule	219	15	-64.5	57	3.32
	left postcentral gyrus	118	-60	-16.5	21	3.21
	right hippocampus	86	21	-37.5	7.5	3.13
	left inferior parietal lobule	49	-37.5	-63	55.5	3.12
	right temporal pole	149	40.5	7.5	-37.5	3.11
	left medial anteroventral superior frontal gyrus/frontal pole	51	-7.5	70.5	18	3.09

LODESTARS_threat, negative (cont.)	right anteroventral superior frontal gyrus/frontal pole	53	33	64.5	12	3.09
	right precuneus	183	6	-55.5	45	3.03
	right orbitofrontal cortex	47	19.5	70.5	-9	2.99
	right superior occipital gyrus	30	31.5	-81	46.5	2.99
	right fusiform gyrus & parahippocampal gyrus	38	31.5	-18	-27	2.89
	left lateral inferior frontal gyrus	20	-60	18	3	2.88
	left occipital gyrus	20	-18	-96	-6	2.86
	right lingual gyrus	22	15	-85.5	-9	2.82
	left fusiform gyrus	11	-36	-76.5	-12	2.79
	right precuneus	15	4.5	-78	49.5	2.77
	left lateral superior frontal gyrus	10	-28.5	57	27	2.76

Table 5.6 Clusters that survived p < 0.005, 10 voxel extent threshold: shared variance between threat and reward included.
Model = Reward orthogonalised with respect to threat. All shared variance assigned to threat.

Regressor and direction of correlation	Anatomical region	Extent (voxels)	MNI coordinates			T-score
			x	*y*	*z*	
LODESTARS_threat, positive	right posterior middle temporal gyrus & superior temporal sulcus	433	45	-58.5	10.5	4.24
	left orbitofrontal cortex	48	-27	25.5	-9	2.90
	right dorsal anterior insula	44	40.5	16.5	4.5	2.87
	left amygdala & parahippocampal gyrus	60	-12	-9	-15	2.86
	right lateral orbitofrontal cortex	14	45	30	-6	2.86
	left hippocampus	17	-28.5	-13.5	-7.5	2.77
	right superior temporal gyrus	11	51	-12	-6	2.76
LODESTARS_threat, negative	right ventromedial PFC/frontal pole	1210	3	69	-4.5	4.01
	left occipital gyrus	342	-28.5	-90	-6	3.80
	left postcentral gyrus	328	-33	-33	57	3.72
	left ventromedial PFC/medial orbitofrontal cortex	547	-9	43.5	-21	3.58
	right postcentral gyrus & supramarginal gyrus	945	60	-12	30	3.58

	right superior parietal lobule & precuneus	312	15	-63	57	3.53
	right inferior temporal gyrus	327	61.5	-13.5	-36	3.39
	right temporal pole	270	42	7.5	-49.5	3.33
	left postcentral gyrus	176	-60	-16.5	21	3.32
	right fusiform gyrus	403	36	-25.5	-21	3.28
	left superior medial PFC	81	-9	70.5	18	3.25
LODESTARS_threat negative (cont.)	left precuneus & supramarginal gyrus	121	-13.5	-67.5	61.5	3.14
	right superior frontal gyrus	61	33	63	16.5	3.13
	left angular gyrus	236	-37.5	-67.5	39	3.11
	right precuneus	65	4.5	-78	49.5	3.09
	left fusiform gyrus, occipital part	25	-34.5	-75	-10.5	3.08
	left superior middle frontal gyrus	75	-28.5	45	36	3.03
	right precuneus	122	4.5	-55.5	46.5	2.95
	left medial PFC	26	-10.5	72	3	2.88
	right middle temporal gyrus	27	37.5	1.5	-25.5	2.86
	left superior medial gyrus	23	-6	61.5	33	2.86

right lingual gyrus	15	15	-85.5	-7.5	2.82
left posterior cingulate cortex	12	-15	-13.5	36	2.77
left dorsomedial PFC	16	-3	42	54	2.74
right superior occipital gyrus	10	31.5	-81	46.5	2.73
left thalamus	12	-19.5	-22.5	10.5	2.70

Table 5.7 Clusters that survived p < 0.005, 10 voxel extent threshold: unique variance of reward only.
Model = Reward orthogonalised with respect to threat. All shared variance assigned to threat.

Regressor and direction of correlation	Anatomical region	Extent (voxels)	MNI coordinates			T-score
			x	*y*	*z*	
LODESTARS_reward, positive	left lateral orbitofrontal cortex	383	-40.5	42	-19.5	3.60
	right fusiform gyrus	125	33	-16.5	-45	3.46
	left dorsomedial PFC	365	-3	49.5	49.5	3.39
	left middle frontal gyrus	65	-39	40.5	37.5	3.36
	right ventral anterior insula & temporal pole	44	34.5	9	-16.5	3.11
	right cerebellum	219	12	-57	-64.5	3.08
	right inferior parietal lobule, supramarginal gyrus & angular gyrus	17	39	-51	51	2.93
	right superior frontal gyrus	34	19.5	28.5	43.5	2.91
	right parietal operculum (secondary somatosensory cortex, SII)	39	45	-36	24	2.90
	left cerebellum	17	-24	-42	-60	2.85
	right anterior fusiform gyrus	36	31.5	-3	-52.5	2.83
	left posterior superior temporal gyrus/temporoparietal junction	11	-46.5	-46.5	22.5	2.82
	left lateral orbitofrontal cortex	10	-40.5	39	0	2.80

	left superior frontal gyrus	15	-22.5	40.5	46.5	2.74
	left superior medial gyrus	13	-9	52.5	37.5	2.71
	left cerebellum	21	-33	-40.5	-40.5	2.71
LODESTARS_reward, negative	[no clusters survive threshold]	-		-		-

5.3.3 Brain regions in which GMvol is correlated with both reward and threat expectancies

To test for brain voxels in which GMvol is significantly correlated (positively or negatively) with threat and reward expectancies, two further GLMs were applied. These models each contained only one LODESTARS variable as the regressor of interest. The statistical parametric maps (SPMs) resulting from these two regression models were as follows:

Model = Reward_only
SPM = reward_positive (no clusters survive threshold for reward_negative so no SPM produced)

Model = Threat_only
SPMs = threat_positive
threat_negative

These three SPMs give rise to three overlap analyses:

- Reward_positive & Threat_negative
- Reward_positive & Threat_positive
- Threat_positive & Threat_negative

The results of these overlays (conducted in SPM12) are given in Table 5.8. The only pair for which there were overlapping clusters (at $p < 0.005$, with 10 voxel extent threshold) was reward, positive and threat, negative. For this pair, there was overlap between clusters in the medial orbitofrontal cortex/vmPFC (Fig. 5.13A), in the right lateral inferior temporal gyrus (Fig. 5.13B) and in the right fusiform gyrus.

Table 5.8 Overlap of clusters that survived $p < 0.005$, 10 voxel extent threshold.
Models = Threat_only *and* Reward_only

Overlap	Anatomical region	Extent of overlap (voxels)	MNI coordinates			T-score
			x	*y*	*z*	
Reward, positive & Threat, negative	right orbitofrontal/ventromedial prefrontal cortex	68	9	48	-21	3.41
	right lateral inferior temporal gyrus	90	61.5	-13.5	-36	3.39
	right fusiform gyrus	19	27	-25.5	-31.5	3.04
Reward, positive & Threat, positive	[no overlap]	-		-		-
Threat, positive & Threat, negative	[no overlap]	-		-		-

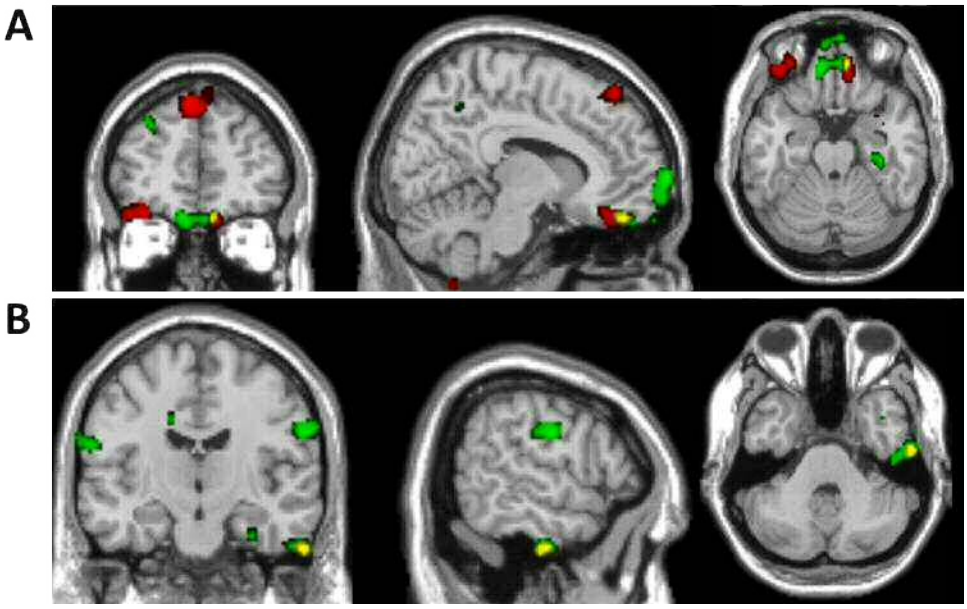


Figure 5.13: Overlay of regions in which GMvol correlates positively with social reward expectancy and negatively with social threat expectancy. Red = reward_positive; green = threat_negative; yellow = overlap. The SPMs were thresholded at $p < 0.005$ with 10 voxel minimum cluster extent.

A (upper panel) shows the extent of overlap in right orbitofrontal/ventromedial prefrontal cortex.
B (lower panel) shows the overlap in right lateral inferior temporal gyrus.

5.4 Discussion

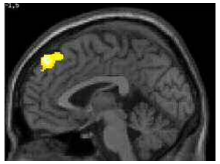
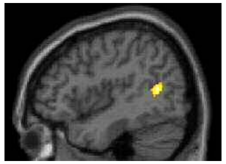
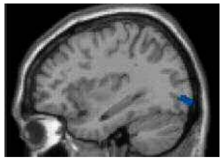
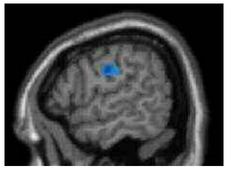
The findings presented in this chapter delineate a set of focal anatomical brain regions in which grey matter volume (GMvol) is associated with individual differences in expectancies of social reward or threat. As with any cross-sectional, correlational study, we cannot determine whether the co-variations observed here describe causal links between brain structure and social expectancies. If the results do reflect causal links, the direction of these associations cannot be inferred from cross-sectional data. Nonetheless, the findings reported here are highly informative in indicating which brain regions are most prominently associated with individual differences in social expectancies.

For ease of reference the results that survived non-stationary cluster extent correction are summarised in Table 5.9. I will discuss these results in detail, before proceeding to a wider-lens discussion of the neural systems that seem implicated in individual differences in social expectancies. It should be noted that, in placing my results in the context of previous work to draw inferences about the processes that may be involved, I shall engage in a certain amount of reverse inference. That is, inferring the engagement of a particular psychological process on the basis of GMvol differences in a brain region previously associated with said psychological process (Poldrack, 2006). Reverse inferences are not deductively valid, but nonetheless can provide useful and even illuminating information with which to advance my understanding of the mind and brain (Doré, Zerubavel, & Ochsner, 2014; Poldrack, 2006). For instance, reverse inferences might suggest new ideas and novel hypotheses, which can be tested in subsequent experiments (Poldrack, 2006). This is particularly important in the case of an exploratory study such as this, in which a major aim is to look for promising leads that can be followed up in subsequent studies, or that may generate new hypotheses.

5.4.1.1 mPFC and social cognition

Both dorsal and ventral mPFC were linked with social expectancies in my data. This accords with the well-established role of the mPFC in social and self-related cognition (Northoff et al., 2006; Van Overwalle, 2009). In particular, judgments about enduring social dispositions and personality traits consistently involve the ventral and/or dorsal part of the mPFC. This is the case for judgements about both one's own personality traits, and those of others (Van Overwalle, 2009). Inferences involving social scripts – which describe appropriate social behaviour in given scenarios – engaged both the dmPFC and vmPFC in all 65 fMRI studies of enduring traits and scripts analysed by Van Overwalle (2009). The use of personality dispositions and social scripts to predict future behaviours of oneself and others in different social situations thus appears to uniquely engage the mPFC (Van Overwalle, 2009). My data indicate that brain structure, as well as function, in the mPFC may reflect the role of this region in generating social expectancies. The directional, valence-specific associations of dmPFC and vmPFC with individual differences in social expectancies may reflect an interaction between the roles of these regions in social cognition and in emotion regulation. This is discussed in sections 5.4.1.2 and 5.4.1.3 that follow.

Table 5.9 Clusters that survived nonstationary cluster extent correction.

LODESTARS variable	Direction of correlation	Anatomical region	In words	Reflects unique variance?
Social reward expectancy	**Positive**	 **left dorsomedial PFC**	Greater GMvol in left dmPFC associated with higher expectations of social reward.	No. Does not survive when shared variance allocated to threat.
Social reward expectancy	**Negative**	[no clusters survive threshold]	-	-
Social threat expectancy	**Positive**	 **right posterior middle temporal gyrus and superior temporal sulcus (pMTG/STS)**	Greater GMvol in right pMTG/STS associated with higher expectations of social threat.	Yes. Survives when shared variance allocated to reward.
ocial threat expectancy	**Negative**	 **right ventromedial PFC**	Greater GMvol in right vmPFC associated with lower expectations of social threat.	No. Does not survive when shared variance allocated to reward.
		 **left lateral inferior occipital lobe**	Greater GMvol in left lateral occipital cortex associated with lower expectations of social threat.	Yes. Survives when shared variance allocated to reward.
		 **right postcentral gyrus (somatosensory cortex)**	Greater GMvol in right postcentral gyrus associated with lower expectations of social threat.	No. Does not survive when shared variance allocated to threat.

5.4.1.2 Greater GMvol in left dmPFC associated with <u>higher</u> expectations of <u>social reward</u>

Higher social reward expectancies were associated with greater GMvol in left dorsomedial prefrontal cortex (dmPFC). This might reflect greater propensity to engage in savouring – a form of cognitive rumination, by which individuals can up-regulate the emotional impact of positive events. Savouring of autobiographical memories of positive past events has previously been found to engage the left dmPFC during fMRI (Speer, Bhanji, & Delgado, 2014). Savouring can be anticipatory as well as retrospective (Gilbert & Wilson, 2007; Kringelbach & Berridge, 2009, 2011). Evidence from fMRI research indicates that re-experiencing past events and pre-experiencing future events are both supported by common neural structures (Botzung, Denkova, & Manning, 2008; Bryant, Chadwick, & Kluwe, 2011; Buckner & Carroll, 2007). These include the left dmPFC, which is consistently activated when participants think about past or future events (Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis, Wong, & Schacter, 2007; Botzung et al., 2008; Okuda et al., 2003). Thus, anticipatory savouring may engage some of the same brain regions as reminiscent savouring, including left dmPFC (Bryant et al., 2011).

Regions associated with the mental construction and elaboration of anticipated future events, which include bilateral dmPFC, have also been found to activate when participants construct imaginary past events (Addis et al., 2009) and when participants imagine that self-relevant scenarios are happening to them in the present (Frewen et al., 2011). This suggests that the dmPFC may support cognitive processes general to envisaging self-relevant events, regardless of whether these are remembered or imagined. It is possible that the dmPFC exhibits a slight bias toward imagining positive social events: this region activated more during this condition that for negative social events or positive or negative non-social events in a study conducted by Frewen et al. (2011).

In addition to savouring, other, similar constructs related to positive emotion regulation have also been associated with the left dmPFC. For instance, in a PET study of placebo effects, higher placebo analgesia and more positive affective states immediately and 24 hours after a pain challenge were associated with increased opioid neurotransmission in left dmPFC. However, similar effects were also seen in other brain regions including dorsolateral PFC, mOFC, ACC, insula, and NAcc. This may indicate that the brain regions identified in this study are involved in a neural network supporting positive emotion regulation, but the general nature of the affective measures used prohibits inferences about the specific contribution of any one region.

In an fMRI study of cognitive emotion regulation, Wager, Davidson, Hughes, Lindquist, and Ochsner (2008) found increased dmPFC activity (bilateral in this case) to be associated with greater reappraisal success. This effect was mediated by the NAcc/VS, in a pathway by which positive appraisals may be generated (Wager et al., 2008). This pathway included ventromedial and lateral prefrontal regions as well, so again the specific contribution of the dmPFC is not clear.

As the functional imaging findings described above suggest, the dmPFC is anatomically connected (via neural pathways) to the VS (Haber, 2011). However, the dmPFC is also connected with the amygdala (Kim et al., 2011; Ray & Zald, 2012) and the insula (Augustine, 1996), regions commonly involved in generating negative emotion. In a neurofeedback study in which participants were instructed to increase activity in amygdalar/insular regions[1], all participants reported that they used negative personal memories as the most effective technique to up-regulate activity in these brain regions (Johnston, Boehm, Healy, Goebel, & Linden, 2010). The up-regulation of amygdala/insula activity in this fashion was associated with simultaneous up-regulation of activity in the left dmPFC.

Together, the evidence discussed thus far suggests that the role of the (left) dmPFC in emotion regulation may be in purposeful up-regulation of emotion (positive or negative). It appears that the dmPFC may be particularly effective in regulating emotion by way of autobiographical rumination – i.e. focussing attention on personal memories or perhaps on imagined or anticipated self-relevant scenarios (Johnston et al., 2010). This links with the well-established role of the dmPFC in self-representations and self-reflection (van der Meer, Costafreda, Aleman, & David, 2010). On the basis of a meta-analysis of 20 published fMRI and PET studies on self-reflection, van der Meer et

[1] The regions were specified for each participant in advance by using a localiser task to identify brain regions responsive to pictures with negative emotional content.

al. (2010) propose that the dmPFC is involved particularly in evaluation and decision-making processes during self- and other-referential processing. Similarly, Gusnard, Akbudak, Shulman, and Raichle (2001) suggest that the dmPFC is particularly important for processing representations of the temporally extended 'narrative' or 'autobiographical' self [2]. They note that conscious awareness of the 'self' requires access to information about one's experience of a past, a present, and a future, and argue that the dmPFC is particularly important for producing this unified, embodied awareness (Gusnard et al., 2001).

The left dmPFC is engaged both when individuals consider themselves in terms of direct appraisals (i.e. one's own self-beliefs) and reflected appraisals (an individual's perception of how others view him or her) (Ochsner et al., 2005). Thus individuals' general bias towards positive versus negative affect, and perhaps more specifically towards positive versus negative self-evaluation, may moderate the effect of rumination in social threat and reward expectancies.

In support of this, consistent results across correlational and experimental studies demonstrate that self-focussed attentional bias to negative aspects of the self is strongly related to higher levels of chronic negative affect (Mor & Winquist, 2002) and social anxiety (Mellings & Alden, 2000). Greater attention to positive aspects of the self is related to lower levels of chronic negative affect (Mor & Winquist, 2002). Convergent structural and functional evidence indicates that the dmPFC is part of an appraisal system involved in the cognitive generation and updating of self-esteem (Chavez & Heatherton, 2015; Kober et al., 2008). Greater habitual savouring is associated with higher trait self-esteem (Livingstone & Srivastava, 2012) whereas habitual negative rumination is associated with lower trait self-esteem (Takano & Tanno, 2009). Decreases in state self-esteem have been linked to greater dmPFC activity in response to negative social feedback (Eisenberger, Inagaki, Muscatell, Byrne Haltom, & Leary, 2011). Conversely, Chavez and Heatherton (2015) found that

[2] Consultation of autobiographical memories relevant to these processes may additionally engage the posterior cingulate cortex (van der Meer, Costafreda, Aleman, & David, 2010).

higher state self-esteem was associated with higher bilateral activity and functional connectivity of mPFC and ventral striatum when participants viewed positively valenced words high in self-relevance. Further, trait self-esteem was positively correlated with the structural connectivity between mPFC and VS, suggesting that long-term maintenance of self-esteem also depends on the connectivity of these fronto-striatal circuits (Chavez & Heatherton, 2015). Thus it seems the dmPFC is involved in self-evaluation. The valence of self-evaluation may be influenced by the connectivity of the dmPFC with core valuation region (amygdala, anterior insula, VS/NAcc), perhaps reflecting individuals' affective biases.

The apparent role of the dmPFC in evaluative self- and other-referential processing corresponds well with its proposed role in conceptual-level belief/desire valuations in Ochsner and Gross's (2014) model. That we see GMvol differences in this region associated more with reward than threat expectancies may perhaps be due to nature of the LODESTARS items. The LODESTARS-reward items are generally more 'cognitive' in nature, whereas the threat items are more 'affective' (which may reflect real differences in the nature of positive and negative anticipatory processing). Note however that the correlation of LODESTARS-reward with GMvol in the dmPFC does not hold when only the variance unique to reward is assessed, indicating some shared variance with threat expectancies. Inspection of the results obtained with the threshold of $p < 0.005$ (unc.) indicates that LODESTARS-threat scores are *negatively* correlated with GMvol in the left dmPFC (see Table 5.6). This is suggestive of a role for the left dmPFC in reducing negative social expectancies (or negative anticipatory affect), as well as up-regulating positive expectancies. So, rather than always up-regulating emotion, it appears that the dmPFC is capable of flexible, purposeful cognitive control, by either up- or down-regulation of positive or negative affect. Greater GMvol here may be indicative of greater ability to employ cognitive control in order to attain and maintain desired affective states, including anticipated future states. In support of this hypothesis, a VBM study of GM correlates of the symptoms of posttraumatic stress disorder found that greater anxious hyper-arousal was associated with reduced GMvol in the left dmPFC (Weber et al. 2013).

In functional neuroimaging studies, dmPFC has been associated with both up- and down-regulation of affect, and with selective attention to emotional states (Denny, Silvers, & Ochsner, 2009). There is substantial evidence that, for negative emotion regulation, the regulatory role of the mPFC, including dmPFC, is effected by down-regulating activity in regions such as the amygdala, that are associated with negative affect (Hechtman, Raila, Chiao, & Gruber, 2013; Ochsner & Gross, 2008). Deployment of cognitive regulatory strategies during reduction of negative affect is robustly associated with increased activity in mPFC regions and simultaneous decreased activity in the amygdala (Diekhof, Geier, Falkai, & Gruber, 2011; Frank et al., 2014; Hechtman et al., 2013; Ochsner et al., 2004).

Although relatively few studies have looked at regulation of positive emotion, a regulatory neural relationship between the mPFC - including dmPFC - and regions such as the ventral striatum is plausible (Hechtman et al., 2013). Such a relationship is supported by the results of the studies which have looked at positive emotion regulation, such as the study conducted by Wager et al. (2008), described earlier. Similarly, Mak, Hu, Zhang, Xiao, and Lee (2009) report that the left dmPFC was activated when participants purposefully regulated (in this case, reduced) both positive and negative emotion.

Collectively, the available data suggest a role for the dmPFC in generating and maintaining cognitive appraisals (and reappraisals) of stimuli in a fashion that involves self-reflection (Denny et al., 2009). It appears that the dmPFC is capable of flexible, purposeful regulation of emotion, by either up- or down-regulation of neuronal activity in brain regions subserving emotion generation and core-level valuations (amygdala, ventral striatum and anterior insula). In my data GMvol differences in the left dmPFC were associated more with reward than threat expectancies; however previous work has also linked this region to conscious appraisal of threat (Mechias, Etkin, & Kalisch, 2010), and anxiety-generating cognitive appraisals (Kalisch, Wiech, Critchley, & Dolan, 2006; Maier et al., 2012). In general, functional neuroimaging studies report engagement of the left dmPFC when participants purposefully up-regulate or down-regulate positive or negative emotion, in line with their affective goals (Kim & Hamann, 2007; Mak et al., 2009).

That my LODESTARS-reward dmPFC finding is lateralised to the left accords with previous work demonstrating that positive (or approach-oriented) affective processes are lateralised towards the left frontal cortex, whereas negative (or withdrawal-oriented) processes are more often lateralised towards the right. Higher stable (over 3 weeks) resting-state frontal activity (measured by EEG) in the left relative to the right PFC has been found to correlate with self-reported greater generalised positive affect (Tomarken, Davidson, Wheeler, & Doss, 1992; Wheeler, Davidson, & Tomarken, 1993). However, Sutton and Davidson (1997), who measured resting-state frontal EEG activity at two intervals 6 weeks apart, did not find self-reported general affect to be associated with prefrontal EEG asymmetry. A more consistent finding is that individuals who exhibit relatively higher left-lateralised resting frontal alpha activity display stronger approach motivation and reward-seeking behaviours than individuals with greater relative activity on the right (Hughes, Yates, Morton, & Smillie, 2014; Pizzagalli, Sherwood, Henriques, & Davidson, 2005; Sutton & Davidson, 1997). These individual differences in motivational bias associated with frontal asymmetry are unrelated to differences in generalized emotional reactivity. However, the underlying anatomical and neurochemical systems that may be indexed by frontal EEG asymmetry remain uncertain (Allen, Coan, & Nazarian, 2004).

Using PET, Tomer et al. (2013) found that relatively higher dopamine D2 receptor binding in the left mPFC and OFC was associated with stronger self-reported approach motivation and behavioural preference for rewarding events. Stronger tendency to avoid aversive outcomes was predicted by relatively higher binding in the right mPFC. Dopamine neurons encode motivational value (Bromberg-Martin, Matsumoto, & Hikosaka, 2010) and Tomer et al.'s results suggest that asymmetric tonic dopamine activity may contribute to asymmetric tonic prefrontal activation and individual differences in motivational bias. Whether grey matter asymmetry in the mPFC occurs in association with differences in neurochemical activity is unclear however. GM asymmetry was regressed out in Tomer et al.'s analysis, as their aim was to specifically investigate dopamine asymmetry.

Two meta-analyses of brain function (PET and fMRI) studies both concluded that approach-related emotions show a trend toward left lateralisation in the frontal cortex (but with many right-lateralised results reported as well), whereas negative/withdrawal emotions are associated with symmetrical frontal activity (Murphy, Nimmo-Smith, & Lawrence, 2003; Wager, Phan, Liberzon, & Taylor, 2003). Structural (VBM) studies have not reported prefrontal GM asymmetry to be associated with individual differences in affective style (Schiffer et al., 2007; Welborn et al., 2009). If emotional valence is lateralised within individual brains, it seems likely that this is not constant across individuals but rather represents a characteristic individual differences variable, like handedness (Schiffer et al., 2007). Any lateralisation of results reported by individual studies, including this one, may therefore have arisen simply as a result of the characteristics of the particular study sample.

5.4.1.3 Greater GMvol in right vmPFC associated with lower expectations of social threat

As predicted, greater GMvol in the vmPFC was correlated with lower social threat expectancies as measured by the LODESTARS. This was lateralised to the right hemisphere in my data. This finding concords with the well-established role of the vmPFC in reducing negative anticipatory affect in fear extinction contexts, discussed in section 5.1.1. The mental construction or maintenance of lowered threat expectancies pertaining to anticipated or imagined future social events does not necessarily involve fear extinction however. It may do, if an individual has previously had negative experiences at social events, and such negative experiences have abated during the more proximate past. Yet it seems unlikely that such fear extinction processes are the sole driver of the vmPFC GMvol association with lower threat expectancies. A more general role for the vmPFC in the regulation of negative anticipatory affect seems implicated.

Indeed, a meta-analysis of 49 human neuroimaging studies of affect regulation across three different experimental domains identified vmPFC activation as the only ‘common neural regulator’ of diminished negative affect (Diekhof, Geier, et al., 2011). These three experimental domains were fear extinction, placebo effects, and cognitive reappraisal. In a different study, Diekhof, Kipshagen, et al. (2011) explicitly assessed how expectancies, in the form of anticipatory imagery, can regulate the perceived intensity of fearful facial expressions. Activity associated with regulation (reduced perceived fearfulness) was observed in the vmPFC in this domain as well, during anticipatory imagery.

These results support the hypothesis that the human vmPFC may play a general, ubiquitous role in reducing fear/anxiety and perceived aversiveness of unpleasant or fear-eliciting events (Diekhof, Geier, et al., 2011). My data extend these findings by indicating that the minimisation of social threat expectancies – and/or the maintenance low threat expectancies – may be implemented in the brain by similar means as the reduction of fear or negative affect in other emotion regulation scenarios.

Individual differences in affect regulation have also been linked to the vmPFC in previous work. As mentioned in section 5.1.1, relatively greater vmPFC GM has been observed in individuals who are more proficient at updating threat expectancies and reducing conditioned fear in fear extinction learning contexts (Hartley, Fischl, & Phelps, 2011; Milad et al., 2005; Milad & Rauch, 2007). Welborn et al. (2009) found that normal variation in vmPFC volume is related to individual differences in affect regulation techniques. More frequent self-reported use of cognitive reappraisal as an emotion regulation strategy was associated with greater vmPFC GMvol in their sample of 117 healthy adults (58 females). Conversely, more frequent self-reported use of expressive suppression was associated with smaller vmPFC volumes. Expressive suppression involves deliberately inhibiting the behavioural display of emotion, e.g. one’s facial expression (Gross & John, 2003). Cognitive reappraisal entails changing the way one thinks about a potentially emotion-eliciting situation in order to alter the way one feels about it (Gross & John, 2003). Experimental and individual differences studies consistently find that reappraisal is a more effective strategy than suppression for reducing negative affect (Gross, 2002). In fact, habitual use of suppression has been associated with greater experience of negative emotion (Gross & John, 2003). That is, habitual suppressors express less emotion (both negative and positive); they also experience less positive emotion. Yet they report experiencing higher levels of negative emotion. In contrast, individuals who habitually employ reappraisal tend to experience and express greater positive emotion and less negative emotion (Gross & John, 2003). In addition to affect, individual differences in reappraisal and suppression tendencies have implications for social functioning and relationships. Higher use of reappraisal has been associated with better interpersonal functioning (both self- and peer-rated) and well-being (self-reported). Suppression, however, was associated with poorer interpersonal functioning and well-being (Gross & John, 2003).

In clinical populations as well, reduced volume and functional activity of the vmPFC area has been linked with lower control of fear and anxiety. For example, adolescents diagnosed with generalised anxiety disorder (GAD) have been found to have decreased GMvol in the left mOFC/vmPFC, compared with healthy adolescents (Strawn et al., 2013). In terms of brain function (assessed by fMRI and PET), hypoactivation of vmPFC/mOFC is detected across anxiety disorders where there is a lack of inhibition of inappropriate fear and anxiety responses (Milad & Rauch, 2007).

The aforementioned clinical studies pertain to anxiety disorders in general; however perceived social threat is a potent cause of anxiety in humans (Wager et al., 2009). Reflecting this, 4 (out of 15) of the adolescents with GAD who participated in Strawn et al.'s (2013) study had been diagnosed with co-morbid social phobia. Social anxiety disorder (SAD) and social phobia were among the disorders reviewed by Milad and Rauch (2007). Brühl et al. (2011) conducted a study specifically designed to examine neural activity during anticipation of emotional stimuli in patients with SAD. The emotional stimuli (pictures) used in this study contained no specific social content. During anticipation of negative and unknown (potentially negative) emotional images, participants with SAD exhibited relatively decreased activity in left OFC, compared with healthy controls. That this effect was observed for images that were not specifically social suggests that alterations in emotion regulation in SAD may be general, not limited to specific feared stimuli. This corroborates the hypothesis, suggested by my data, that regulation of social threat expectancies may be implemented in the brain by similar means as the regulation of fear or negative affect in other contexts. The vmPFC appears to perform a pivotal role in the regulation of negative anticipatory affect, perhaps including the regulation of social threat expectancies.

5.4.1.4 Greater GMvol in left lateral occipital cortex associated with lower expectations of social threat

The association of the left lateral occipital cortex (OCC) with social threat expectancies was unexpected, in that this region is not included in the networks of brain regions involved in valuation (Ochsner & Gross, 2014) nor usually in brain networks subserving processes important for social behaviour (Bickart, Dickerson, & Feldman Barrett, 2014).

The left OCC might support mental imagery processes (Farah, 1989), useful for imagining social scenarios – but this does not explain the directional, or valence-specific, findings of my study. Greater GMvol in the OCC was specifically correlated with lower social threat expectancies in my data. Further, although the left lateral OCC is typically activated during autobiographical memory, OCC involvement is not reliably observed during prospection (Spreng, Mar, & Kim, 2008). Thus it is unlikely that the left lateral OCC GMvol association with threat expectancies is due to individual differences in LODESTARS-related mental imagery.

Although not the focus of attention in neuroimaging studies of social cognition and anxiety, left lateral OCC involvement is frequently reported. For example, increased activity in this region has been found (using fMRI) during anticipation of social reward (gestures of approval), compared with anticipation of monetary incentives (Gossen et al., 2014). This activity was greater in participants higher in 'social proficiency,' as measured by the empathy quotient questionnaire (EQ, Baron-Cohen

& Wheelwright, 2004). In fact, the left lateral OCC was the only region in which the interaction of empathy with social reward anticipation (high > low EQ in social > monetary anticipation) survived correction for multiple comparisons in the whole-brain analysis conducted by Gossen et al. (2014). As this effect was observed during the anticipation phase of Gossen et al.'s task, when participants were viewing geometric-shape cues indicative of the feedback they were to receive, it is unlikely to be an artefact of visual processing activity. Gossen et al. suggest that their data provide evidence for a link between self-reported deficits in social proficiency and reduced perceived salience of positive social stimuli.

Given the lateral inferior OCC's well-established role in face perception (Haxby, Hoffman, & Gobbini, 2000), it seems possible that this region may operate at the interface between social perception and social cognition. This is supported by the anatomical connections of the lateral inferior OCC. This region shares reciprocal connections with the amygdala, which facilitate rapid analysis of socially relevant information (Skuse & Gallagher, 2009). The inferior occipital region borders the face-responsive lateral fusiform region ventrally and the STS/MTG/TPJ region dorsally, and there is extensive evidence that these regions are all engaged during social information processing (Hari & Kujala, 2009; Haxby et al., 2000). For example, increased functional connectivity between left OCC and 'social brain' regions (vmPFC, posterior cingulate cortex (PCC), rTPJ) has been reported during reflective theory-of-mind judgments about self and other, compared with physical judgements (Lombardo et al., 2009). Similarly, increased activity in the left lateral OCC – along with typical theory-of-mind regions – has been reported during observation of actions with a social (communicative) intent, compared to actions performed with private intent (Ciaramidaro, Becchio, Colle, Bara, & Walter, 2014). A meta-analysis of 30 theory-of-mind studies indicated that the lateral inferior OCC – in this case right-lateralised – is consistently engaged during this type of social cognition (Spreng et al., 2008).

With regard to social anxiety, Wager et al. (2009) have found that greater activity in a region of left lateral inferior OCC mediates increased subjective anxiety in response to a social evaluative threat challenge in healthy adults. Conversely, Taylor et al. (2014) report that attention modification training in socially anxious individuals resulted in increased activity in bilateral inferior OCC. This was not associated with changes in subjective emotional state: participants' self-reported state anxiety did not differ significantly from baseline to post-treatment[3]. However, observed changes in BOLD activity in vmPFC and amygdala following attention training predicted subsequent anxiety in response to a social evaluative threat challenge. Taylor et al. suggest that changes in regional brain activity following attention training reflect alterations in the relative strengths of components of a neural system for social information processing. Specifically, they propose that such training can modulate activity in both 'top–down' (emotion regulation) and 'bottom–up' (attention, salience) brain regions within this network. Other work supports the view that the inferior OCC region forms part of this network, specifically that decreased connectivity between PFC/dACC and occipital cortex is associated with poor social adjustment and cognition in participants with psychosis (Taylor, Chen, Tso, Liberzon, & Welsh, 2011) and SAD (Ding et al., 2011). Prefrontal brain regions, as discussed elsewhere in this chapter, are involved in regulatory processes. This includes guiding decisions to affiliate with or avoid potential social partners based on their appearance (Bickart et al., 2014). Examples include decisions to trust people based on their approachable appearance or to reject cooperation with a potential partner based on their untrustworthy appearance. Ding et al. (2011) suggest that decreased resting connectivity between PFC and OCC in SAD may reflect habitual abnormal processing ('misinterpretation') of social information contained in visual stimuli, especially facial expressions. They argue that decreased fronto-occipital connectivity may be symptomatic of a defective system for the assessment or assignment of threat to social stimuli.

Overall, evidence from functional neuroimaging research indicates that the lateral inferior OCC is engaged during social cognition and that activity within this region, within the context of its functional connectivity to other 'social' brain regions, is associated with social anxiety. Results are

[3] This finding is consistent with other attention training studies.

mixed however, regarding whether lateral inferior OCC activity is positively or negatively correlated with levels of social anxiety. Such mixed results are also present at the structural level. To date, little work has assessed the structural correlates of social anxiety. That which has, has compared individuals with a clinical diagnosis of SAD with healthy participants. Talati, Pantazatos, Schneier, Weissman, and Hirsch (2013) found that participants with SAD (compared with healthy controls) had greater GMvol in the left lateral inferior OCC. Syal et al. (2012) found thinner lateral OCC GM, bilaterally, in SAD patients compared with healthy participants. This only survived correction for multiple comparisons in the right hemisphere however.

Although in its infancy, the early indications from brain-structural studies of social anxiety support the evidence from the more extensive functional neuroimaging literature, that the lateral inferior OCC may be implicated. If, as argued by Ding et al. (2011), this region is involved in assessing or assigning subjective threat perceptions to social stimuli, then my data suggest that greater GMvol here is associated with lower social threat perceptions (expectations). However, it seems clear that the connectivity of the lateral inferior OCC, rather than its GMvol or activity per se, may be of greater importance in social threat processing (Qiu et al., 2011). This may explain some of the apparent discrepancies in the evidence available to date. Another explanation is that the role of the left lateral OCC within the social cognition network may be in an appraisal process that increases anxiety for some individuals but decreases it for others (Wager et al., 2009). Further work is required to discern the role of the (left) lateral inferior OCC in social cognition. That this region survives cluster-extent correction in my data indicates that it is robustly involved, in some way, in individual differences in dispositional social threat expectancies. My study suggests that the role of the inferior OCC in social cognition is deserving of greater research attention, in healthy participants as well as those with SAD.

5.4.1.5 Greater GMvol in right postcentral gyrus associated with <u>lower</u> expectations of <u>social threat</u>

The postcentral gyrus constitutes part of the somatosensory cortex in the anterior parietal region of the human brain. Somatosensation is the process by which information about the body's interaction with its environment is represented in the brain. This involves the processing of tactile, proprioceptive, and nociceptive information. Traditionally, somatosensory processing and the brain regions supporting it were thought to be reserved for the experience of somatosensory perception arising from one's own body (Keysers, Kaas, & Gazzola, 2010). However, mine is not the first study to link GMvol in the postcentral gyrus to social cognition.

Previous work has found that lower GMvol in the postcentral gyrus is associated with reduced quality of social functioning in individuals at clinical high risk for psychosis (Lincoln & Hooker, 2014). Significant bilateral GM thinning has also been observed in the postcentral gyrus of patients with SAD (Syal et al., 2012). A study of 108 patients with focal brain lesions has demonstrated that right somatosensory cortex is important for emotion recognition (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000). Functional neuroimaging work has consistently found brain activity in the postcentral gyrus and related somatosensory regions to be associated with greater proficiency in affective theory of mind (Hooker, Verosky, Germine, Knight, & D'Esposito, 2008) and higher empathy (Keysers & Gazzola, 2009; Keysers et al., 2010).

One interpretation of these findings is that empathic responding may rely on simulating the observed or inferred emotion of others, including associated bodily states, within one's own neural systems (Adolphs, 2002; Keysers et al., 2010). Greater GMvol in the postcentral gyrus may therefore reflect a greater propensity to engage in empathy, or greater empathic accuracy (Keysers & Gazzola, 2014). The nature of the potential link between empathy and reduced social threat expectancies is discussed in section 5.4.7.

5.4.1.6 Greater GMvol in right pMTG/STS associated with higher expectations of social threat

The superior temporal sulcus (STS) separates the superior temporal gyrus (STG) from the middle temporal gyrus (MTG). These areas of the human temporal cortex are involved in processing social information from perceptual cues such as gaze, tone of voice, facial expression and body motion (e.g. Bayliss, Bartlett, Naughtin, & Kritikos, 2011; Carlin, Rowe, Kriegeskorte, Thompson, & Calder, 2012; Downing, Jiang, Shuman, & Kanwisher, 2001; Fusar-Poli et al., 2009; Pelphrey, Morris, Michelich, Allison, & McCarthy, 2005; Thompson, Clarke, Stewart, & Puce, 2005; Wildgruber, Ackermann, Kreifelts, & Ethofer, 2006).

The posterior portion of the STS, extending into posterior MTG and STG (pMTG/STG) has also been consistently linked with attentional processing (Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002; Mars et al., 2012). Specifically, this region, which extends into the ventral, anterior portion of the temporo-parietal junction (TPJa) area (Mars et al., 2012) appears to control attention selection and re-orienting (Corbetta et al., 2008; Corbetta & Shulman, 2002; Mars et al., 2012). In its capacity as a multisensory perceptual integration zone (Driver & Noesselt, 2008), the STS is concerned with assessing the behavioural relevance of environmental stimuli (Redcay, 2008). The STS is particularly activated in response to dynamic, socially meaningful stimuli, with less or no activation seen in response to static, non-socially relevant stimuli (Redcay, 2008). Thus the pMTG/STS may be particularly important in the control of social attention (Nummenmaa & Calder, 2008). Anatomically, this region is situated at the interface between the social perceptual processing regions of more anterior STS/MTG/STG, and the temporoparietal junction (TPJ), associated with theory of mind (ToM; Saxe & Kanwisher, 2003; Saxe & Young, 2013). There is substantial evidence that functionally, as well as anatomically, the pMTG/STS represents an intersection between social perception and social cognition (e.g. Bayliss et al., 2011; Kreifelts, Ethofer, Huberle, Grodd, & Wildgruber, 2010).

The notion that the pMTG/STS may be a social attention control region fits well with its position connecting social perception and cognition circuits. In humans and other primates, attention to conspecifics and the objects of their attention is modulated by the interaction of neural social perception circuits with valuation circuits (Klein, Shepherd, & Platt, 2009). These transduce sensory information about others into value signals that bias orienting (Klein et al., 2009). The affective significance of a stimulus modifies not only an organism's attention to it, but the perceptual processing of it as well (Vuilleumier, 2005). The pMTG/STS/TPJa plays a crucial role, possibly as a 'circuit breaker,' interrupting ongoing attentional activity to re-orient towards novel information of interest (Corbetta et al., 2008; Corbetta & Shulman, 2002; Mars et al., 2012), particularly in relation to threat (Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2006). This re-orienting of attention can also initiate top-down influences on perception networks, influencing the sensory representation of a stimulus (Pourtois et al., 2006; Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005; Vuilleumier, 2005). By this mechanism, behaviourally significant stimuli, such as a fearful face, can promote deeper processing at early stages of perception, e.g. in primary visual cortex (V1), in the occipital lobe (Pourtois et al., 2006, 2005). Figure 5.14 illustrates the key connections of the MTG/STS with other regions involved in perception, as well as with ToM and valuation regions.

The influence of a stimulus' affective significance on attention may explain why individual differences in pMTG/STS GMvol are associated with social threat expectancies. Individuals who are more threat-sensitive are generally more vigilant towards threat stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Bögels & Mansell, 2004). Anxious individuals exhibit an attentional bias toward threat-related stimuli (Bishop, 2007). The magnitude of this bias is comparable across populations with different anxiety disorders, as well as highly-anxious individuals not diagnosed with a clinical disorder (Bar-Haim et al., 2007). A meta-analysis of 172 studies showed that cognitive processes requiring conscious perception of threat contribute to the attentional bias in anxious individuals (Bar-Haim et al., 2007). However, the bias is also observed for stimuli outside conscious awareness (Bar-Haim et al., 2007; Mogg & Bradley, 2002). These findings are consistent with the attention model discussed here (illustrated in Fig. 5.14), which suggests that (hyper)vigilance for social threat may maintain anxiety states by enhancing the perception and detection of threat cues in the social environment (Bögels & Mansell, 2004). Heightened expectancies of social threat may exert a top-down influence upon perceptual systems, with the pMTG/STS playing a key role (Leppänen & Nelson, 2009).

Personality processes relating to social attention and perception thus seem to play a significant role in individual differences in the subjective experience of social threat (Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007). The brain networks supporting these processes begin to emerge early in life (Leppänen & Nelson, 2009). Initial biases in affect and valuation-related brain circuits and the early coupling of these networks with perceptual regions provide a foundation for the acquisition of heightened sensitivity to social cues of some emotions (such as threat) in some individuals (Leppänen & Nelson, 2009). This, together with experience-driven refinement of the relevant brain networks and their connectivity, may predispose more vulnerable individuals to learn to associate fear with social situations (Leppänen & Nelson, 2009; Mathews & MacLeod, 2005; Olsson & Phelps, 2007). This ties in with the development of attachment style and of cognitive working models of self and others (discussed in Chapter 4). These aspects of social cognition, associated with biases in social expectancies, may influence social perception and attention, perhaps via the TPJ and pMTG/STS. My finding of greater GMvol in pMTG/STS associated with higher expectations of social threat is consistent with the characterisation of the pMTG/STS as a social attention control region (Nummenmaa & Calder, 2008). Although the pMTG/STS is the only threat-related region to survive cluster-extent thresholding, it is probable that this region represents a hub connecting wider networks of regions in which processing and brain structure vary with heightened expectancies of social threat. This is discussed further in section 5.4.5.

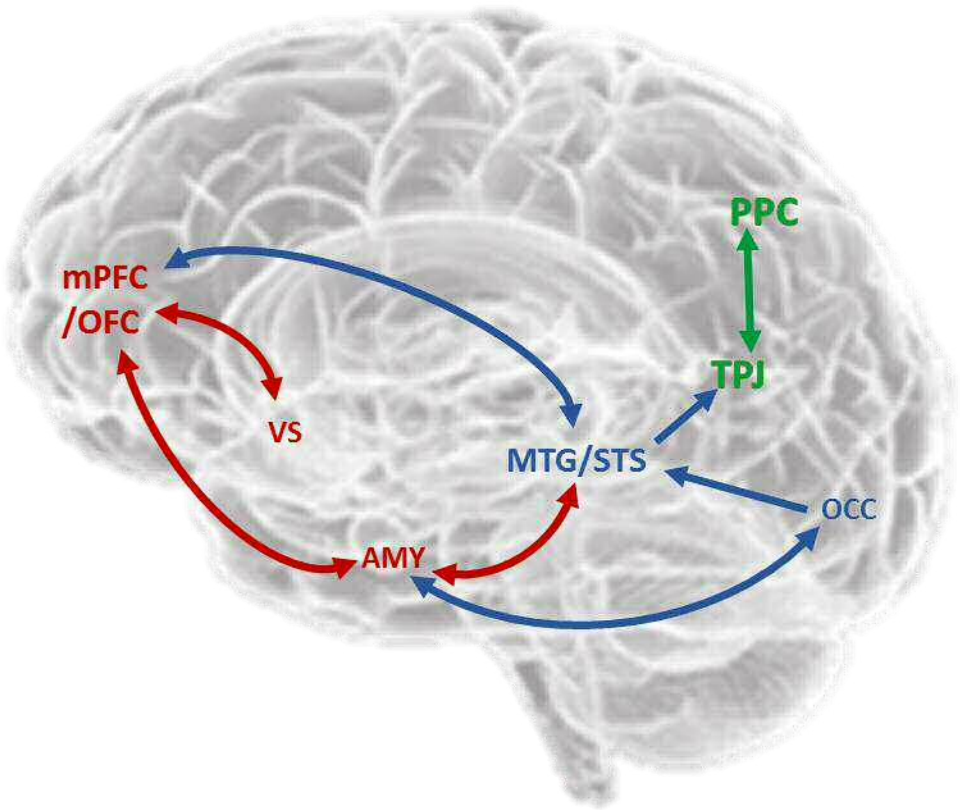


Figure 5.14. Schematic representation of the connectivity between valuation (red), perception (blue), and ToM (green) brain regions involved in social attention.
OCC – occipital cortex; MTG – middle temporal gyrus; STS – superior temporal sulcus; TPJ – temporoparietal junction; VS – ventral striatum; AMY – amygdala; mPFC – medial prefrontal cortex; OFC – orbitofrontal cortex.

5.4.2 Neural networks supporting individual differences in social expectancies?

Having discussed in detail each of the focal brain regions that survived cluster-extent correction thresholding, I shall now proceed to a wider-lens discussion of the neural systems that seem implicated in individual differences in social expectancies. For the purpose of this discussion, the $p < 0.005$ results (uncorrected for multiple comparisons; reported in Tables 5.4 – 5.7) will also be considered. This is because, as described in section 5.2.2.5, complex cognitive functions – such as forming social expectancies – do not arise from the solitary actions of isolated brain regions. Such functions require multiple contributory processes to be performed by a system, or network, of functionally related brain regions (Bressler, 1995; Fuster, 2003). Thus it is important to take into account the networks of brain regions beneath the surface of my most stringent statistical threshold, but with the caution that these results should be seen as preliminary, for the purpose of hypothesis generation, rather than as definitive findings.

5.4.3 Social expectancies and the reward network

The core 'hub' of neural reward processing, the ventral striatum, did not show structural variation related to social reward expectancies. However, GMvol in a nearby brain region, the subgenual prefrontal cortex[4] (sgPFC), did show a positive correlation with social reward expectancies (see Table 5.4). The sgPFC provides the densest neural inputs that the 'shell' sub-territory of the VS receives (Haber, 2011). The VS 'shell' is particularly important in circuitry underpinning goal-directed behaviours, changes in affective states and behavioural sensitisation (Haber, 2011). Like the VS/NAcc, the sgPFC is involved in evaluating the reward-related motivational significance of stimuli (Charney & Nestler, 2011).

The sgPFC forms part of a neural network supporting social affiliation (Bickart et al., 2014) and is activated by stimuli that generate expectancies of social reward (Fareri & Delgado, 2014). A region of vmPFC extending into sgPFC has been found to code the anticipated pleasantness of imagined future social interactions (Benoit, Szpunar, & Schacter, 2014). The sgPFC was also engaged when participants recalled positive autobiographical memories in Speer et al.'s (2014) study of savouring. Damage to the sgPFC is associated with anhedonia, specifically with an inability to maintain arousal in anticipation of reward (Rudebeck et al., 2014). Convergent evidence from neuroimaging and post-mortem studies shows reduced GMvol of the sgPFC in individuals with depression, reflecting a reduction in the size of neurons and the number of glial cells (Charney & Nestler, 2011). My data extend this substantial evidence, by indicating that increased GMvol in the sgPFC is associated with greater dispositional expectancies of social reward. This result did not survive cluster-extent correction however, so should be regarded as preliminary.

[4] Also known as the subgenual cingulate cortex or subcallosal cortex.

5.4.4 Social expectancies and the aversion network

GMvol in the left amygdala was positively correlated with social threat expectancies (see Table 5.5). This accords with the prominent role of the amygdala in fear and aversion processing: the left amygdala was the strongest activation cluster to emerge in a meta-analysis of human aversion-related functional imaging studies (Hayes & Northoff, 2011). In my data, GMvol was also positively correlated with threat expectancies in right lateral orbitofrontal cortex (OFC) and right dorsal anterior insula, also regions implicated in aversion (Hayes & Northoff, 2011).

In DeWall et al.'s 2012 Cyberball study, BOLD activity in response to social exclusion in right dorsal anterior insula and right lateral OFC was heightened in participants with a more anxious attachment style. The exclusion-related BOLD activity in the right dorsal anterior insula correlated with greater self-reported distress (DeWall et al., 2012). This supports the view that the anterior insula is important in generating subjective affective states, and specifically that the dorsal anterior insula is specialised for the experience of pain, including social pain (Kross, Berman, Mischel, Smith, & Wager, 2011).

However, other regions in which we found GMvol co-variation with social threat expectancies are less consistently associated with social aversion (Bickart, Hollenbeck, Barrett, & Dickerson, 2012). Notably, many of these brain regions form part of a neural network associated with social perception (Bickart et al., 2014, 2012; discussed in section 5.4.5 below). This suggests that individual differences in social threat expectancies may be reflected in brain regions mediating social vigilancein addition to, generating the affective experience of social anxiety.

5.4.5 Social expectancies and the social perception/attention network

On the basis of multimodal evidence from humans and non-human primates[5], Bickart et al. (2014, 2012) have identified a network of brain regions that support social perception. Bickart et al. define this network (shown in Fig. 5.15) as "performing the sensory processes involved in detecting, decoding and interpreting social signals from others in the context of past experience and current goals" (Bickart et al., 2014, p. 238). The hub of this perception network is the ventrolateral part of the amygdala, with extensive interconnections throughout the orbitofrontal cortex (OFC) and sensory association areas of the temporal cortex. In addition to receiving input from sensory association areas, the ventrolateral amygdala and lateral OFC send feedback-like excitatory projections to temporal-lobe sensory association regions (Bickart et al., 2014; see Fig. 5.14). The amygdala's projections extend as far as primary sensory cortices (Bickart et al., 2014; Vuilleumier, 2005; see Fig. 5.14). These direct, excitatory connections can enhance perceptual processing of relevant stimuli during emotional situations (Vuilleumier, 2005), in accordance with the individual's current affective state and perceived situational context (Bickart et al., 2014).

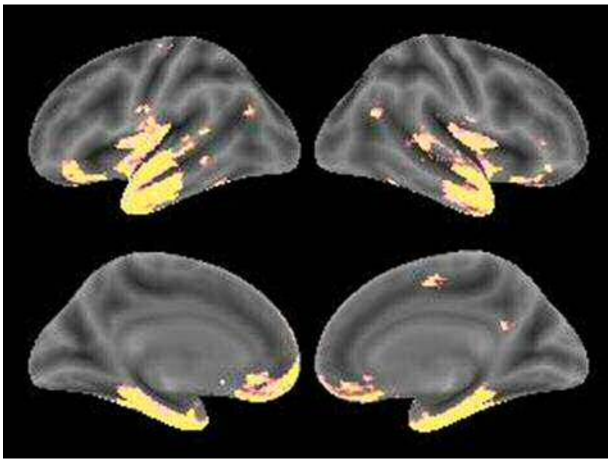


Figure 5.15. The brain regions (shown in yellow) comprising the social perception network identified by Bickart et al. The upper panel shows the lateral surface of the brain (left and right); the lower panel shows the medial surface.
Figure created in bspmview (http://www.bobspunt.com/bspmview/) using Bickart et al.'s social perception brain map, part of the supplementary data for Bickart et al. (2014), downloaded from http://dx.doi.org/http://dx.doi.org/10.1016/j.neuropsychologia.2014.08.013.

[5] Constituting resting-state functional connectivity (assessed using fMRI); functional neuroimaging and electrophysiology evidence; lesion-based neuropsychology evidence; and evidence from anatomical connectivity (tract-tracing) studies in non-human primates.

The amygdala cluster we find, in which GMvol correlates with higher social threat expectancies (Table 5.5), is in the subregion of the amygdala that forms the hub of Bickart et al.'s social perception network.[6] This is consistent with the hypothesis that individuals with higher social threat expectancies are more vigilant for cues of threat in the social environment, and perceive these more readily. My finding of greater GMvol in the ventrolateral amygdala suggests that this region may be tonically more active in individuals with higher social threat expectancies. This would result in heightened perception both by the direct excitatory influence of the amygdala on social perception regions, as well as indirectly, via attention modulation (effected via the pMTG/STS; see fig. 5.14) (Vuilleumier, 2005). In support of this, functional neuroimaging work has found that anxiety-related attentional biases to threat are associated with amygdala hyperactivity during the processing of potentially threatening information from the environment (Bishop, 2007; Freitas-Ferrari et al., 2010). This has been found during the anticipation of potentially threatening stimuli as well, indicating hypervigilance among more anxious individuals. For example, Brühl et al. (2011) report a correlation between trait anxiety and enhanced activity in amygdala and OCC during anticipation of unpleasant emotional stimuli across a combined sample of 16 patients with SAD (5 taking medication) and 18 healthy control participants. In the same brain regions, activity in the SAD patients was correlated with their level of social phobia (Brühl et al., 2011).

My results indicate that the modulation of brain circuits involved in attention and perception by affective-bias-related amygdala reactivity may be reflected in regional GMvol variation in these circuits. Higher social threat expectancies were associated with greater GMvol in ventrolateral amygdala, temporal pole, and lateral OFC, all regions identified by Bickart et al. (2014) as components of the network supporting social perception. The amygdala plays a crucial role in modulating the activity of social perception pathways, which can influence individuals' representations of events, especially when related to threat (Vuilleumier, 2005). However, activity

[6] 56 out of 57 of the voxels in my amygdala cluster are within the region identified by Bickart et al. (2014). This was assessed by using Bickart et al.'s social perception brain map as an inclusive mask within which to display my results, to assess whether my amygdala cluster was within this map.

of the amygdala is itself regulated by prefrontal cortical brain regions (discussed in the next section, 5.4.6). Prefrontal regions also have direct feedback-like connections with sensory association regions (Bickart et al., 2014). While excitatory up-regulation of social perception by the amygdala is usually in the context of threat vigilance, heightened social perceptual processing or attention may not always be fear-related. Indeed, impaired (i.e. reduced) social attention and perception is also associated with anxiety (Newsome, Day, & Catano, 2000; Schroeder, 1995; Schroeder & Ketrow, 1997; Slessor, Phillips, & Bull, 2008). In low-anxious individuals, social perception is not biased toward threat signals (Bishop, 2007). In such individuals higher GMvol in social perception regions may be linked with greater social perceptiveness, i.e. detecting and understanding social signals. Greater social perceptiveness is associated with less worry and higher sociability (Schroeder, 1995; Schroeder & Ketrow, 1997). Affective-bias related modulation may therefore explain why we see some regions within the social perception network in which GMvol correlates negatively with social threat expectancies, and/or positively with social reward expectancies.

5.4.6 Social expectancies and emotion regulation systems

As hypothesised, individual differences in GMvol associated with social expectancies were more strongly manifested in brain areas involved in contextual and conceptual level valuations, rather than core level valuation regions. Among the results that survived cluster-extent correction thresholding, there was an absence of subcortical regions that have classically been thought to represent the brain's 'reward centre' (VS/NAcc) or 'anxiety centre' (amygdala).

These results do not refute the importance of the VS in reward anticipation, nor of the amygdala in processing threat and generating anxiety. At the more lenient threshold of $p < 0.005$ (unc.), a positive correlation between left amygdala volume and social threat expectancies was observed (Tables 5.5. and 5.6). At the cluster-corrected level, individual differences in LODESTARS scores correlated with GMvol variation in regions of the mPFC. That the mPFC results survived cluster-extent correction while the amygdala result did not suggests that individual differences in valenced social expectancies are not predominantly due to differences in core-level appraisals of potential threat and reward. As discussed in sections 5.4.1.1 and 5.4.1.2, the mPFC regions implicated are involved in emotion regulation. Thus my data suggest that the main locus of individual differences in social reward and threat expectancies may be differences in the regulation of affective and cognitive responses to core-level appraisals.

This interpretation of my structural results is supported by previously reported functional findings. Pezawas et al. (2005) found that only the functional connectivity between mPFC and amygdala was associated with anxiety, whereas amygdala reactivity to fearful faces was not. Kim and Whalen (2009) also found that amygdala response to fearful faces was not correlated with self-reported trait anxiety. Kim and Whalen suggest that the strength of the connectivity between the amygdala and vmPFC may be a better predictor of anxiety than amygdala reactivity alone.

It is broadly agreed that cognitive biases towards threat-related processing in anxiety are linked to disrupted connectivity between regulatory prefrontal regions and the amygdala (Bishop, 2007; Etkin & Wager, 2007; Freitas-Ferrari et al., 2010; Kim et al., 2011). This is consistently associated with amygdala hyperactivity (Miskovic & Schmidt, 2012) but the nature of the fronto-amygdalar network disruption appears to be variable. Several studies have found evidence that stronger connectivity is associated with greater emotion regulation proficiency and lower anxiety (Kim et al., 2011). For instance, Hahn et al. (2011) report reduced functional resting-state connectivity between left amygdala and medial orbitofrontal cortex in patients with SAD compared with healthy controls. The strength of this functional connectivity showed a negative association with the severity of state anxiety. This effect was in a heterogeneous sample of 10 patients (2 of whom had comorbid panic disorder and 1 of whom had panic disorder only, without SAD) and 27 healthy controls. However, a similar result was reported by Eden et al. (2015), this time using diffusion tensor imaging (DTI) to assess structural connectivity (via white-matter pathways). These authors measured trait anxiety and use of reappraisal in 48 female participants. More frequent use of reappraisal was linked with stronger structural connections between the amygdala and dorsolateral prefrontal cortex (dlPFC), dmPFC, vmPFC, and OFC in the left hemisphere. Higher trait anxiety was associated with weaker connections between the amygdala and vmPFC and OFC in the right hemisphere (Eden et al., 2015). A similar result was reported by Kim and Whalen (2009), who also found that structural connectivity strength between vmPFC and amygdala was inversely correlated with trait anxiety.

However, other studies report social anxiety-related alterations in fronto-amygdalar connectivity in the opposite direction (Freitas-Ferrari et al., 2010). For example, Ding et al. (2011) found that patients with SAD exhibited strengthened connectivity between the left amygdala and the right mPFC, compared with healthy controls. One possible explanation for this is that amygdala hyperactivity in SAD may be, or may become, intrinsic to the amygdala (not merely arising due to inadequate modulation of normal amygdala activity). The strengthened connections with regulatory mPFC regions may then reflect a compensatory mechanism in SAD, by which the neural network attempts to adapt to exaggerated responsivity of the amygdala (Ding et al., 2011; Liao et al., 2011).

It is also possible that the nature of the connections is altered in some cases of clinical social anxiety. Sladky et al. (2015) found evidence for positive connectivity from mOFC to amygdala in SAD patients, indicating an excitatory connection in this direction. This was in contrast to healthy controls, in which mOFC-amygdala connectivity represents a negative feedback loop. This study highlights the importance of considering the direction of connections as well as their strength.

The apparent discrepancies in the findings described above indicate that further fine-grained work is required to elucidate the nature of individual differences in mPFC-amygdala interactions. It appears that there may be qualitative differences between healthy participants and those with SAD, indicating a need for caution when making inferences about healthy brain function on the basis of results from studies of clinical populations.

In healthy adults, successful down-regulation of negative affect is consistently associated not only with increased activity in the vmPFC, but also with concordant reduction of activity in the (typically left) amygdala (Diekhof, Geier, et al., 2011; Hänsel & Känel, 2008; Hariri, Mattay, Tessitore, Fera,

& Weinberger, 2003; Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Kim et al., 2011). Unlike fear extinction, more cognitive forms of emotion regulation frequently recruit dorsal and lateral prefrontal regions (dmPFC, dlPFC and vlPFC) in addition to vmPFC (Diekhof, Geier, et al., 2011; Kim et al., 2011). Cognitive regulation strategies such as reappraisal are more conscious than the implicit associations underlying placebo conditioning or fear extinction (Diekhof, Geier, et al., 2011). Cognitive (reappraisal) processes also need to be voluntarily engaged. These may be reasons why reappraisal often involves other prefrontal regions, above and beyond vmPFC (Diekhof, Geier, et al., 2011). Nonetheless, the vmPFC remains the brain region most consistently associated with reappraisal, as well as other forms emotion regulation (Diekhof, Geier, et al., 2011; Kim et al., 2011).

Greater habitual use of reappraisal to regulate emotion has been related to more pronounced increases in mPFC activity and associated reductions in amygdala activity during the processing of negative emotional facial expressions. These associations were not attributable to individual differences in trait anxiety, neuroticism, or habitual use of suppression (Drabant, McRae, Manuck, Hariri, & Gross, 2009). This finding suggests that individuals who are more proficient at regulating negative emotion may habitually down-regulate amygdala activity via increased mPFC activity. Long term, trait-like use of such strategies may be linked not only to a greater negative correlation between activity in vmPFC and (left) amygdala, but perhaps also to a greater negative correlation in the volume of these two brain regions. In support of this, greater habitual use of reappraisal has been shown to be related to increased vmPFC volume (Welborn et al., 2009). Greater GM thickness in vmPFC has also been found to be negatively correlated with amygdala reactivity (Foland-Ross et al., 2010).

My study did not include a measure of participants' use of emotion regulation strategies. However, my data may be used to test the more general hypothesis that vmPFC and amygdala volumes are negatively correlated. To this end, a post-hoc correlation analysis was conducted of the peak voxels in the vmPFC and amygdala clusters in which GMvol was associated with social threat expectancies. As predicted, GMvol in the peak amygdala voxel was significantly negatively correlated with GMvol in the peak vmPFC voxel (p = .008; see Table 5.10)

		Adjusted GMvol at -28.5 -12 -7.5 left amygdala (Threat_o_wrt_Rew_threat_pos_amygdala)
Adjusted GMvol at 3, 70.5, -4.5 right vmPFC (Threat_o_wrt_Rew_threat_neg_vmPFC)	Pearson's r	-.263**
	p (2-tailed)	.008
	N	100

Table 5.10 Correlation of GMvol in the peak voxel in the vmPFC with GMvol in the peak voxel of the amygdala. The GMvol values were for the peak voxels of clusters in which GMvol was associated with the variance unique to threat. Peak voxels were taken from clusters that survived p < 0.005, 10 voxel extent threshold (Table 5.5).

The negative correlation between vmPFC and amygdala GMvol in my data provides further evidence that emotion regulation processes are key to individual differences in social expectancies. Further research is needed to clarify the associations between expectancies and emotion regulation processes such as rumination (positive or negative) and cognitive reappraisal. In some ways, expectancies may operate very similarly to certain emotion regulation strategies (Ochsner & Gross, 2014). Like emotion regulation strategies, expectancies influence individuals' affective responses to stimuli (Diekhof, Kipshagen, et al., 2011; Ochsner & Gross, 2014). Expectancies can alter individuals' experience of a stimulus by leading them to experience it as subjectively more similar to what they expected than would have been the case had they held no preconceived beliefs about its nature. This is the basis of placebo effects, one of the emotion regulation procedures found to strongly and consistently recruit the vmPFC in Diekhof et al.'s (2011) meta-analysis.

From the perspective of Ochsner and Gross's (2014) valuation framework, expectancies can modulate emotion via top-down influences of cognitive control systems on valuation systems, or of higher-level valuation systems on lower-level valuation systems (see Figs. 5.1, 5.14 and 5.15). Functional neuroimaging studies of expectancies indicate that they are maintained in a combination of lateral parietal and prefrontal regions, and/or medial prefrontal regions (Ochsner & Gross, 2014). Consistent with this, GMvols in these regions were found to be associated with social threat and reward expectancies in my data (see Tables 5.4 – 5.7). In Ochsner and Gross's (2014) framework, expectancies are represented as conceptual-level beliefs (e.g. "drinking alcohol will make the social event more fun") or contextual-level expectancies about the properties of a stimulus or placebo. Attention to and appraisal of stimuli in lower contextual and/or core-level systems is then modulated to be consistent with these top-down beliefs, according to Ochsner and Gross's (2014) model. This may be an accurate representation of the mechanisms by which social expectancies link to emotion regulation, especially during a social encounter. However, dispositional social expectancies, which can be accessed and reported hours or days before a potential social encounter, may also influence emotion by mechanisms other than attention deployment and cognitive reappraisal. According to Gross's (2001) process model of emotion regulation, emotion may be regulated at five points during the emotion-generative process: (1) selection of the situation, (2) modification of the situation, (3) deployment of attention, (4) change of cognitions (reappraisal), and (5) modulation (e.g. suppression) of experiential, behavioural, or physiological responses. Social expectancies might influence individuals' selection of a situation (i.e. whether or not to attend a social event) and modification of it (e.g. whether to approach groups or individuals at the event; whether to initiate conversation).

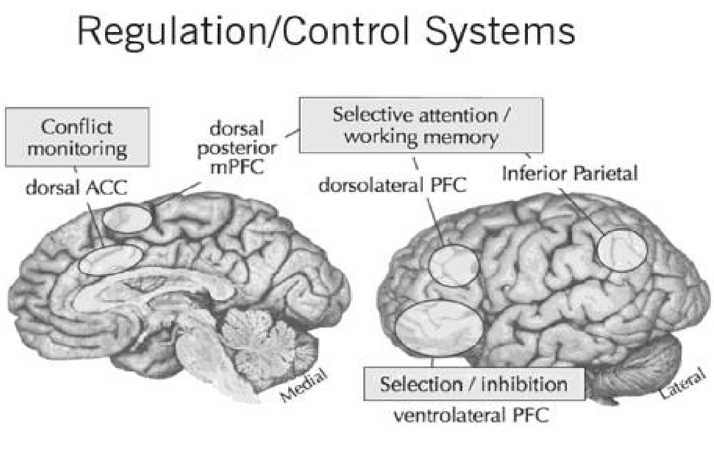


Figure 5.15: Brain regions involved in emotion regulation.
From Ochsner & Gross (2014), p 26.

Although further research is needed to elucidate the mechanisms by which social expectancies may regulate affect, there is considerable empirical and theoretical support for their importance in emotion regulation. The current study extends previous work by demonstrating that dispositional tendencies towards positive or negative social expectancies are accompanied by structural individual differences in brain systems associated with emotion regulation.

5.4.7 Social expectancies and empathy

All three of my cluster-corrected results for negative correlation with threat expectancies are in brain regions that may be linked with empathy. As described in section 5.4.1.1, the mPFC is a core brain region mediating social cognition; the contributions to social cognition performed by the vmPFC include empathy (Bernhardt & Singer, 2012). And as discussed in sections 5.4.1.4 and 5.4.1.5, the postcentral gyrus and the left lateral occipital cortex have also been linked to empathy in previous work (Gossen et al., 2014; Keysers & Gazzola, 2009; Keysers et al., 2010). At the $p < 0.005$ (unc.) level the right postcentral gyrus cluster extends into the adjacent supramarginal gyrus (SMG; see Tables 5.5 and 5.6). The SMG is part of the somatosensory association cortex. The right SMG has previously been identified as important in empathy, perhaps playing a particular role when self-related affective representations need to be disentangled from representations of the affective states of others (Silani, Lamm, Ruff, & Singer, 2013). At $p < 0.005$ (unc.) we also observed clusters in the left postcentral gyrus, left vmPFC, left posterior cingulate cortex (PCC), left angular gyrus[7], bilateral precuneus, and parietal regions – all previously associated with empathy (Bernhardt & Singer, 2012).

My results indicate that greater GMvols in brain regions associated with empathy and/or theory of mind (ToM) are concomitant with lower expectations of social threat. It may be that the functions of these regions in social cognition are not limited to ToM/empathy, or it may indeed be the case

[7] Clusters here are usually labelled as temporo-parietal junction (TPJ) in neuroimaging literature on theory of mind and empathy.

that individual differences in ToM and empathy are linked with individual differences in social expectancies.

In support of the first hypothesis, Evans, Fleming, Dolan, and Averbeck (2010) found that the contribution of social value – in the form of a smiling or angry face – to decision-making in a financial-reward paradigm engaged brain regions previously implicated in ToM. The differential effect of the social information was mediated by the middle cingulate cortex and dorsal temporo-parietal junction (angular gyrus). This suggests that these 'social brain' regions, commonly characterised as ToM or empathy regions, may also be directly involved in assigning subjective value to social stimuli.

In support of the second hypothesis, empathic perspective-taking ability has previously been found to correlate negatively with social anxiety (Davis, 1983). Similarly, attachment anxiety and avoidance are negatively correlated with self-reported empathy (Mikulincer et al., 2001). It is possible, developmentally, that lower empathic ability early in life increases the likelihood of negative social interactions and rejection (Bellini, 2006), perhaps in turn leading to higher expectations of social threat. In support of this, children's empathic responding at age 9 has been shown to predict their teacher-reported social competence two years later (Zhou et al., 2002). As far as I am aware, longitudinal studies have not specifically addressed the role of empathy in social anxiety. However empathy has been shown to correlate negatively with depression and positively with social relationship quality across the adult lifespan (Grühn, Rebucal, Diehl, Lumley, & Labouvie-Vief, 2008). The direction(s) of these effects largely remain to be elucidated however.

It is possible that greater empathy for others reduces expectations of social threat, by increasing the perceived similarity of others to oneself and thus reducing fear of others. If one empathises with others and perceives that they are like oneself, then one may be less likely to fear them or react badly to negative social behaviour from others. This links with the emotion regulation role of social expectancies that my data suggest. The process of regulating emotion by means of compassion-focussed reappraisal has been linked with increased empathy, positivity and perceived control, and with reduced anxiety (Witvliet, DeYoung, Hofelich, & DeYoung, 2011; Witvliet, Knoll, Hinman, & DeYoung, 2010). More generally, higher capacity to regulate one's own emotion is associated with increased likelihood of experiencing empathy in adults (Decety & Lamm, 2006). Developmental research has also linked greater dispositional empathy-like responding with more effective emotion regulation in young children (Eisenberg et al., 1996). Greater dispositional empathic tendencies may predispose individuals to engage more readily in compassion-focussed reappraisal as an emotion regulation technique. This may in turn lead to lower expectancies of social threat, by virtue of the reduced anxiety that results from compassion-focussed reappraisal (Witvliet et al., 2011, 2010).

However, it is equally plausible that the reverse effect occurs: that when one does not fear others, one's empathic tendencies are more likely to emerge. Priming a sense of attachment security strengthened empathic reactions across 5 studies with a total of 411 adult participants conducted by Mikulincer et al. (2001). Further, emotion regulation proficiency has been found to mediate the link between secure attachment and empathy in children (Panfile & Laible, 2012). These data indicate that less socially fearful (more securely attached) children are more empathic *because* they are more proficient emotion regulators (Panfile & Laible, 2012). Although cross-sectional and correlational, the adult data linking emotion regulation and empathy is consistent with this hypothesis. During empathic responding to others' negative circumstances, it is important to regulate one's own vicarious emotion so that this is not experienced as excessively aversive (Decety & Lamm, 2006). Individuals who are more prone to distress – including empathic distress – may be more inclined to focus on reducing their own negative affect, with reduced motivation to feel for the other. Over time therefore, an initial deficit in the ability to modulate one's own personal distress may lead to a reduced tendency to engage in empathy. This implies that lower expectations of social threat – and associated emotion regulation skill – may result in increased empathy over time, thus offering another potential pathway to the observed greater GMvol in empathy-related brain regions.

5.4.8 Summary of findings related to social threat expectancies

Higher social threat expectancies were associated with greater GMvol in brain regions involved in social attention and perception. This may reflect attentional bias and hypervigilance directed towards potential social threat signals in the environment. Attentional deployment is influenced by expectancies (Diekhof et al., 2011; Ochsner & Gross, 2014).

Lower expectancies of social threat were associated with greater GMvol in brain regions involved in emotion regulation. This suggests that the minimisation of social threat expectancies – and/or the maintenance low threat expectancies – may be implemented in the brain in much the same way as the reduction of fear or negative affect in other emotion regulation scenarios.

My findings provide support for the importance of expectancies not only in motivating behaviour, but also in modulating subjective experiences of social situations. Thus a person who is primed (by their high social threat expectancies, and perhaps their neural anatomy) to attend particularly to signals of potential threat in the social environment will perceive these more readily than will a person who is not primed in this way. Other individuals may even have activated (by virtue of their low threat expectancies) emotion regulatory systems that facilitate attentional deployment *away* from potentially threatening stimuli. This raises the intriguing possibility that 'thinking makes it so' (Ochsner & Gross, 2004). Although of course, the effects of social expectancies and social experiences are probably bidirectional.

5.4.9 Summary of findings related to social reward expectancies

My results indicate that the main locus of individual differences in social reward expectancies may be propensity to engage in positive rumination/savouring. Higher expectancies of social reward were associated with greater GMvol in the left dmPFC, left dlPFC, bilateral orbitofrontal cortex, right parietal cortex, and left subgenual cingulate cortex. These brain regions are all implicated in savouring processes (Bryant et al., 2011), such as reminiscing about positive past experiences (Speer et al., 2014).

Neuroimaging studies of self-esteem, affective biases and related concepts strongly support the view that the dmPFC contributes to evaluative self-referential processing by integrating conceptual self-representations with core-level valuation in VS, anterior insula and amygdala (Engel, Bandelow, Gruber, & Wedekind, 2009). Beliefs and expectations about oneself and others can modulate activity in brain regions involved in valuation and emotion processing (DeWall et al., 2012; Eisenberger & Cole, 2012; Engel et al., 2009; Ochsner & Gross, 2014). It appears that social reward expectancies may be shaped by neural systems that support flexible, cognitive regulation of emotion. The brain regions involved in these systems, particularly OFC, dmPFC and dlPFC, may be involved in appraisal processes that increase positive expectancies for some individuals, but decrease them for others. This may partially explain why my results show fewer GMvol associations with reward expectancies than threat expectancies.

5.4.10 Overlap analyses

In order to directly interrogate whether there are brain regions in which GMvol is significantly correlated (positively or negatively) with both threat *and* reward expectancies, overlap analyses were performed. When SPMs for reward, positive correlation, and threat, negative correlation were overlaid, there was overlap between clusters in the mOFC/vmPFC, in the right lateral inferior temporal gyrus and in the right fusiform gyrus (see Table 5.8 and Fig. 5.13).

These findings are consistent with the previously reported ubiquitous involvement of the vmPFC/mOFC in emotion regulation. My results indicate that, in addition to a domain-general role in diminishing negative affect (Diekhof, Geier, et al., 2011), the vmPFC may also participate in the regulation or experience of anticipatory positive affect. Indeed, greater GMvol in the vmPFC has previously been linked with higher positive emotionality as well as more effective emotion regulation within the same study (Welborn et al., 2009). Such a role for the vmPFC in positive affect would explain why this region has been consistently linked with reward processing (Diekhof, Kaps, Falkai, & Gruber, 2012) and implicated in positive reappraisal (Wager et al., 2008).

However Roy, Shohamy, and Wager (2012) note that characterising the vmPFC's broad functional roles with terms such as 'affect,' 'regulation,' and 'valuation' does not capture the full range of processes that involve this brain region. These include autonomic control (Critchley, Nagai, Gray, & Mathias, 2011), episodic and semantic memory, prospection, self-directed cognition (Buckner & Carroll, 2007), and representing the mental, physical or affective states of others (Saxe & Powell, 2006). Roy et al. (2012) suggest that the vmPFC functions as a hub, which integrates information from systems involved in episodic memory, representation of affect, social cognition, and interoception. They argue that the vmPFC is not necessary for affective responses per se, but for the construction of 'affective meaning.' That is, when affective responses are shaped by conceptual information. Roy et al. propose that to conceptualise oneself in context is to conceive the meaning of a situation for one's physical and social well-being and future prospects. This is very similar to the process of contextual valuation described by Ochsner and Gross (2014), also mediated by the vmPFC. Roy et al. suggest that, by linking these contextual valuations with brainstem systems capable of co-ordinating organism-wide emotional behaviour, the vmPFC controls the generation of affective meaning. Roy et al.'s view of the construction of affective meaning by the vmPFC is depicted in Fig. 5.16.

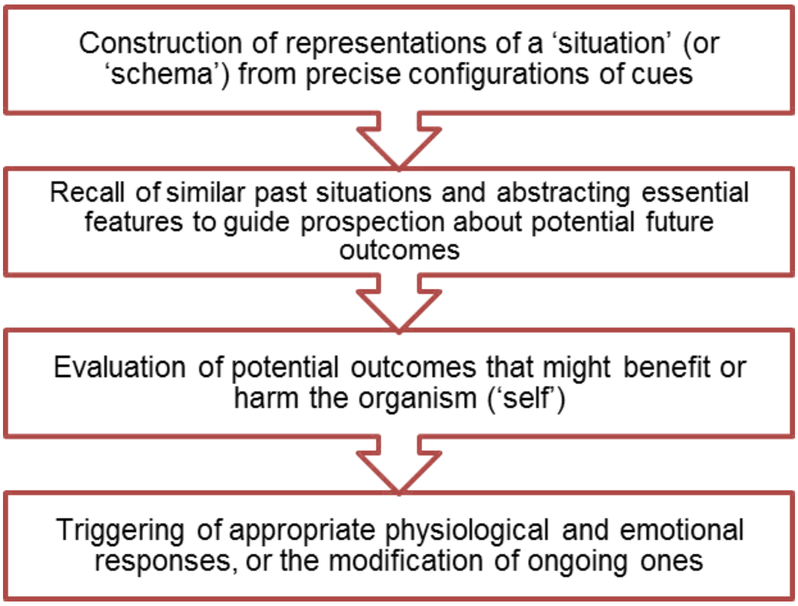


Figure 5.16: The construction of affective meaning by the vmPFC, as proposed by Roy et al. (2012). Their meaning-centred view of vmPFC functioning predicts that the vmPFC and its subcortical connections are not essential for simple forms of valuation and affective learning, but are essential when conceptual information determines affective physiological and behavioural responses.

Based on Roy et al. (2012).

The processes described in Fig. 5.16 seem likely to be engaged by participants completing the LODESTARS. Generation of affective meaning is required for both threat and reward expectancies, but this does not explain the directional, or valence-specific, findings of my study. Greater GMvol in vmPFC was associated with higher expectations of social reward and lower expectations of social threat. If the functions of the vmPFC were all entirely valence-general, we would not expect to see these valence-specific correlations. If the vmPFC was engaged in assessing the salience of stimuli present in the internal or external environment, as suggested by Gusnard et al. (2001), we would expect greater GMvol in this region to be associated with higher, not lower, expectations of social threat.

It may be that the function of the vmPFC when constructing affective meaning is aimed at emotion regulation: reducing negative affect and increasing positive affect. This links with the generation of social expectancies, in the sense that expectancies can operate like emotion regulation strategies (Ochsner & Gross, 2014).

The regulatory role of expectancies may also account for the overlap between threat and reward expectancy correlations with GMvol that we observed in right inferior temporal lobe regions. Both the inferior temporal gyrus (ITG) and the fusiform gyrus (FG) are involved in high-level visual processing; both are included in the social perception network identified by Bickart et al. (2014, 2012), discussed in section 5.4.5.

Ventromedial prefrontal and inferior temporal regions have also been linked with self-reflective processes, including insight into one's future prospects (Okuda et al., 2003). In the social domain, reduced GMvol in vmPFC and lateral ITG has been found to correlate with diminished insight into own social interaction skills among patients with frontotemporal dementia and Alzheimer's disease (Hornberger et al., 2014). Reduced vmPFC GMvol was associated with insight deficits across multiple domains, whereas the association of ITG atrophy was specific to social interaction insight only. Reduced GMvol has also been observed in inferior temporal regions in patients with SAD; GMvol in these regions was negatively correlated with patients' self-reported fear of social situations (Liao et al., 2011). My results indicate that in healthy individuals as well, greater GMvol in the ITG is associated with lower social threat expectancies and, further, with higher social reward expectancies. Further research will be required, using functional as well as structural techniques, to elucidate the contribution of the ITG to social cognition and self-related evaluation or insight.

5.4.11 Limitations of the VBM study

A major limitation of this study, as with any cross-sectional, correlational study, is that the direction of the associations found between social expectancies and regional brain volumes cannot be inferred. Another difficulty in interpreting the results is that the biology underpinning grey matter differences identified by VBM is still poorly understood, especially in healthy participants (Mechelli, Price, Friston, & Ashburner, 2005). In studies of degenerative disorders such as dementia, neuronal loss is likely to be the primary cause of GMvol changes detected by VBM (Mechelli et al., 2005). However, it is unclear in most structural imaging studies whether GMvol differences reflect differences in glial cell numbers or size, neuronal size, or dendritic or axonal branching (Mechelli et al., 2005). In the neocortex, greater observed GMvol could also result from increased folding or from thicker grey matter (illustrated in Fig. 5.17).

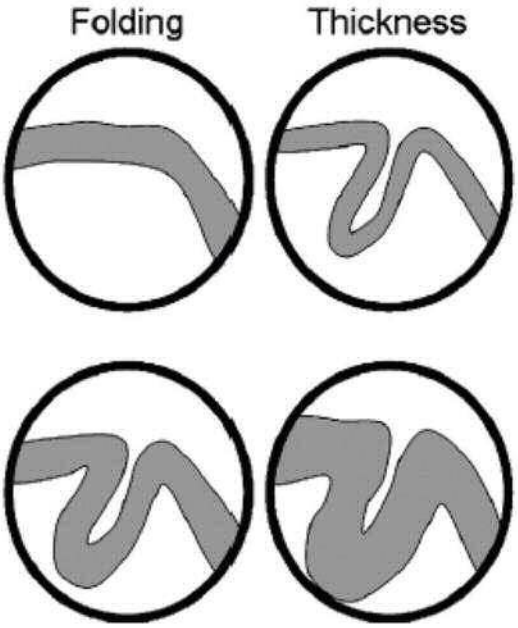


Figure 5.17: Differences in GMvol may result from differences in folding or thickness. Here, the upper two illustrations show situations where there is less GM in a given cortical region compared with the situation below it. In the first case, the difference is due to folding; in the second it is due to cortical thickness.

Adapted from Ashburner (2010).

GMvol is influenced by both genetic and environmental factors (Blokland, de Zubicaray, McMahon, & Wright, 2012; Lewis et al., 2014; Toga & Thompson, 2005), including skill training such as cognitive therapies, but again, whether experience-dependent changes result from differences in neuronal size, axonal branching etc. is unknown. Ideally, VBM should be combined with functional methods such as fMRI to better characterize brain structure-function relationships (Mechelli et al., 2005). This is explored in Appendix 8, in which a preliminary fMRI study conducted in a sub-set of 22 of the VBM participants is reported.

5.5 Conclusion

The main theme to arise from the data presented in this chapter is that individual differences in social expectancies appear very similar, at the structural level of the brain, to individual differences in emotion regulation. This provides support for Ochsner and Gross's (2014) proposal that expectancies can operate as emotion regulation techniques. Expectancies may modulate emotion via top-down influences of cognitive control systems on valuation systems, or of higher-level valuation systems on lower-level valuation systems (Ochsner & Gross, 2014). Of the five results that survived cluster-extent correction for multiple comparisons, three were in brain regions involved in contextual and conceptual level valuations. Two of these were in mPFC, in regions consistently linked with emotion regulation (Diekhof, Geier, et al., 2011) and with the generation of social expectancies (Van Overwalle, 2009) as well as valuation. The third was in STS, part of Ochsner and Gross's contextual valuation network, in which its proposed function is to integrate multisensory inputs with expectancies and modulate attention accordingly. My data support this role, and indicate possible hypervigilance associated with habitual high attention (controlled by the pMTG/STS) to social threat cues in individuals who report high dispositional social threat expectancies.

Beyond the domain of emotion regulation via modulation of valuation systems, my data suggest that social expectancy-related modulation extends to social perception systems as well. My results are consistent with the view that anxiety-related cognitive biases – such as selective attention to threat and negative interpretation of emotionally ambiguous stimuli – are associated with dysregulated prefrontal control and amygdala hyper-reactivity (Bishop, 2007; Freitas-Ferrari et al., 2010). Functional neuroimaging work has demonstrated that amygdala hyper-reactivity to social threat increases the processing of potentially social-threat-related sensory stimuli both through direct feedback projections to sensory cortices, and indirectly via biasing signals to attention control regions – with convergent influences on perception (Brosch, Pourtois, Sander, & Vuilleumier, 2011; Liao et al., 2010; Miskovic & Schmidt, 2012; Pessoa, Kastner, & Ungerleider, 2002). In addition to reduced regulation of amygdala reactivity, the bias towards social threat perception may be further exacerbated in more socially anxious individuals, due to reduced direct influence of prefrontal emotion regulation regions upon attention control (Bishop, Duncan, Brett, & Lawrence, 2004; Leppänen & Nelson, 2009) and social perception (Ding et al., 2011; Leppänen & Nelson, 2009; Teufel, Fletcher, & Davis, 2010).

My findings are consistent with the idea that individual differences in affective biases are reflected in the functioning of prefrontal regions that implement emotion regulation by modulating the configuration of functional pathways involved in valuation, attention and perception (Vuilleumier, 2005). It is hypothesised that the interaction of genetic factors with early interpersonal (attachment) experiences contributes to the development of structural differences in these neural networks (Benetti et al., 2010; Leppänen & Nelson, 2009). My data support this hypothesis, as do previous findings that anxiety-related affective biases[8] are associated with reduced GMvol in brain structures involved in emotion regulation (Fuentes et al., 2012). This converges with behavioural work demonstrating that individual differences in affective biases moderate associations linking emotion regulation strategies (reappraisal; suppression) with trait anxiety and consistent depressed mood (Dennis, 2007).

I found no regions in which GMvol was positively correlated with both reward and threat expectancies. This is contrary to the predictions of social sensitivity hypothesis, which suggests that certain biological predispositions conferring greater sensitivity to social threat may also confer greater sensitivity to social reward (Falk, Way, & Jasinska, 2012). However, the results of the VBM reported in this chapter do not preclude the possibility that there are brain regions, or sub-regions, which encode the salience of social stimuli. It may be that such brain regions exist, but code salience in a reactive fashion, in response to social stimuli. Further studies, employing functional neuroimaging, are required to investigate this possibility.

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[8] Operationalised by behavioural inhibition and behavioural activation sensitivity (BIS/BAS) assessments. BAS relates to approach motivation (tendency to emotionally respond to and approach potentially rewarding situations); BIS reflects avoidance motivation (tendency to emotionally respond to and avoid or withdraw from potentially threatening situations).

Chapter 6

Development and validation of a task-based measure of social motivation and reactivity to social reward and punishment

6.1 Introduction

The theoretical framework proposed and tested in this thesis was introduced in Chapter 2 (Fig. 2.7). For ease of reference, this is shown again below (Fig. 6.1).

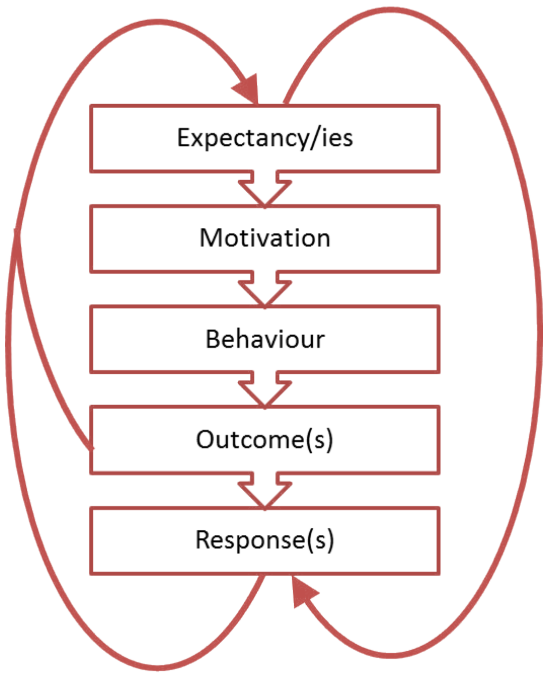

Figure 6.1: Copy of the theoretical framework proposed in this thesis.

Chapters 4 and 5 have explored mainly the first components in this model: that is how dispositional social reward and threat expectancies may influence social approach and avoidance motivation and social outcomes such as perceived belonging. Thus far, individual differences in socially motivated behaviour have not been directly addressed; neither have responses to social reward or threat/punishment been measured. The focus of the present chapter is upon these latter parts of the proposed model.

In this chapter I describe the development and validation of a task-based paradigm designed to measure behavioural (reaction time) differences in individuals' motivation to attain social reward (praise) and to avoid social punishment (negative evaluation). By asking participants how they felt in response to the task, and by measuring their state self-esteem before and after the task, affective biases in responses to reward and punishment can be also tapped. Behavioural and self-report data can then be examined to see if and how they relate to each other and to individual differences at other levels of the model, e.g. participants' dispositional social expectancies.

6.2 Task development

In a task-based measure of motivation for and responsivity to social feedback, a comparison 'non-social' form of outcome is desirable. Individual differences in *social* approach/avoidance motivation can then be more accurately disentangled from overall approach/avoidance motivation.

6.2.1 Conceptualising 'non-social' reward and punishment

Rewards that fulfil basic biological needs are termed primary rewards, or primary reinforcers. These include water, food and sex (Leotti & Delgado, 2011). Of these, water and food may be classed as physical, non-social (material) rewards, although in human society eating and drinking often occur as part of social occasions. Thus, one may eat because one is hungry (to fulfil a basic need: primary reward), out of habit because it is a mealtime,[1] or at a social occasion where food consumption is the norm (Cacioppo & Decety, 2011). At such social occasions the consumption of food (or drinks) may also be experienced in part as a social reward (fulfilling the need to belong) or avoidance of a social punishment (exclusion from this social activity). As eating and drinking are so often social experiences for humans, their effects on social and non-social reward systems (if these are separate) may be confounded (Watson, Werling, Zucker, & Platt, 2010). I will therefore not study food and drink rewards as part of this project, as the aim is to investigate differences in social and material reward processing.

Secondary rewards, such as money, acquire their rewarding properties through association with primary rewards (Leotti & Delgado, 2011) – that is, one cannot eat or drink money, but it can be exchanged for food or drink (or many other things that have intrinsic value). Although the value of money is socially defined – it acquires its value through social interaction and communication (Delgado, Labouliere, & Phelps, 2006) – the acquisition of money in modern society is generally not social. The payment of wages generally occurs via an automated process into individuals' bank accounts. In psychology experiments in which money is the incentive, participants are generally alone in performing the task and in their responses (which are aimed at attaining or maximising the money available). While participants might later exchange money for goods or experiences that engender social reward, the money itself is material and the process of acquiring it involves little or no confounding social reward. I therefore decided to use money as the material ('non-social') reward in the task described here.

6.2.2 Task design

The task was based on the monetary incentive delay (MID) paradigm originally developed by Knutson, Westdorp, Kaiser, and Hommer (2000). Several authors have recently adapted this task

[1] This behaviour is considered to be mediated by habitual valuation systems rather than Pavlovian or goal directed systems (Rangel, Camerer, & Montague, 2008).

to include social outcomes as well as monetary ones (e.g. Lin et al., 2011; Spreckelmeyer et al., 2009) and have found that social incentive delay (SID) trials give rise to robust and theoretically meaningful data. As it incorporates both social and monetary outcomes, the task developed and described here was named the social and monetary incentive delay (SMID) task.

The SMID task was programmed using Cogent 2000 (http://www.vislab.ucl.ac.uk/cogent.php) and MATLAB 2012 (http://www.mathworks.co.uk/products/matlab). Extensive pilot testing conducted in 2012[2] yielded a set of visual and auditory stimuli that most participants find to be salient and unambiguous social or monetary rewards, neutral outcomes or punishments. Affective ratings of the stimuli collected during pilot testing indicated that the neutral outcomes were generally perceived as neutral (neither happy nor unhappy), and that participants do generally find the reward trials to elicit positive affective responses (happiness), the punishment trials to elicit negative affective responses (unhappiness). The social and monetary trials in each of the three conditions (reward, neutral and punishment) elicit similar overall levels of pleasure, arousal and dominance, indicating that they are comparable. That is, differences in participants' responses to these different trial types should be due to whether the trial is monetary or social, not to differences in pleasure, arousal or dominance responses associated elicited by the stimuli. The stimuli used are described below.

6.2.3 Monetary stimuli

Visual stimuli: Photographs of British coins, placed on a black velvet background, were taken using a Panasonic Lumix fz40 digital camera. The images were re-sized such that the coins in the final images are correctly proportioned with respect to themselves and each other. Some previous studies that have used images of money as outcome stimuli have presented the currency in the context of a wallet or other money container (e.g. Spreckelmeyer et al., 2009), whereas others have presented the money image on a plain background (e.g. Lin, Adolphs, & Rangel, 2011; Clithero, Smith,

[2] Reported in Appendix 4.

Carter, & Huettel, 2011). Pilot testing for the present study revealed that participants found coin images presented on a plain background to be the most realistic and easy to comprehend, so that form is used in the current work. In the reward and punishment stimuli, the amount of money gained or lost was shown by images of coins summing to that amount, with a red cross through them in the loss (punishment) trials (see Fig. 6.3). The amount gained or lost was displayed in green (for reward) or red (punishment) text, under the images (see Fig. 6.3). For neutral outcomes, a blank space was shown, with 'No change' displayed in yellow text (see Fig. 6.3).

Sounds: The visual stimuli were accompanied by trial-outcome appropriate monetary reward, neutral and punishment auditory cues. These were taken from non-vocal artificial sound stimuli produced by Capilla, Belin, & Gross (2012; downloaded from http://vnl.psy.gla.ac.uk/resources.php).

6.2.4 Social stimuli

Previous studies have used stimuli such as beautiful faces, faces displaying positive emotional expressions, and voices speaking words of approval as social rewards (Krach, Paulus, Bodden, & Kircher, 2010; Lin et al., 2011). Social punishments include stimuli such as faces displaying angry expressions and voices speaking derogatory words (Lin et al., 2011).

As discussed in Chapter 1, praise will be used as a social reward, and correspondingly criticism as a social punishment. Humans value praise and will work to attain it. Conversely humans dislike criticism and will work to avoid it (Buss, 1983; Leary, Springer, Negel, Ansell, & Evans, 1998; Leary, Twenge, & Quinlivan, 2006; Richman & Leary, 2009). Therefore praise and criticism satisfy the definitions of social reward and punishment employed in this thesis.

Faces showing positive expressions, as well as words of approval are forms of praise or positive social feedback. Derogatory words and faces showing disapproving expressions are forms of negative social feedback (criticism). Faces combined with positively and negatively valenced feedback words were therefore used as the visual components of the social feedback stimuli. These were paired with appropriately valenced social sounds, as pilot work (reported in Appendix 4) indicated that the inclusion of sound enhanced the salience of the outcomes.

Faces: Happy (reward), angry (punishment) and calm (neutral) faces were used from the NimStim (Tottenham et al., 2009) set of faces for the social outcome stimuli. There is good evidence that smiling faces activate reward-related regions of the human brain and are salient motivators of behaviour - i.e. humans will work to view smiling faces (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Lin et al., 2011; Rademacher et al., 2010). Similarly, angry and disapproving faces have been shown to activate punishment-related regions of the human brain (Burklund, Eisenberger, & Lieberman, 2007). Human participants will also work to avoid viewing angry faces (Rolls, 2000). These outcomes therefore satisfy the definition of reward and punishment outlined in the conceptual overview, so are appropriate to use in the present experiments. Four different individuals' faces from the NimStim set were used – two females and two males - with a happy, angry and calm expression for each face. This resulted in a total of 12 face images used in the SMID. Calm expressions rather than neutral expressions were used as the comparison/neutral outcome. This is because of evidence that neutral expressions are frequently perceived as being somewhat threatening or otherwise negatively valenced (Iidaka et al., 2005; Somerville, Kim, Johnstone, Alexander, & Whalen, 2004; Thomas et al., 2001, all cited in Tottenham et al., 2009). The calm faces were created for the NimStim set by instructing the actors who posed the facial expressions to transfigure their neutral face into a more relaxed one, as if they were engaged in a calming activity or were pleasantly preoccupied. The calm faces were therefore essentially neutral faces with less overall muscle tension in the face (Tottenham et al., 2009). These were found to be perceptually similar to neutral faces, but less likely to be perceived as negatively valenced (Tottenham et al., 2009).

Words: Reward and punishment words were selected from the English Lexicon Project list of words (Balota et al., 2007) on the basis of 'happiness' ratings collected by Dodds, Harris, Kloumann, Bliss, & Danforth, (2011). Dodds et al. acquired their happiness ratings by asking users of Amazon's

Mechanical Turk to rate how a given word made them feel on a nine-point integer scale. They obtained 50 independent evaluations per word. Dodds et al.'s happiness ratings for the reward and punishment words trialled in this study are shown in Fig. 6.2. As can be seen, none of the error bars (representing standard deviation) reach the midpoint of 'neither happy nor unhappy', indicating that the reward words are invariably rewarding (elicit happiness) and the punishment words are invariably punishing (elicit unhappiness). The words were presented in green (for reward) or red (punishment) text under the faces (see Fig. 6.2). Four different individuals' faces from the NimStim set were used so as to minimise differences associated with intrinsic qualities of the faces. The reward and punishment words were paired on the basis of the mean reaction time to them (from the English Lexicon Project data, Balota et al., 2007) and their number of syllables. These pairs were then allocated to the angry and happy faces of the same individual. The pairs were as follows:

Yes	**No**
Great	**Stupid**
Good	**Bad**
Perfect	**Awful**
Splendid	**Worthless**
Brilliant	**Pathetic**
Superb*	**Dismal***
Wonderful	**Wrong**
Fantastic	**Idiot**
Excellent	**Terrible**
Fabulous	**Disgusting**
Marvellous*	**Inadequate**

*Happiness ratings (from Dodds et al., 2011) are not available for these words. However they are included because in pilot-testing for the present work they elicited similar responses to the rest and they complete a set of twelve pairs of words, meaning that each of the 4 individuals' faces are used the same number of times.

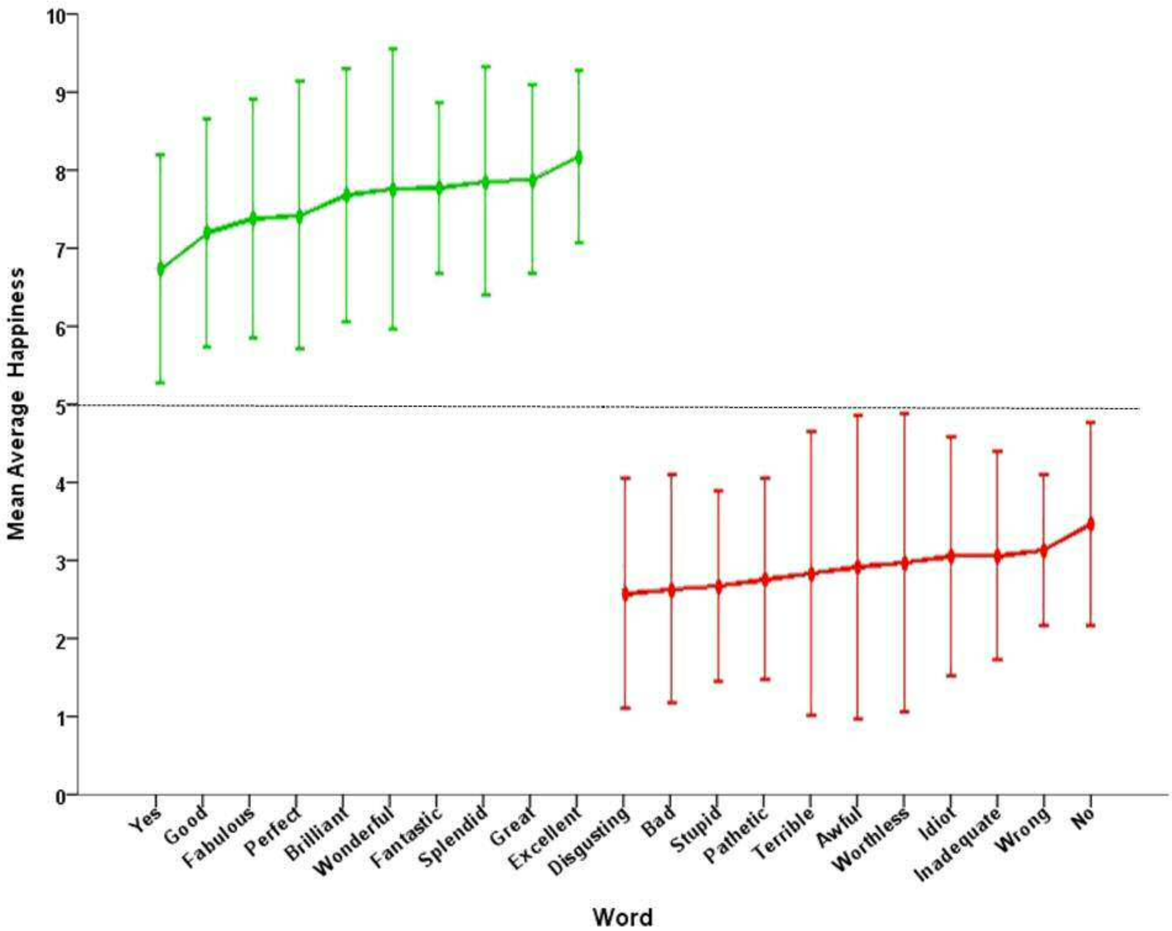

Figure 6.2: Mean happiness ratings (collected by Dodds et al., 2011) for reward and punishment words. Error bars represent ± 1 standard deviation. Ratings were collected on a 9-point integer scale, with 1 being the most unhappy and 10 being the most happy. Reference line at 5 = 'neither happy nor unhappy'.

There are very few words in the English language that confer neutral feedback – most feedback words are aimed at informing someone either that their performance is adequate or inadequate. Therefore the word OK (presented in yellow text) was used for all the neutral social stimuli (see

Fig. 6.3). The neutral monetary outcome text was also the same in all trials ('no change') so the neutral outcomes are similar in that sense across all trial types (see Fig. 6.3).

Sounds: The social reward cues were taken from a set of triumph/achievement sounds developed by Sauter & Scott (2007; auditory files kindly provided by Sauter). The neutral cues were taken from the neutral stimuli from the Montreal affective voices collection (Belin, Fillion-Bilodeau, & Gosselin, 2008) and the social punishment cues were taken from the anger and disgust stimuli in the same dataset (downloaded from http://vnl.psy.gla.ac.uk/resources.php).

6.2.5 'No outcome' stimuli

In addition to the social/monetary reward/punishment stimuli, 'no feedback' trials occurred at semi-random intervals throughout the practice and test sessions. Participants were instructed that these would occur, and that they would know when it was a no feedback trial because the cue takes the form of an equals sign rather than a simple geometric shape. Participants were advised that in these trials they would not receive any feedback as to whether their response was fast enough or not, but that they should still try to press the key as fast as possible. After displaying the no feedback target for 1000 msec, the display reverts to the fixation cross and a 'no feedback' sound is played. The no feedback sounds were taken from non-vocal artificial sound stimuli produced by Capilla, Belin, & Gross (2012; downloaded from http://vnl.psy.gla.ac.uk/resources.php).

The reason for inclusion of the no feedback trials was to provide a baseline condition for purposes of comparison when using the task to examine neural responses to the outcomes. Although neutral outcomes occurred in each of the main task conditions, these were always embedded within a reward or punishment context. Thus in reward trials the neutral outcome is the less favourable (and so might be perceived with disappointment) whereas in the punishment trials the neutral outcome is the least unfavourable (and might be perceived with relief). The no feedback trials were distributed throughout all conditions; therefore the average response to these should cancel out any context effects. No feedback trials were not present in the version of the SMID piloted in Study 1A, nor in the SMID version administered to the first five participants in Study 1B. Study 1B was used to pilot and refine the nature of the no feedback trials; as these were therefore not exactly the same for all participants in Study 1B, responses on these trials are not included in the analyses reported here.

6.2.6 SMID task procedure

The SMID task involves a 30-trial practice session, in which there are two sets of each of the four blocks (i.e. three sets of four blocks, with two monetary/social feedback trials in each block). Thus there are six trials of each type, and correspondingly six 'no feedback' trials occurred during the practice session. Participants' 20% trimmed mean reaction time is calculated from the second and third sets in the practice session. The average of these is used to calibrate the test session, in accordance with the recommendations of Ratcliff (1993). In the first set of the test session participants 'win' a trial if their RT is less than their 20% trimmed mean RT - 25 msec. In each of the following sets, the threshold RT is updated based on participants' performance, such that overall most participants win between 45-55% of trials[3]. The 20% trimmed mean was used as the measure of central tendency throughout, to mitigate effects of outlying RTs that occur if participants' performance is unusual in occasional trials, for instance due to lapses of attention or slips of the hand (Ratcliff, 1993).

The test session consists of four sets of four blocks, with ten reward or punishment trials in each block, plus forty no feedback trials for comparison. See Fig. 6.3 for an overview of the task and sample stimuli. The block order and association of shapes to block types was constant for each participant, but fully counterbalanced across participants.

[3] The algorithm for updating the threshold RT required to win trials in the SMID was developed, pilot-tested and refined in Study 1A.

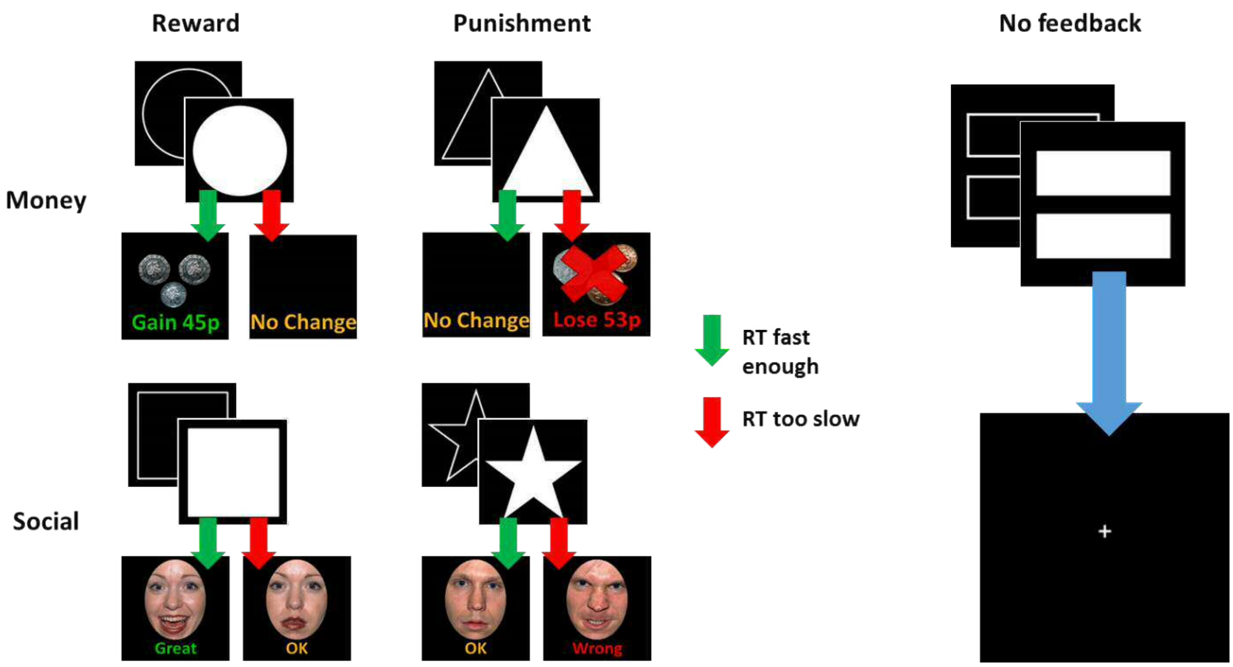

Figure 6.3: Experimental paradigm for the social and monetary incentive delay (SMID) reaction time task. Participants were instructed to hit a key (the space bar) as fast as possible when the cue (outline shape) turned white (target). The cue was presented for a variable duration; the cue durations were from randomly generated normal distributions in which the mean was 1000 msec and the standard deviation was 200 msecs.

The experimenter remained in the testing room with the participant during the practice session, to ensure that the participant understood the task. Participants were left alone to complete the test session (but were aware that the experimenter was nearby and available to help if they encountered any problems). See Appendix 5 for a copy of the instructions given to participants.

6.3 Task validation: Reaction time metrics

Study 1B was conducted to assess the validity and utility of the SMID task as a behavioural measure of approach and avoidance motivations. One hundred and twenty-eight participants (64 male) took part in Study 1B. Please see Chapter 3 for full details of these participants, as well as the measures and procedure employed in the study.

6.3.1 Interpretation of reaction time (RT) results

To quantify the extent to which reward type (monetary or social) and outcome valence (reward or punishment) influenced RTs, I calculated, for each participant, the difference between their average RT on monetary versus social trials (impact of type; imp_type) and the difference between their average RT on reward versus punishment trials (impact of valence; imp_valence). Additionally, values for the impact of type were computed separately for the punishment and reward conditions (pun_imp_type; rew_imp_type). Similarly values for the impact of valence within social and monetary conditions were computed (soc_imp_valence; mon_imp_valence). Table 6.1 provides full details of these reaction time metrics. There were no significant gender differences in any of these metrics.

One-sample *t*-tests were conducted to test the extent to which type and valence influenced reaction times. Participants' RT metrics were compared with 0 to test whether they differed significantly from what would be expected if they were uninfluenced by the type or valence of the trial. Results are shown in Table 6.2.

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	*p* (2-tailed)	Mean Difference	Lower	Upper
Imp_type	-6.712	127	.000***	-12.11	-15.68	-8.54
Rew_imp_type	-7.050	127	.000***	-15.05	-19.27	-10.82
Pun_imp_type	-4.189	127	.000***	-9.65	-14.20	-5.09
Imp_valence	.144	127	.885	0.15	-1.85	2.14
Soc_imp_valence	-1.536	127	.127	-2.85	-6.51	0.82
Mon_imp_valence	1.718	127	.088	2.55	-0.39	5.50

Table 6.2: Results of one-sample *t*-tests comparing participants' impact of type and valence RT metrics with 0, i.e. no difference.

As can be seen in Table 6.2, participants' RTs were significantly influenced by trial type, especially in reward trials. Participants responded faster, on average, during monetary trials than during social trials (mean RTs of 231.7 and 243.8 msecs respectively). A repeated measures ANOVA with within-subjects factors type (monetary or social) and valence (reward or punishment) confirmed the significant main effect of type ($F(1,127) = 47.293$, $p < .001$, partial eta^2 = .271). The main effect of valence was not significant ($F(1,127) = 0.019$, $p = .890$, partial eta^2 = .000). These findings replicate those of Rademacher et al. (2010) and Spreckelmeyer et al. (2009). However, the present data differ from previous work in that there was a significant interaction between trial type and valence: $F(1,127) = 4.275$, $p = .041$, partial eta^2 = .033. Participants responded faster on average for monetary reward than monetary punishment, but faster on average in social punishment trials compared with social reward trials, as shown in Fig. 6.4.

Table 6.1: Summary details of the calculation and interpretation of all SMID reaction time (RT) metrics.

Metric Name	Abbreviation	Formula	Interpretation
Impact of type	Imp_type	Av_mon_RT – Av_soc_RT	Imp_type > 0 means faster responding on social trials. Imp_type < 0 means faster responding on money trials.
Impact of valence	Imp_valence	Av_pun_RT – Av_rew_RT	Imp_valence > 0 means faster responding on reward trials. Imp_valence < 0 means faster responding on punishment trials.
Impact of type in reward trials only	Rew_imp_type	Av_RT_mon_rew – Av_RT_soc_rew	Rew_imp_type > 0 means faster responding for social rewards. Rew_imp_type < 0 means faster responding for money rewards.
Impact of type in punishment trials only	Pun_imp_type	Av_RT_mon_pun – Av_RT_soc_pun	Pun_imp_type > 0 means faster responding to avoid social punishments. Pun_imp_type < 0 means faster responding to avoid money punishments.
Impact of valence in social trials only	Soc_imp_valence	Av_RT_soc_pun – Av_RT_soc_rew	Soc_imp_valence > 0 means faster responding on social reward trials. Soc_imp_valence < 0 means faster responding on social punishment trials.
Impact of valence in money trials only	Mon_imp_valence	Av_RT_mon_pun – Av_RT_mon_rew	Mon_imp_valence > 0 means faster responding on money reward trials. Mon_imp_valence < 0 means faster responding on money punishment trials.

Metric Name	Abbreviation	Formula	Interpretation
Relative motivational index - overall	RMI	Av_mon_RT / Av_soc_RT	RMI > 1 means greater relative motivation (faster responding) for social outcomes. RMI < 1 means greater relative motivation (faster responding) for money outcomes.
Relative motivational index for reward trials	RMI_rew	Av_RT_mon_rew / Av_RT_soc_rew	RMI_rew > 1 means greater relative motivation (faster responding) for social rewards. RMI_rew < 1 means greater relative motivation (faster responding) for money rewards.
Relative motivational index for punishment trials	RMI_pun	Av_RT_mon_pun / Av_RT_soc_pun	RMI_pun > 1 means greater relative motivation (faster responding) to avoid social punishments. RMI_pun < 1 means greater relative motivation (faster responding) to avoid money punishments.

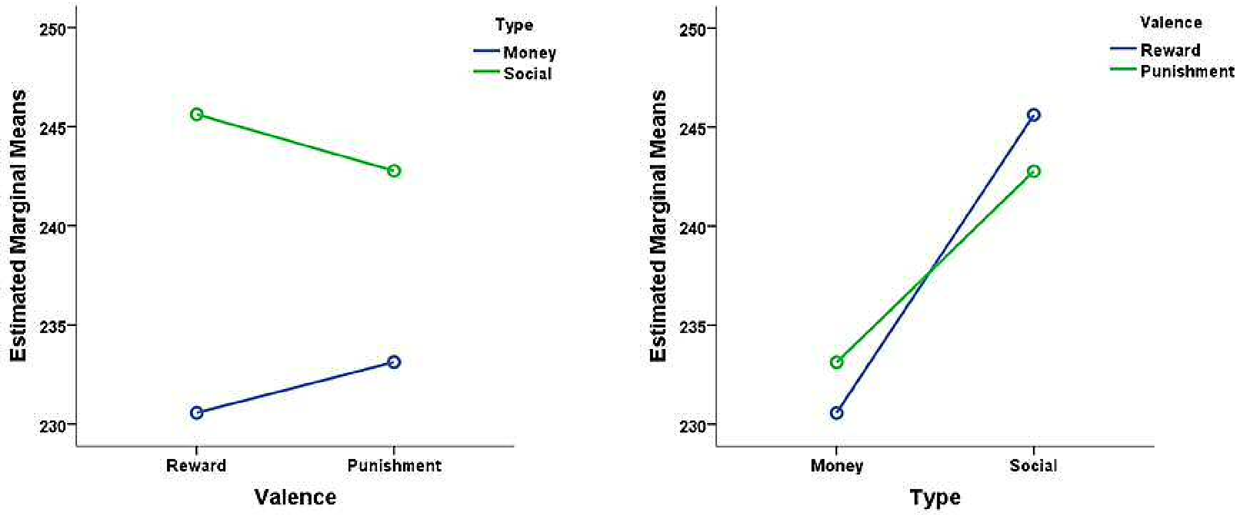

Figure 6.4: Interaction plots showing the estimated marginal mean RTs for monetary and social reward and punishment trials in the SMID task.

While participants in this and other studies responded faster, on average, during monetary trials than social trials, there are thought to be individual differences in relative motivation for different types of outcome (Clithero, Reeck, Carter, Smith, & Huettel, 2011). To visualise these, relative motivational indices (RMIs) were calculated for each participant for reward trials and for punishment trials. RMIs are ratios, obtained by dividing participants' trimmed mean RT in, for example, monetary reward trials by their trimmed mean RT in social reward trials. The resulting ratio reflects how much the participant is motivated to respond fast in monetary compared with social reward trials. Values of greater than 1 indicate greater relative motivation for social than for monetary rewards (cf. Clithero, Reeck, et al., 2011). Table 6.1 provides full details of the RMIs calculated in the present study. Distributions of the RMIs for reward and punishment conditions are shown in Figs. 6.5 and 6.6. The mean RMI for reward trials was 0.94 (SD = 0.096). The mean RMI for punishment trials was 0.96 (SD = 0.108). That these mean RMIs are less than 1 confirms that most participants were relatively more motivated (responded faster) on monetary trials compared with social trials. Both RMI distributions were negatively skewed (skew of reward RMIs = -0.41, skew of punishment RMIs = -1.15) confirming the general trend for most participants to have stronger motivation for monetary trials.

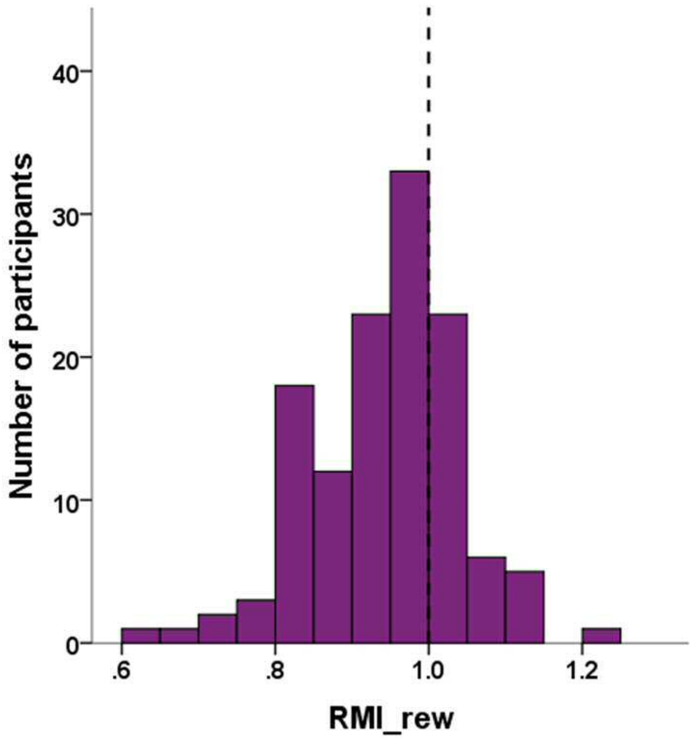

Figure 6.5: Relative motivational index in reward trials. Values of greater than 1 indicate greater relative motivation for social than for monetary rewards.

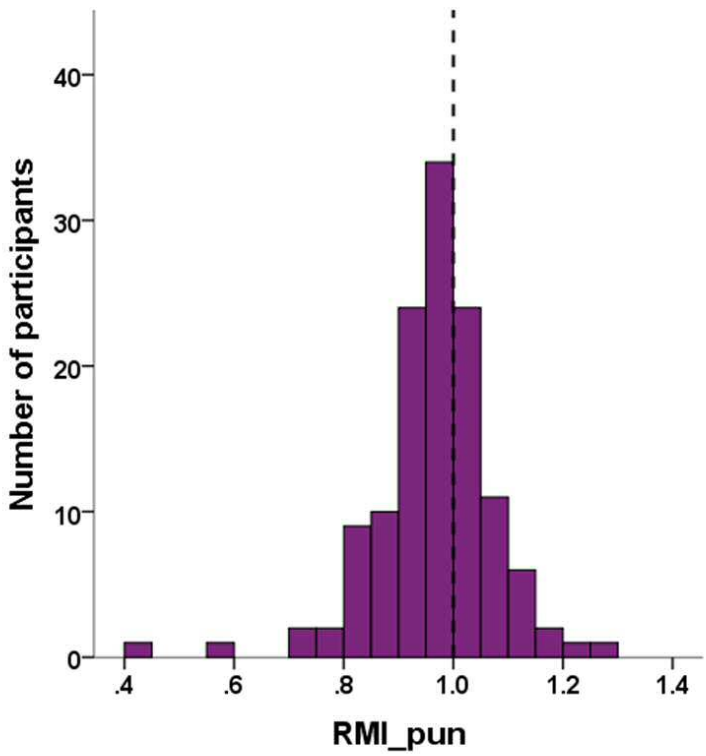

Figure 6.6: Relative motivational index in punishment trials. Values of greater than 1 indicate greater relative motivation to avoid social rather than monetary punishments.

6.3.2 Discussion

The RT data acquired in Study 1B demonstrates that participants' responses were affected by the type of trial. Participants' responses were also affected by the valence of the trials, but the direction of this effect differed depending on the type of trial. Although skewed, there appears to be sufficient spread of RMI scores (Figs. 6.5 and 6.6), indicating that the SMID task is sensitive to individual differences in relative motivations for social versus 'non-social' outcomes. Whether the RT metrics described here relate to participants' consciously reportable perceptions of how motivating they found the different conditions is examined in the next section.

6.4 Task validation: Affective responses

6.4.1 Method

All participants in Study 1B completed the state self-esteem (SSE) scale directly before and after the SMID task. Forty-four male participants (mean age 25.7 years, S.D. 7.6, range 19–54) from the summer 2013 wave of Study 1B answered some additional questions about their affective experience of the SMID task (see Appendix 6). Some of these questions were based on typical post-Cyberball questionnaire items (e.g. Zadro, Williams, & Richardson, 2004). A second set of questions explicitly asked participants to rate how motivating they found each of the four main categories of outcomes in the SMID task. The purpose of these questions was twofold: firstly, to gauge, formally, how motivating participants found the task outcomes in general. Before this, I had simply asked participants during the debriefing period whether they had found the outcomes motivating. The second main purpose of asking participants to rate the motivational value of the outcomes was to see if these conscious, self-reported ratings would correlate with participants' motivation for different outcomes as indicated by their RT metrics. This was by way of a validity check, to assess whether the RT metrics are meaningful indicators of participants' motivation.

A third set of questions interrogated how participants perceived the social reward and punishment outcomes. The faces used for these outcomes were happy and angry faces from the NimStim collection but anger is an extreme form of negative emotion, rarely displayed in social situations between non-intimate individuals. Disapproval is a more common social punishment. While the faces are indeed angry, they are paired with words and sounds which might well be construed as disapproving or contemptuous (or angry). Also, the participants are engaged in the task when they experience the social punishment outcomes – and they experience these in response to slower reaction times on their part. Because the participants experience the social punishments as a whole (not just the angry facial expression) as feedback on their task performance, they might well interpret them as contemptuous or disapproving rather than angry. As part of the SMID procedure, participants are informally asked about their experience of the task after they complete it, and pilot work indicated that the social punishment outcomes are certainly perceived as criticising – but whether contemptuous, angry or disapproving could not be assessed from these records. Similarly, pilot work demonstrated that the social reward outcomes are perceived as positive, but the level of positive emotion that participants subjectively perceived (e.g. pleased, happy, joyful) could not be assessed. The post-SMID affective responses questions included ones asking participants to specify how they perceived the facial expressions.

Procedure: This was the same as for the rest of Study1B, with the addition of the SMID affective response questions (as shown in Appendix 6) directly after the post-SMID task state self-esteem (SSE) scale.

Full correlations of post-SMID affect response questions with all other self-report variables administered in Study 1B and with the SMID RT indices are reported in Appendix 7.

6.4.2 <u>Results</u>

6.4.2.1 State self-esteem (SSE) responses to the SMID task

Before statistical analyses were conducted, the data were screened for outlying scores. Univariate outliers were identified using standard (z) scores. A relatively liberal threshold of ±4 standard deviations was used; cases were considered outliers and removed if their standard score was ±4 or more standard deviations from the mean. Because the current study is investigating individual differences, it is desirable to include relatively extreme scores as well as average scores on the self-report measures. While 'extreme' scores in this context are extreme relative to the rest of the dataset, they are within the range that the questionnaires etc. are designed to measure.

The difference in participants' SSE before and after the SMID task was calculated. For each participant there are thus three SSE metrics: pre-SMID SSE (SSE 1^{st}), post-SMID SSE (SSE 2^{nd}) and the difference between these two (SSE diff, $2^{nd} - 1^{st}$). None of the SSE metrics were significantly related to participants' objective performance on the task, in terms of the percent of trials participants won (see Table 6.5). Paired samples *t*-tests (reported in Table 6.3) revealed that on average the differences in SSE were significant, with most participants reporting higher levels of SSE across all of the sub-scales following the task as compared with before the task. However there was considerable inter-individual variation in the SSE differences (standard deviations for the difference scores on the subscales were between 2 and 3.5; the standard deviation of differences in the SSE total score was 6.38). This is illustrated in Fig. 6.7. In the absence of any association with objective performance on the task, this suggests that individual differences in reactivity to reward and punishment may account for the SSE differences observed.

Pair	Paired Differences						
			95% CI of the Difference				
	Mean	Std. Dev.	Lower	Upper	t	df	*p* (2-tailed)
SSE: Academic Performance - pre-SMID; SSE: Academic Performance - post-SMID	-.81	3.84	-1.52	-.09	-2.24	113	.027*
SSE: Social Evaluation - pre-SMID; SSE: Social Evaluation - post-SMID	-.83	2.89	-1.37	-.30	-3.08	113	.003**
SSE: Appearance - pre-SMID; SSE: Appearance - post-SMID	-.75	2.07	-1.13	-.36	-3.85	113	.000***
SSE: Overall - pre-SMID; SSE: Overall - post-SMID	-2.39	6.89	-3.67	-1.11	-3.70	113	.000***

Table 6.3: Results of paired-sample *t*-tests comparing participants' state self-esteem (SSE) before and after they completed the SMID task.

A

	N	Min.	Max.	Mean	Std. Dev.
SSE: Academic Performance diff	113	-8	11	.98	3.370
SSE: Social Evaluation diff	114	-7	11	.83	2.893
SSE: Appearance diff	114	-3	7	.75	2.069
SSE: Overall diff	113	-10	19	2.64	6.377

B

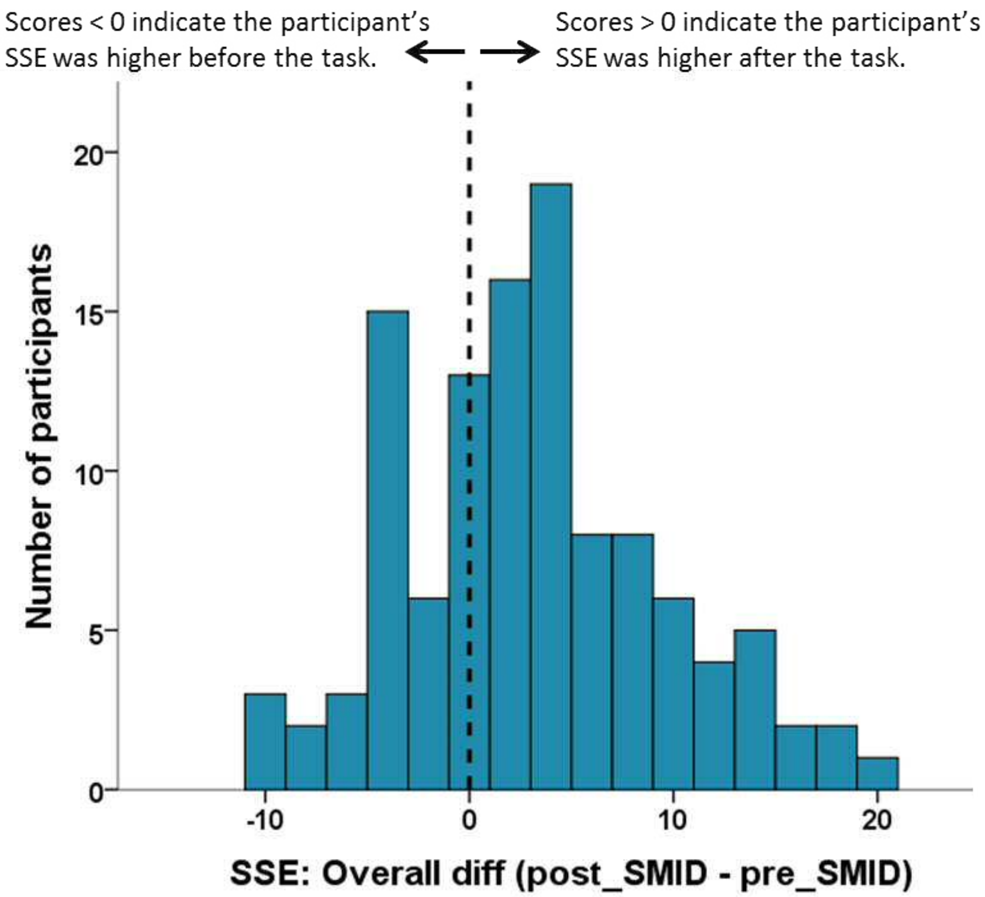

Figure 6.7: A. Descriptive statistics showing inter-individual variation in SSE difference scores. **B.** Histogram of SSE total (overall) difference scores.

6.4.2.2 SSE and self-reported affective responses to the SMID task

The higher participants' state self-esteem (SSE) was before the task, the more they enjoyed the task, in general, and the less likely it was to make them feel insecure or angry (see Table 6.4 for full results). This is shown for the social component of SSE in Fig. 6.8.

	SSE: Academic Performance 1st	SSE: Social Evaluation 1st	SSE: Appearance 1st	SSE: Overall 1st
I felt angry during the task	-.240	-.370*	-.053	-.282
Participating in the task made me feel insecure	-.194	-.306*	-.420**	-.366*
I enjoyed the task	.397**	.478**	.329*	.492**
Participating in the task made me feel good about myself	.022	.248	.271	.219

Table 6.4: Correlations (Pearson's r) between state self-esteem (SSE) scores prior to the SMID task and affective responses to the task.
* $p < .05$, ** $p < .01$, *** $p < .001$

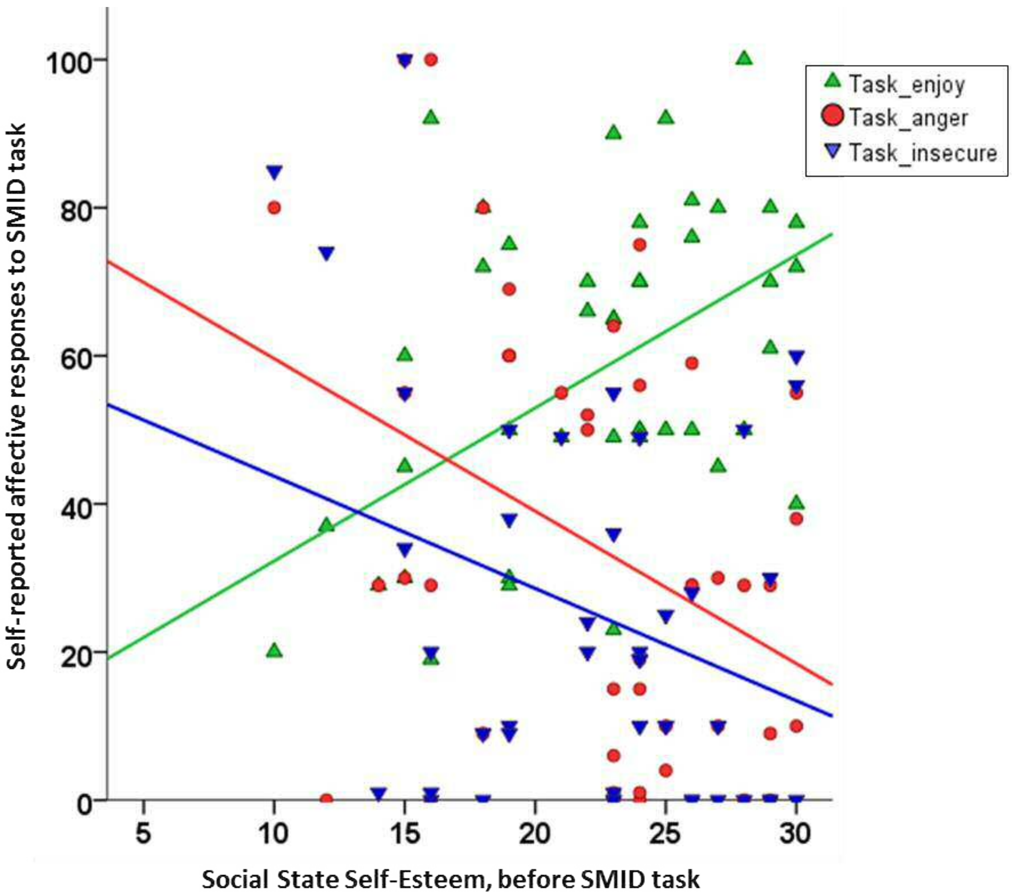

Figure 6.8: Scatter-plot showing the association between participants' social SSE before the SMID task and their self-reported enjoyment, anger, and feelings of insecurity during the SMID task.

Feelings of insecurity in response to the SMID task were associated with significant reductions in performance SSE, but not in social or appearance SSE. This is shown in Table 6.5 and Figure 6.9.

		percent wins	SSE: Academic Performance diff (2nd - 1st)	SSE: Social Evaluation diff (2nd - 1st)	SSE: Appearance diff (2nd - 1st)	SSE: Overall diff (2nd - 1st)
percent wins	*r*		.130	.166	-.044	.101
	N		113	114	114	113
I felt angry during the task	*r*	-.404**	-.045	-.193	-.189	-.121
	N	44	43	44	44	43
Participating in the task made me feel insecure	*r*	-.265	-.367*	-.079	-.060	-.120
	N	44	43	44	44	43
I enjoyed the task	*r*	.309*	-.159	-.151	.155	-.165
	N	44	43	44	44	43
Participating in the task made me feel good about myself	*r*	.306*	-.083	-.031	.191	-.054
	N	44	43	44	44	43

Table 6.5: Correlations (Pearson's *r*) between SSE difference scores and affective responses to the SMID task. * $p < .05$, ** $p < .01$, *** $p < .001$

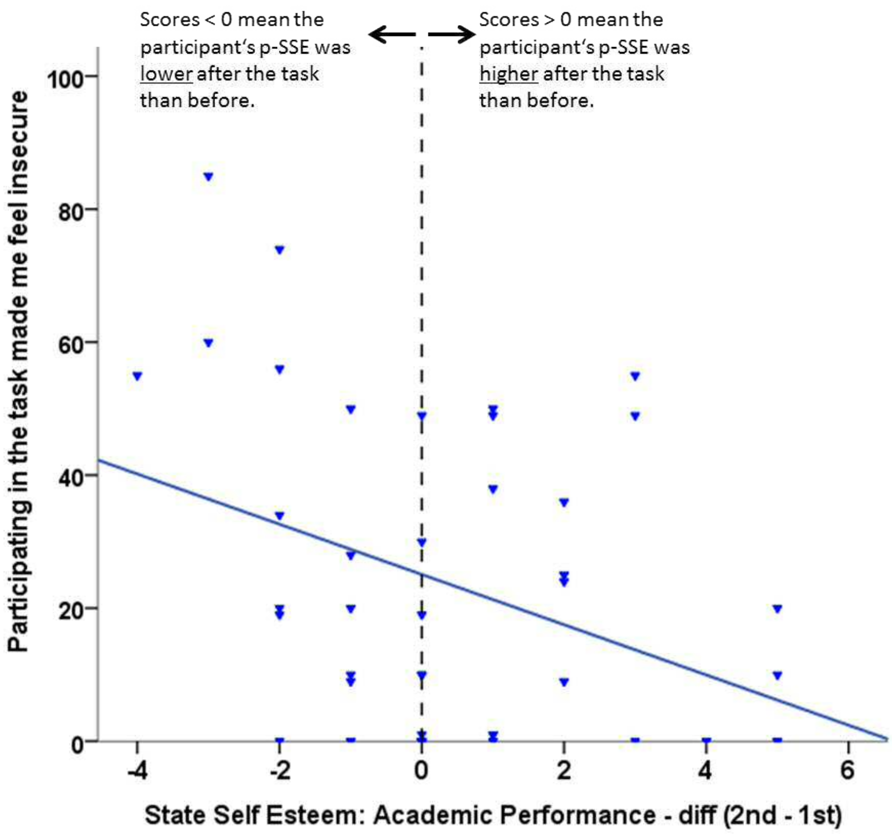

Figure 6.9: Scatter-plot showing the association between participants' performance SSE (p-SSE) difference and their self-reported feelings of insecurity in response to the SMID task.

6.4.2.3 *Self-reported motivation for SMID task outcomes*

Participants reported agreement with the statement "I found the [outcome category, e.g. 'social rewards] to be motivating". Participants indicated their agreement to each statement on a scale of 1 – 100, where scores lower than 50 indicate disagreement (lower motivation) and scores higher than 50 indicate increasing agreement (higher motivation). On average, most participants found the monetary and social rewards, and monetary punishments, to be rewarding (average scores were higher than 50; see Table 6.6). The mean motivation score for social punishment outcomes in this sample was lower (34) but there was considerable inter-individual variation, as shown in Fig. 6.10. The distributions of the motivation scores for social rewards and monetary punishments were also quite dispersed. Less inter-individual variability was observed for the monetary rewards, with almost all participants reporting that they found these to be motivating.

	Min.	Max.	Mean	Std. Dev.	Skew
I found the money rewards to be motivating	2	100	73.23	21.61	-1.26
I found the social rewards to be motivating	0	100	52.45	23.31	-.58
I found the money punishments to be motivating	1	100	58.36	29.63	-.57
I found the social punishments to be motivating	0	80	34.43	24.76	.20

Table 6.6: Descriptive statistics for self-reported levels of motivation for each of the four main categories of SMID outcomes. N = 44.

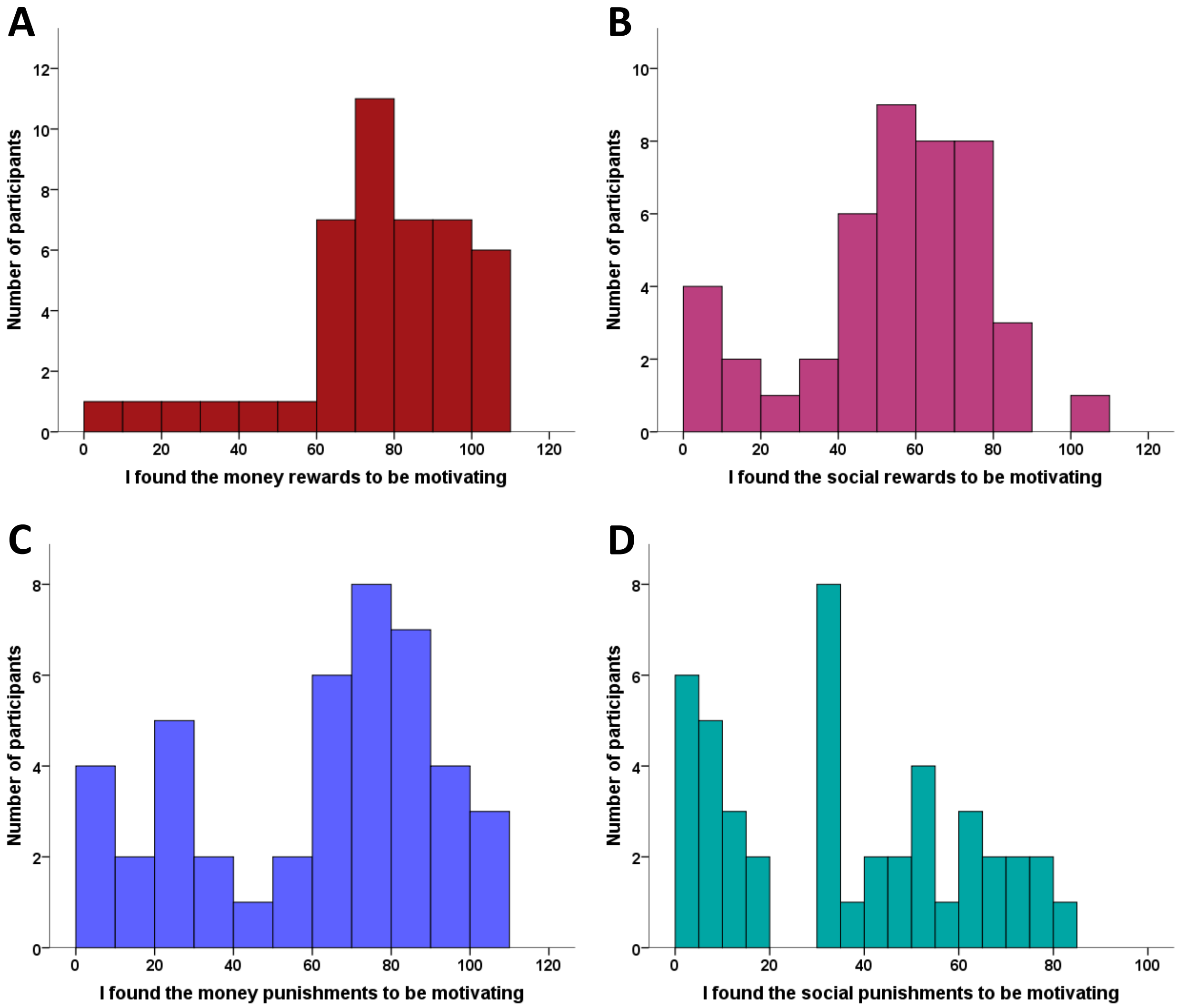

Figure 6.10: Histograms showing the distribution of participants' self-reported motivation for the SMID outcomes. A: Monetary reward; B: Social reward; C: Monetary punishment; D: Social punishment. Scores reflect participants' agreement with the statement "I found the [outcome category, e.g. 'social rewards] to be motivating". Participants indicated their agreement to each statement on a scale of 1 – 100, where scores lower than 50 indicate disagreement (lower motivation) and scores higher than 50 indicate increasing agreement (higher motivation). N = 44.

With the exception of mon_imp_valence, all of the RT metrics were significantly correlated with participants' self-reported motivation for at least some of the SMID outcomes. Full results are given in Table 6.7. For illustrative purposes, the associations between participants' self-reported motivation for the main categories of SMID outcomes and the impact of trial type (money versus social) on their RTs are depicted in Fig. 6.11.

	I found the money rewards to be motivating	I found the social rewards to be motivating	I found the money punishments to be motivating	I found the social punishments to be motivating
Imp_type	-.360*	.272	-.416**	.202
Rew_imp_type	-.349*	.384*	-.302*	.359*
Pun_imp_type	-.217	.105	-.375*	-.011
Imp_valence	-.125	.439**	-.196	.180
Soc_imp_valence	-.152	.434**	-.070	.344*
Mon_imp_valence	.009	.117	-.218	-.147
RMI_overall	-.317*	.209	-.402**	.190
RMI_rew	-.299*	.300*	-.286	.359*
RMI_pun	-.198	.082	-.354*	-.019

Table 6.7: Correlations (Pearson's *r*) between self-reported motivation for SMID task outcomes and RT metrics. * $p < .05$, ** $p < .01$, *** $p < .001$. N = 44.

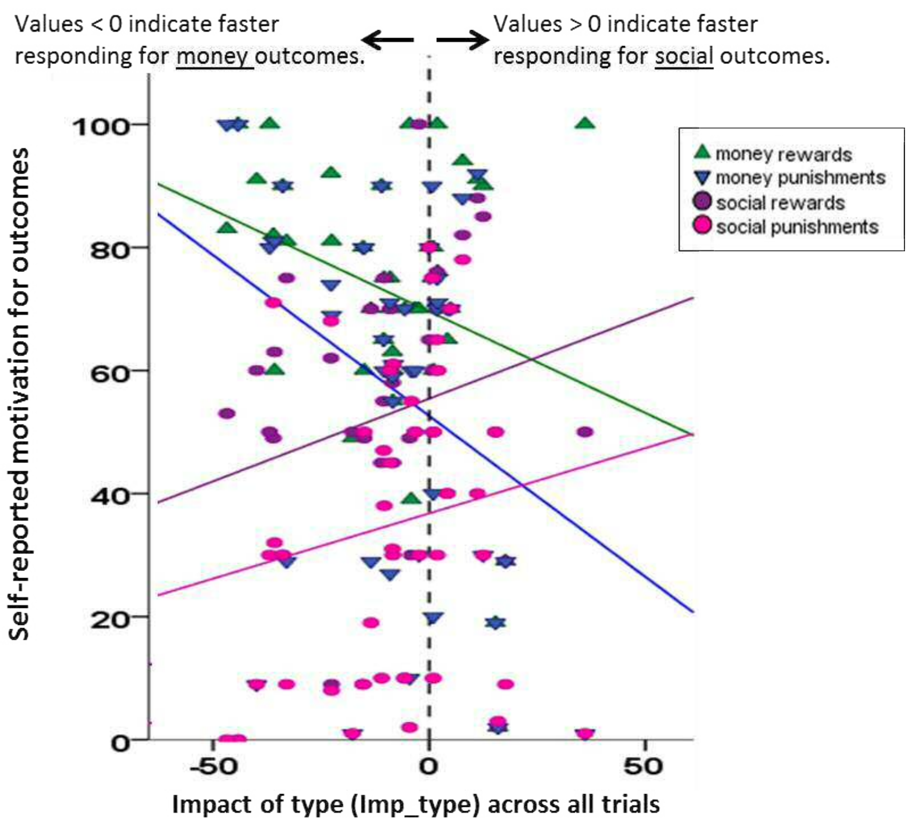

Figure 6.11: Scatter-plot showing the association between participants' self-reported motivation for the main categories of SMID outcomes and the impact of trial type (money versus social) on their reaction times.

6.4.2.4 Perception of facial expressions in the social reward and punishment outcomes

The majority of participants perceived the facial expressions presented as part of the SMID social reward outcomes as displaying positive emotion. Ninety-three percent of participants indicated that they had perceived the faces as joyful, pleased, or happy (see Fig. 6.12A). Of the remaining 7% (3 participants), 1 considered the faces to be neutral, and 1 perceived them in a negatively valenced fashion as being "slightly creepy" (Fig. 6.12A1).

All participants perceived the facial expressions presented as part of the social punishment outcomes as displaying negative interpersonal emotion. Most participants (52%) considered the expressions to be disapproving (see Fig. 6.12B).

A

Answer		Response	%
Happy		9	20%
Joyful		18	41%
Pleased		14	32%
Other (please specify)		3	7%
Total		44	100%

A1

Other (please specify)
drunk? (but happy)
Neutral
slightly creepy

B

Answer		Response	%
Contemptuous		5	11%
Angry		16	36%
Disapproving		23	52%
Other (please specify)		0	0%
Total		44	100%

Figure 6.12: Participants' perceptions of the facial expressions in the SMID social reward and punishment outcomes. **A**: participants' perceptions of the social reward facial expressions; **A1**: responses given by participants who ticked 'other' for the social rewards expressions; **B**: participants' perceptions of the social punishment facial expressions.

6.4.3 Discussion

Overall, the results reported in this section suggest that most participants find the SMID task outcomes to be motivating, although there were considerable inter-individual differences in self-reported motivation. It would be interesting to administer the post-SMID affective responses questions to a sample of females, as informal pilot work suggests that female participants find the social punishment outcomes more motivating, in general, than do male participants.

With the exception of mon_imp_valence, all of the RT metrics were significantly correlated with participants' conscious, self-reported motivation for at least some of the SMID outcomes. This suggests that the RT metrics are indeed meaningful indicators of participants' motivation.

The data presented here indicate that the SMID task is sensitive to individual differences in affective biases, e.g. in self-esteem, which may impact upon reactions to subsequent feedback (monetary or social). A limitation of the post-SMID affective questions in the context of such inferences is their lack of specificity. For example, for the item "I felt angry during the task", the instructions did not ask the participant to state towards *whom* they felt angry. Thus it is possible that at least some of the reported anger was self-directed. Conversation with one of the participants revealed that, while he expressed anger towards the male social punishment 'characters' in the SMID task, his anger was mainly with himself: frustration at not being able to respond fast enough to win all trials. Further, while the questions asked about affective responses during the task, they did not differentiate between different conditions. Thus it is possible, for instance, that participants who reported that they felt angry during the task only experienced this during social punishment blocks, or only during monetary reward blocks (frustration at not winning more trials). While such information would be useful to know, the main purpose of the SMID task is to measure behavioural (RT) indicators of individual differences in social motivation. The data presented here and in section 6.3 demonstrate the validity of the SMID RT metrics for this purpose.

6.5 Assessing predictions of the proposed model: links between motivation, behaviour and reactions to feedback

This chapter has described the development and validation of the SMID task. This task was designed to enable assessment of the predictions of the model proposed in this thesis, that individual differences in affective and interpersonal dispositions are associated with differences in social expectancies and motivation, which in turn are associated with differences in social behaviour. Individuals' behaviour results in outcomes, which may include feedback on one's performance, as in the context of the SMID. The model proposed here suggests that individual differences in reactions (e.g. affective reactions) to feedback are also linked to expectancies, motivation and behaviour (see Fig. 6.1).

It was not possible to conduct mediation analyses to test the predictions of the proposed model around motivated social behaviour, as there were no instances in which the zero-order correlations of variables representing three levels in the model were all significant. This is likely due to the relatively lower general levels of correlation between task measures (in this case RTs) and self-report measures (Robinson, 2009), compared with correlations among task or self-report measures. Nonetheless, correlational data between self-report and RT indices of individual differences collected in Study 1B are consistent with the predictions of the model. For full intercorrelations tables for all variables in the study please see Appendix 3. In this section, associations between SMID RT metrics and self-reported approach and avoidance traits, tendencies and goals are assessed. Additionally, associations between SMID metrics and reactivity to feedback (as indexed by changes in state self-esteem) are examined. Finally, links between social expectancies (as measured by the LODESTARS) and reactivity to feedback (SSE) are considered.

6.5.1 Methods

All correlation analyses were conducted using SPSS version 20. Gender differences were observed in many of the self-report measures, but not in the RT metrics. All results are reported separately for males and females in this section, but results for the full sample are also given. This is because it was noted that, on occasion, the relative homogeneity of males-only scores or females-only scores on self-report measures resulted in non-significant correlations with the RT metrics, which may have been due partially to the lack of variance in the data.

6.5.1.1 Associations between SMID RT metrics and self-reported approach and avoidance traits, tendencies and goals

The first question considered was whether approach and avoidance motivations at the level of traits and dispositional tendencies are associated with behavioural measures of motivation yielded by the SMID task. To address this question correlations between SMID RT metrics and the following self-report measures were examined (see Chapter 3 for full details of the psychometric measures and testing procedures).

- Extraversion – measuring tendencies to take an energetic approach toward the social and material world. Extraversion encompasses traits such as sociability, activity, assertiveness, and positive emotionality (John & Srivastava, 1999).
- Neuroticism – measuring (lack of) emotional stability and even-temperedness; tendencies towards negative emotionality, such as feeling anxious, nervous, sad, and tense (John & Srivastava, 1999).
- BIS – measuring tendencies to experience avoidant motivation.
- Friendship Approach Goals – measuring goals focussing on positive interpersonal possibilities in the context of the participants' friendships.
- Friendship Avoidance Goals – measuring goals focussing on avoiding negative possibilities in the context of respondents' friendships.

6.5.1.2 Associations between SMID RT metrics and reactivity to feedback

Whether individual differences in motivated behaviour – as measured by SMID RT metrics – are related to differences in reactivity to the task was assessed by examining changes in state self-esteem (SSE). It was hypothesised that individuals who were particularly motivated to avoid social punishments may be more sensitive to social punishment. The social evaluation component of SSE may be impacted by the SMID task in such individuals. More generally, the social evaluation component of SSE may be more affected by the SMID task in individuals with higher relative motivation (RTs) for the social outcomes. Correlations between the SMID RT metrics and scores on the SSE scale were examined.

6.5.1.3 Links between social expectancies and reactivity to feedback

It is hypothesised that expectancies may influence perceptions of the frequency and salience of outcomes in the SMID. As discussed in Chapter 5, it appears that holding relatively high expectancies of social threat may predispose individuals to take particular notice of any signals of social threat in the environment. Conversely, higher expectancies of social reward may be associated with greater activation of emotion regulation systems, perhaps resulting in lower perceived frequency and salience of social threat signals. Possibly higher reward expectancies predispose individuals to perceive greater frequency and salience of social reward signals. It was predicted therefore that higher LODESTARS-reward scores would be associated with an increase in social SSE following the SMID, while higher LODESTARS-threat scores would be associated with a decrease in social SSE.

6.5.2 Results

Results (Pearson's *r* correlations coefficients) for all analyses conducted are reported in Tables 6.8 – 6.10.

		Imp type	Rew imp type	Pun imp type	Imp valence	Soc imp valence	Mon imp valence	RMI overall	RMI rew	RMI pun
Extraversion	Full sample	-.095	-.056	-.108	.106	.111	.052	-.102	-.064	-.107
	Males only	-.172	-.127	-.167	.007	.045	-.009	-.168	-.121	-.168
	Females only	.009	.047	-.048	.209	.174	.084	.002	.033	-.035
Neuroticism	Full sample	.042	.050	.029	-.217*	-.122	-.180*	.078	.077	.050
	Males only	.005	.054	-.049	-.041	.057	-.095	.047	.067	.000
	Females only	.075	.000	.127	-.370**	-.284*	-.160	.094	.040	.107
BIS	Full sample	-.062	-.053	-.035	-.242**	-.160	-.176*	-.026	-.025	-.015
	Males only	-.130	-.180	-.033	-.262*	-.262*	-.099	-.082	-.150	.000
	Females only	-.010	.041	-.025	-.170	-.041	-.138	-.009	.082	-.052
Friendship Approach Goals	Full sample	-.043	.065	-.128	.063	.150	-.105	-.046	.058	-.127
	Males only	-.116	-.026	-.164	.092	.132	-.056	-.115	-.031	-.162
	Females only	.090	.218	-.068	.072	.214	-.107	.079	.226	-.076
Friendship Avoidance Goals	Full sample	-.192*	-.253**	-.047	-.240**	-.242**	-.012	-.164	-.247**	-.016
	Males only	-.330**	-.445***	-.088	-.251*	-.347**	.134	-.292*	-.432***	-.054
	Females only	.009	.005	.015	-.189	-.104	-.112	.030	.032	.033

Table 6.8: Correlations (Pearson's *r*) between SMID RT metrics and self-reported approach and avoidance traits, tendencies and goals.
* $p < .05$, ** $p < .01$, *** $p < .001$

		Imp type	Rew imp type	Pun imp type	Imp valence	Soc imp valence	Mon imp valence	RMI overall	RMI rew	RMI pun
State Self Esteem: Academic Performance - diff (2nd - 1st)	Full sample	-.056	-.027	-.045	-.108	-.050	-.099	-.051	-.013	-.055
	Males only	.106	-.014	.190	-.020	-.166	.131	.107	-.002	.183
	Females only	-.176	-.040	-.189	-.150	.029	-.194	-.204	-.032	-.227
State Self Esteem: Social Evaluation - diff (2nd - 1st)	Full sample	.167	.139	.134	-.037	-.009	.004	.164	.117	.139
	Males only	.354*	.243	.349*	.126	.013	.229	.345*	.200	.361**
	Females only	-.077	.004	-.102	-.204	-.016	-.176	-.119	-.014	-.137
State Self Esteem: Appearance - diff (2nd - 1st)	Full sample	-.137	-.071	-.132	-.072	.020	-.084	-.131	-.056	-.132
	Males only	-.077	-.051	-.077	-.170	-.050	-.118	-.068	-.061	-.050
	Females only	-.199	-.094	-.174	-.006	.068	-.058	-.214	-.067	-.202
State Self Esteem: Overall - diff (2nd - 1st)	Full sample	-.015	.000	-.007	-.108	-.043	-.067	-.004	.013	-.009
	Males only	.213	.070	.284*	-.012	-.140	.197	.227	.071	.300*
	Females only	-.191	-.052	-.199	-.159	.033	-.190	-.227	-.045	-.242

Table 6.9: Correlations (Pearson's *r*) between SMID RT metrics and reactivity to feedback as measured by self-reported changes in SSE following the SMID task.
* $p < .05$, ** $p < .01$, *** $p < .001$

		LODESTARS Threat	LODESTARS Reward	LODESTARS T-ct.-for-R	LODESTARS R-ct.-for-T
State Self Esteem: Academic Performance - diff (2nd - 1st)	Full sample	.181	-.064	.186*	.048
	Males only	-.012	-.185	-.109	-.138
	Females only	.269*	.016	.300*	.138
State Self Esteem: Social Evaluation - diff (2nd - 1st)	Full sample	.235*	-.028	.242*	.077
	Males only	.145	-.080	.131	-.002
	Females only	.280*	.014	.311*	.140
State Self Esteem: Appearance - diff (2nd - 1st)	Full sample	.052	.068	.079	.104
	Males only	.007	.207	.082	.264
	Females only	.059	-.010	.060	.014
State Self Esteem: Overall - diff (2nd - 1st)	Full sample	.215*	-.027	.232*	.094
	Males only	.067	-.095	.050	.012
	Females only	.270*	.011	.298*	.132

Table 6.10: Correlations (Pearson's *r*) between social expectancies (LODESTARS scores) and reactivity to feedback as measured by self-reported changes in SSE following the SMID task.

LODESTARS T-ct.-for-R = LODESTARS Threat controlling for Reward
LODESTARS R-ct.-for-T = LODESTARS Reward controlling for Threat

* $p < .05$, ** $p < .01$, *** $p < .001$

6.5.3 Discussion

6.5.3.1 Associations between SMID RT metrics and self-reported approach and avoidance traits, tendencies and goals

In the data reported here, there were no significant associations between SMID RT metrics and self-reported approach tendencies and goals (as measured by extraversion and friendship approach goals respectively). While it seems a reasonable hypothesis that extraversion should be linked with greater motivation for social rewards, perhaps the nature of the SMID social reward outcomes (praise) does not correspond with the types of social rewards that individuals higher in extraversion seek out.

As can be seen in Table 6.8, there were several correlations between SMID RT metrics and self-reported avoidance tendencies and goals. Neuroticism, BIS and friendship avoidance goals were all negatively correlated with impact of valence metrics. Lower imp_valence scores represent faster responding to punishment trials compared with reward trials. Thus higher neuroticism, BIS and friendship avoidance goals scores are related to faster responding on punishment trials. As far as we are aware, this represents the first direct behavioural evidence that neuroticism is related to punishment sensitivity, as was hypothesized by Gray (1987; Moeller & Robinson, 2010).

Neuroticism and BIS were associated with faster responding on monetary punishment trials as well as social trials. The correlation between higher friendship avoidance goals and faster responding on punishment trials (relative to reward trials) was driven entirely by social trials. These results are consistent with the nature of the variables measures: neuroticism and BIS are broad dispositions, while friendship avoidance goals are specific to social motivation. Closer inspection of the data indicated that the friendship avoidance goals correlation with imp_valence was driven by slower responding on social reward trials. Follow-up correlation analyses with the trimmed mean RTs confirmed this (see Table 6.11). This is consistent with previous findings that social avoidance (e.g. attachment avoidance, discussed in chapter 4) is associated with lower sensitivity to social reward.

		Trimmean RT mon rew	Trimmean RT mon pun	Trimmean RT soc rew	Trimmean RT soc pun
Friendship Avoidance Goals	Full sample	.108	.101	.217*	.128
	Males only	.062	.101	.264*	.154
	Females only	.137	.078	.110	.061

Table 6.11: Correlations (Pearson's *r*) between friendship avoidance goals and trimmed mean RTs in each of the four main conditions of the SMID task.
* p < .05, ** p < .01, *** p < .001

6.5.3.2 Associations between SMID RT metrics and reactivity to feedback

As predicted, SMID RT metrics were associated with changes in social SSE, although these effects were present in male participants only. In particular, relatively higher motivation to avoid social punishments (indexed by RMI pun) was associated with changes in social SSE. However, the direction of this effect was opposite to that which was predicted: greater motivation to avoid social punishment was associated with an *increase* in social SSE following the task. That is, faster responding on social trials, particularly social punishment trials, was associated with increase in social SSE. A logical explanation for this would be that participants who responded faster on social punishment trials won more of these trials and so experienced fewer social punishment outcomes. However this was not the case: as stated in section 6.4.2, none of the SSE metrics were significantly related to the percent of trials participants won. This is shown for social SSE difference scores in Table 6.12 below.

	Percent wins total	Percent mon rew wins	Percent soc rew wins	Percent mon pun wins	Percent soc pun wins
State Self Esteem: Social Evaluation - diff (2nd - 1st)	.166	.095	.246	.039	.175

Table 6.12: Correlations (Pearson's *r*) between social SSE difference scores and percent of trials won in in each of the four main conditions of the SMID task, as well as the task overall.
* p < .05, ** p < .01, *** p < .001

While it seems counter-intuitive that greater motivation to avoid social punishment was associated *increased* social SSE following the task, perhaps this reflects a sense of relief once the task was over. However, the correlations between the impact of type/RMI RT metrics and social SSE difference were significant only in the males who participated in Study 1B. Until such findings are replicated, it would be premature to infer too much from these results.

6.5.3.3 Links between social expectancies and reactivity to feedback

Contrary to predictions, there were no significant correlations between social reward expectancies and changes in social SSE following the SMID task. LODESTARS-threat scores were associated with changes in academic performance- and social- SSE, but again contrary to predictions higher social threat expectancies were associated with increases in SSE following the SMID. However, this counter-intuitive effect appears to be specific to the *change* in SSE. Overall higher social threat expectancies were strongly correlated with lower SSE across the full sample and in the female participants, as shown in Table 6.11. In the male participants, higher LODESTARS-threat expectancies were correlated with higher social SSE scores. Again, unless such findings are replicated, it is not possible to know whether they are generalizable beyond the Study 1B male participants.

		SSE: Academic Performance pre-SMID	SSE: Social Evaluation pre-SMID	SSE: Appearance pre-SMID	SSE: Overall pre-SMID	SSE: Academic Performance post-SMID	SSE: Social Evaluation post-SMID	SSE: Appearance post-SMID	SSE: Overall post-SMID
LODESTARS Threat	Full sample	-.536***	-.621***	-.460***	-.611***	-.489***	-.590***	-.478***	-.577***
	Males only	.470***	.506***	-.394**	.541***	-.459**	.510***	-.410**	.508***
	Females only	-.563***	-.694***	-.474***	-.644***	-.475***	-.631***	-.489***	-.603***
LODESTARS Reward	Full sample	.206*	.247**	.212*	.250**	.190*	.279**	.250**	.265**
	Males only	.187	.216	.200	.237	.084	.238	.296*	.221
	Females only	.253*	.285*	.240	.288*	.330**	.331**	.259*	.348**

Table 6.11: Correlations (Pearson's *r*) between social expectancies (LODESTARS scores) and SSE directly before and directly following the SMID task.

* $p < .05$, ** $p < .01$, *** $p < .001$

6.6 Conclusion

The SMID task was designed to measure behavioural (reaction time) differences in individuals' motivation to attain social reward (praise) and to avoid social punishment (negative evaluation). The work reported in this chapter demonstrates that the SMID paradigm represents a valid instrument for studying individual differences in social motivation. Using the SMID task, it was demonstrated that neuroticism and BIS are both associated with greater relative motivation to avoid punishment (compared with reward). It was not possible to determine whether this effect was driven by faster responding on punishment trials or slower responding on reward trials, as none of the trimmed mean RT variables correlated significantly with BIS or neuroticism. However, the results are consistent with the conceptualisation that greater sensitivity to punishment represents one component of neuroticism (Gray, 1987; Torrubia, Ávila, Moltó, & Caseras, 2001).

Higher levels of goals focussed on avoiding negative possibilities in the context of respondents' friendships were specifically associated with slower RTs in social reward trials. This is consistent with previous findings that social avoidance is associated with lower motivation for social reward. Although this result was highly significant in the male participants, and was present in the full sample, there were no significant correlations between friendship avoidance goals and SMID RT metrics in the female participants. It is possible that this was due to there being less variance among the female participants, but this does not seem very likely as the variance in the female scores was not particularly low (std. deviation of .89; among the male participants the std. deviation was 1.08).

The data presented in this chapter are consistent with the predictions made by the model proposed in this thesis. Using the SMID paradigm, it was found that individual differences in affective and interpersonal dispositions, social expectancies and motivation, are associated with differences in motivated behaviour during the SMID task. Individual differences in affective reactions to the SMID task outcomes were also linked to expectancies, motivation and behaviour, as predicted by the model. However, the direction and mechanisms underlying these correlations could not be fully assessed using the present data. Further work is needed to test how robust the findings reported here are and to investigate the underlying processes that give rise to the associations reported here. One method that can be employed to glean further insight into individuals' reactions to social feedback is functional magnetic resonance imaging (fMRI). In Appendix 8, I report preliminary work using fMRI to non-invasively detect changes in activity in the human brain associated with experiences of the social versus non-social feedback outcomes in the SMID task.

Chapter 7

General Discussion

The aim of this project was to investigate the relationships between individual differences in social expectancies and motivation, and how these relate to broader personality traits and to social integration outcomes such as individuals' sense of belonging. A cognitive model of social motivation and reactivity to social feedback was proposed. In this model, generalised expectancies are considered to play a pivotal role in motivating human social behaviour. A copy of the model is shown for reference in Fig. 7.1.

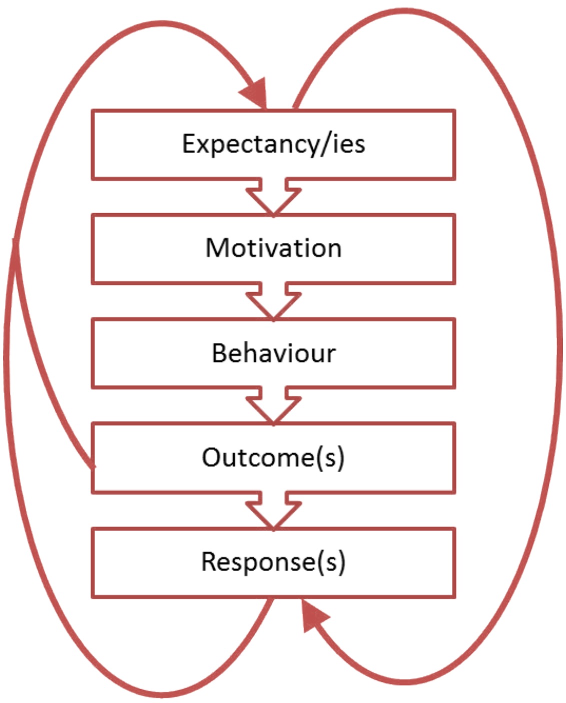

Figure 7.1: Copy of the theoretical framework proposed in this thesis. It is suggested that dispositional biases in expectancies of social reward and punishment directly inform social approach and avoidance motives and goals. These motives and goals direct social behaviour accordingly. Individual differences in interpretation of and reactivity to social feedback from others (i.e. the outcomes of one's interpersonal behaviour) are considered to be intimately linked with expectancies, such that valenced expectancies serve to bias one's subsequent perceptions of and reactions to social cues. These perceptions and reactions in turn inform expectancies for future social scenarios.

7.1 Contributions

A strength of the work reported in this thesis is that all studies included both social reward and threat/punishment within the same design. A great deal of previous work on these and related constructs (e.g. social motives, social bonds) has focussed on either reward or threat/punishment. Particularly in neuroimaging studies, these two potent categories of social reinforcement have rarely been examined concurrently. Given that social encounters present us with both potential rewards and threats, expectancies regarding both of these may operate simultaneously in regulating social behaviour (in a 'push-pull' fashion similar to social affective processing in social approach and avoidance (Vrtička, 2012)). Therefore research aiming to understand the regulation of social behaviour, important for explaining social outcomes such as social connection or loneliness, needs to simultaneously address factors contributing to both social approach and social avoidance (Gable & Elliot, 2008). These include cognitive factors such as expectancies, as well as affective and behavioural reactivity. This thesis has presented a cognitive model of social motivation and reactivity to social feedback in which generalised expectancies are considered to play a pivotal role in motivating human social behaviour. This model bears similarities to cognitive-behavioural models of emotional disorder, in which the relationship between cognitive processes (negative expectancy biases in social contexts) and social behaviours (perpetuated avoidance and withdrawal) is the core mechanism that comprises and maintains emotional disorder (Cao, Gu, Bi, Zhu, & Wu, 2015).

Chapter 4 employed self-report methods to explicitly test whether dispositional levels of social reward/threat expectancies mediate associations between broader traits, such as extraversion, and social approach and avoidance goals. The results provided strong support for the hypothesis that social reward expectancies mediate links between interpersonal traits and social approach goals. These results underline the crucial importance of reward expectancies in motivating behaviour (see also Sherdell, Waugh, & Gotlib, 2012).

The available data did not yield evidence that social threat expectancies mediate associations between interpersonal traits and social avoidance goals. This may have been partly due to a paucity of data to probe for such mediation effects, as discussed in Chapter 4 (section 4.7.3).

In Chapter 5, the neuroanatomical correlates of social threat and reward expectancies were explored. The data presented in this chapter indicated that individual differences in social expectancies appear very similar, at the structural level of the brain, to individual differences in emotion regulation. This is consistent with Ochsner and Gross's (2014) proposal that expectancies can operate as emotion regulation techniques. It appears that a main locus of individual differences in social reward expectancies may indeed be in neural systems that support flexible, cognitive regulation of emotion, namely medial prefrontal cortices. My results are thus also in line with neurocognitive models of emotional disorder, which posit that information processing biases, including biased expectancies of threat and reward, may *result from* aberrant emotion regulation strategies, caused by impaired top-down regulation of affect mediated by prefrontal systems (Admon & Pizzagalli, 2015; Van der Molen et al., 2014). Beyond the domain of emotion regulation, higher social threat expectancies were associated with greater grey matter volume (GMvol) in brain regions involved in social attention and perception. This may reflect attentional bias and hypervigilance directed towards potential social threat signals in the environment.

In Chapter 6, a task-based measure of motivation for and behavioural reactivity to social reward and punishment was described. It was found that individual differences in self-reported affective and interpersonal dispositions, social expectancies and motivation were associated with differences in motivated behaviour during the SMID task. These associations were consistent with the model proposed in this thesis. Furthermore, individual differences in affective reactions to the SMID task outcomes were linked to expectancies, motivation and behaviour, as predicted by the model.

By having participants engage in the SMID task during a functional neuroimaging experiment, neurobiological substrates of responses to social reward and punishment can also be probed. A preliminary study of the neural correlates of exposure to social and monetary incentives in the SMID task is reported in Appendix 8.

During social outcomes, compared with monetary outcomes, increased BOLD activation was observed in brain regions involved in theory of mind (ToM), including bilateral temporo-parietal junction and left medial prefrontal cortex. This is consistent with previous work indicating that the rewarding (or threatening) nature of social interactions involves an interplay of valuation circuits with regions commonly associated with ToM (Skuse & Gallagher, 2009). For example, in order to feel pleasure in response to praise, it is necessary to understand whether it is sincere. This judgement requires activation of ToM circuitry.

Increased activation in bilateral amygdala was also observed during social outcomes. This is consistent with the central role of the amygdala as a 'hub' in several systems (including valuation) relating to social perception and cognition in the brain (Bickart, Dickerson, & Feldman Barrett, 2014).

Functional and structural brain imaging data were examined to see if and how they relate to each other and to individual differences at other levels of the model, specifically in a measure of self-reported autistic-like social characteristics. This measure, BAP-Social, encompasses a lack of interest in or enjoyment of social interaction combined with deficits in the social aspects of language, resulting in difficulties communicating effectively or in holding a fluid, reciprocal conversation (Hurley, Losh, Parlier, Reznick, & Piven, 2007). Previously, BAP-Social has been shown to be significantly associated with difficulties in social cognition and reduced social skill (Sasson, Nowlin, & Pinkham, 2013) as well as diminished social motivation (Dubey, Ropar, & Hamilton, 2015). Previous work by Kreifelts, Ethofer, Huberle, Grodd, and Wildgruber (2010) has linked lower trait emotional intelligence (measured by self-report; Schutte et al., 1998) with reduced BOLD activity in the posterior MTG/STS (pMTG/STS) during social signals from voices and faces. On the basis of this result I investigated whether social motivation and autistic-like social traits correlate with BOLD activation in response to self-relevant social feedback (SMID outcomes). I hypothesised that activity in pMTG/STS would correlate negatively with autistic-like social traits, in line with the findings of Kreifelts et al. (2010).

As predicted, social-feedback related BOLD activity in pMTG/STS correlated negatively with self-reported autistic-like social characteristics in my sample. These social characteristics include difficulties with the social aspects of language and communication, as well as reduced social motivation. As a follow-up, I examined associations between social-feedback related BOLD activity and a behavioural index of motivation for social outcomes relative to money outcomes[1] . Social-feedback related BOLD activity in pMTG/STS correlated positively with higher motivation for social compared to monetary outcomes as indicated by faster reaction times during the task. These results suggest that greater motivation for social incentives and lower expression of autism-like social traits (perhaps indicative of greater social skill; Sasson et al., 2013) are linked with greater reactivity of the pMTG/STS to social feedback. The potential role(s) of the pMTG/STS in social cognition are discussed further in section 7.2.3 of this chapter.

7.2 Implications

7.2.1 On the independence of social reward and threat processing

Although approach and avoidance are mutually exclusive at the behavioural level (one cannot approach a stimulus and avoid it at the same time), the data presented in this thesis argue against a simplistic view of social approach and avoidance being underpinned by independent (social) reward and punishment/threat neural systems.

As stated earlier, a great deal of previous neuroimaging work has focussed on either reward or threat/punishment. One social incentive delay (SID) study which did incorporate both social reward (approval) and punishment (disapproval) outcomes was conducted by Kohls et al. (2013) however. These authors were interested in the dual motives that govern human social behaviour: pursuit of

[1] Derived from SMID RT responses

social reward and avoidance of social punishment. They therefore interrogated participants' BOLD activity during anticipation of social reward and during anticipation of avoidance of social punishment. They found that anticipation of avoidance of social punishment recruited the NAcc in a similar manner to the NAcc activation observed during anticipation of social reward. This provides evidence that the avoidance of social threat/punishment can be experienced as rewarding. It also provides further evidence that the VS/NAcc functions as a general encoder of anticipated value, irrespective of reward type (as discussed in Chapter 5, section 5.1).

Consistent with this, the brain structure analyses reported in Chapter 5 do not point to a straightforward view of social reward expectancies mediated by social reward-sensitive brain regions and social threat expectancies mediated by punishment-sensitive and/or threat-detection regions. Rather, the results reported in Chapter 5 suggest an altogether more holistic involvement of many cognitive functions including, most prominently, emotion regulation and attention control. As mentioned in Chapter 1, regulation of attention and emotion are strongly interlinked at the behavioural level (MacLeod & Mathews, 1988; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; See, MacLeod, & Bridle, 2009). The data presented in Chapter 5 suggest that this is the case that the neuroanatomical level as well.

7.2.2 On the links between individual differences in social perception brain regions and biases in dispositional expectancies of social reward and threat

The results of my VBM study suggest that dispositional biases in individuals' levels of social reward and threat expectancies are intimately linked with grey matter volume differences in brain regions involved in social perception. This is consistent with the important role of expectancies in influencing our perception of our environments (Diekhof et al., 2011; Petrovic et al., 2005). This can occur by means of stimulus selection, i.e. selective attention to particular features of the environment in accordance with current goals and affective states. There is evidence that the inferior temporal gyrus (ITG) – which was found to be associated with levels of both reward and threat expectancies in my study – is involved in selecting the visual stimuli to which we attend (Chelazzi, Miller, Duncan, & Desimone, 1993; Kastner & Ungerleider, 2000). Although the selection of stimuli for representation is ultimately resolved within visual cortex, the top-down attentional biasing signals that affect this derive from the valuation and attention networks of frontal-temporal and parietal brain regions (Kastner & Ungerleider, 2000), including the ITG. The amygdala is connected with the ITG, and there is evidence that altered functional connectivity between these two regions is associated with the increased attention to and perceptual processing of social-threat related visual stimuli in SAD (Liao et al., 2010).

In addition to stimulus selection, expectancies can influence perception of attended stimuli, in terms of perceptual judgments and affective responses (Diekhof et al., 2011). Diekhof et al. (2011) demonstrated that anticipatory mental imagery of mildly fearful faces altered participants' subsequent perception of highly fearful faces, causing participants to perceive these as less fearful. Regulatory influences from lateral and ventromedial prefrontal regions on the fusiform gyrus (FG) during anticipatory imagery primed the FG for a subsequent misperception of lower fearfulness. Greater vmPFC and FG activation during face perception was associated with greater illusory reduction in fearfulness. Diekhof et al. suggest that the increased activation in these brain regions reflects a greater contribution of top-down contextual framing influences on the perceptual evaluation of the fearful faces. Greater top-down regulation may alter perception and affective interpretation of stimuli partly by restricting the contribution of bottom-up arousal (Diekhof et al., 2011).

It appears that within the ITG and FG, identification and affective interpretation of emotional stimuli during social perception may be integrated, creating a valenced perceptual representation of a social stimulus or scene (Geday, Gjedde, Boldsen, & Kupers, 2003). Rather than only the domain of specialised valuation circuits, valence coding may also occur during perceptual encoding (Chikazoe, Lee, Kriegeskorte, & Anderson, 2014). Accurate valence assessments during social perception are crucial for empathic reactions and appropriate social responses (Geday et al., 2003).

As mentioned in Chapter 5 (section 5.4.5), greater social perceptiveness is associated with less worry and higher sociability (Schroeder, 1995; Schroeder & Ketrow, 1997). The results of my VBM overlap analysis suggest that the anatomical locus of these associations may be in the inferior temporal lobe (ITG and FG).

7.2.3 On the role of the posterior superior temporal sulcus and middle temporal gyrus in social cognition

The pMTG/STS emerged as a brain region that is important both in individual differences in social threat expectancies and in reactivity to social feedback. Increased pMTG/STS reactivity to social feedback was correlated with higher motivation for social compared to monetary outcomes as indicated by faster reaction times during the SMID task. Furthermore, pMTG/STS reactivity to social feedback was negatively correlated with self-reported levels of autistic-like social characteristics. These results suggest that greater motivation for social incentives and lower expression of autism-like social traits are linked with greater reactivity of the posterior MTG/STS (pMTG/STS) to social feedback. VBM additionally revealed that BAPQ-social scores correlated negatively with grey matter volume in the pMTG/STS.

My results support the hypothesis that the pMTG/STS serves as an interface between perception of social information and social cognition (Bayliss, Bartlett, Naughtin, & Kritikos, 2011; Kreifelts et al., 2010). The pMTG/STS may play a critical role in analysing socially relevant perceptual information, evaluating its implications and orienting attention accordingly, in line with the individual's present affective state and social goals (Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002).

My findings indicate that the pMTG/STS may also play a role in social motivation. This is consistent with previous work demonstrating that individuals higher in the need to belong are particularly attentive to social cues (Pickett, Gardner, & Knowles, 2004).

Previous work has also linked loneliness with diminished grey matter in the posterior superior temporal sulcus (pSTS) (Cacioppo, Capitanio, & Cacioppo, 2014; Kanai et al., 2012). Kanai et al. (2012) found that loneliness and decreased pSTS volume were related to poorer performance on a gaze perception task. Gaze perception performance mediated the link between loneliness and pSTS volume.

Thus the pMTG/STS is implicated in empathy, attention control, loneliness and social motivation. A parsimonious explanation of these findings has been offered by Cacioppo (2015). Cacioppo suggested that the pMTG/STS operates as a modulator of attentional focus on others versus self-focussed attention. When individuals feel secure, they have little need to focus on themselves or on potential signals of social threat. Thus their attention can be focussed in an empathic manner on those around them. Individuals who are experiencing greater levels of social anxiety may be more focussed on themselves and on surveillance of the social environment for signals of potential threat (Cacioppo, 2015). This can result in reduced empathy and social engagement, which may ultimately result in loneliness. This explanation is consistent with behavioural work showing that highly rejection sensitive individuals frequently behave in ways that increase their likelihood of rejection by social partners, because of their hypervigilance for threat (Downey, Feldman, & Ayduk, 2000; MacDonald, Borsook, & Spielmann, 2011; Murray, Bellavia, Rose, & Griffin, 2003).

7.3 Limitations

There are some limitations that should be considered when interpreting my results. Firstly all studies reported in this thesis were cross-sectional. Although my results are consistent with the proposed model, in almost all cases there is no indication as to whether the observed correlations imply causal relationships. One exception is in Chapter 4 (sections 4.7 and 4.8) in which the predictions of the directional processes proposed in the model could be tested by mediation analyses. Mediation models enable inference about the direction of effects in models of psychological processes (Hayes, 2013; Wu & Zumbo, 2007). It has been argued that, on this basis, mediation models can be interpreted as causal models because they test the predictions of underlying theories that are intrinsically causal (Wu & Zumbo, 2007). However, in the absence of experimental manipulation, one cannot infer true causality.

Another consideration that should be borne in mind is that all of the studies reported in this thesis employed self-report measures, either exclusively or in tandem with behavioural (SMID or Cyberball tasks) and/or brain imaging measures. Psychological research using self-report measures has told us a great deal, but there are limitations to this technique. First, it assumes that the requested information is available for participants to report. This is not true for much that happens in our mental lives (Snowden, Craig, & Gray, 2011), possibly including motivations for connecting with others (MacDonald, Tackett, & Bakker, 2011). Also, self-report measures rely on the respondent being honest in their answers. Even if participants do not consciously engage in impression-management when completing the LODESTARS, they may wish to believe, and therefore present, themselves to be less socially anxious (for example) than they really are. For these reasons, it may be preferable to use an alternative technique that does not require an explicit report from participants, yet still reveals reliable information about their underlying cognitions (Snowden et al., 2011). The SMID task was developed and employed in the research reported here as one method of addressing the limitations of self-report. However, task measures have limitations as well. Of particular relevance to the present work is the fact that responses in task-based paradigms are more influenced by state rather than trait variance (Duckworth & Kern, 2011; Robins, Fraley, & Krueger, 2009). Self-report measures are better suited to capture trait-level variance (Robins et al., 2009). As a major focus of the present work was on variance in traits and stable trait-like interpersonal dispositions and cognitive biases, it was necessary to rely on self-report measures for a substantial amount of the data collection, including the measurement of dispositional levels of social reward and threat expectancies.

With regards to my brain imaging measures, the cellular basis underpinning grey matter differences identified by VBM is still poorly understood, especially in healthy participants (Mechelli, Price, Friston, & Ashburner, 2005). Furthermore, the biological basis of observed relationships between brain structure and brain activity as measured by functional MRI is unknown (Kanai & Rees, 2011). Thus, although the convergent links of structural and functional MRI findings with self-reported and behaviourally indexed social dispositions reported in this thesis are compelling, for instance in the case of the pMTG/STS, specific inferences about the neurobiology of social-cognitive processes, e.g. orienting attention to social cues, would be premature at this time.

As was noted in Chapter 5, the practice of placing neuroimaging results in the context of previous work to draw inferences about the cognitive processes that may be involved, involves engaging in reverse inference. That is, inferring the engagement of a particular psychological process on the basis of GMvol or BOLD activity differences in a brain region previously associated with said psychological process (Poldrack, 2006). Reverse inferences are not deductively valid, but nonetheless can provide useful and even illuminating information with which to advance our understanding of the mind and brain (Doré, Zerubavel, & Ochsner, 2014; Poldrack, 2006). For instance, reverse inferences might suggest new ideas and novel hypotheses, which can be tested in subsequent experiments (Poldrack, 2006). This is particularly important in the case of an exploratory study such as this, in which a major aim is to look for promising leads that can be followed up in subsequent studies, or that may generate new hypotheses. However, it should be borne in mind that interpretations of results based on reverse inferences are by no means conclusive.

Finally, my sample for the VBM study was not evenly matched for sex, comprising 74% females. We did not see any significant differences between males and females in LODESTARS scores in the VBM sample nor in any other study conducted to date. However there are known to be gender differences in in some related constructs, such as behavioural inhibition (BIS). There may also be gender differences in the neural mechanisms that give rise to observed traits and characteristics. For example, evidence for gender differences in the neural correlates of emotion regulation (cognitive reappraisal) has previously been reported (McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008). We accounted for gender in the GLM. Further, there were no differences between the relationship between grey matter volumes and LODESTARS scores in the full sample, compared with a sample comprising the female participants only. However, we did not have sufficient power (sufficient male participants) to systematically test for gender differences in GMvol–LODESTARS correlations so it is possible that there are relatively subtle differences that could not be detected in my data. Future large scale-studies could test for potential gender differences in the neural substrates of dispositional social expectancies.

7.4 Future directions

The cognitive model of social motivation and reactivity to social feedback proposed in this thesis sought to address the role of generalised expectancies in motivating human social behaviour. The role of cognitive processes in social motivation has previously been somewhat neglected compared with affective processes (e.g. hope and fear). Although hope for affiliation was not examined in this thesis, it would be useful in future work to include this variable, to assess if and how it relates to and interacts with cognitive expectancies of social reward. While hope for affiliation and generalised social reward expectancy both motivate social approach, it may not be the case that these co-occur. Their co-occurrence (or lack thereof) may be moderated by personality traits such as attachment style. For instance, individuals who are high in attachment anxiety may hold strong hopes for affiliation (Gable, 2015) but simultaneously low expectancies of social reward. Further work is needed to address hypotheses such as this and, more generally, the effects and interactions of both affective and cognitive processes in motivating human social behaviour. One way to take this work forward would be to examine the development of dispositional expectancies using longitudinal studies. For example, studying associations between attachment in childhood and the development of cognitive biases in social threat and reward expectancies, as well as affective social motives (hope for affiliation and fear of rejection) may help to elucidate the mechanistic links between these variables.

While hope for affiliation and expectancy of social reward may be distinct, at least in some individuals, it appears there may be less of a distinction between affective and cognitive processes in the social avoidance domain. As discussed in Chapter 4, generalised expectancies of social threat, at least as measured by the LODESTARS, appear to be predominantly worries and concerns about negative evaluation, that is, fear of rejection.

The model proposed here bears similarities to cognitive-behavioural models of emotional disorder, in which the relationship between cognitive processes (negative expectancy biases in social contexts) and social behaviours (perpetuated avoidance and withdrawal) is the core mechanism that comprises and maintains emotional disorder (Cao et al., 2015).

One potential future direction, given evidence for biased expectancies in emotional disorders – such as social anxiety (Cao et al., 2015) and depression but also schizophrenia and bipolar disorder (Bentall et al., 2008; O'Sullivan, Szczepanowski, El-Deredy, Mason, & Bentall, 2011) – would be to administer the LODESTARS to individuals at high risk (including genetic risk) of developing emotional disorder. These individuals could then be studied longitudinally, to see if expectancies play a role in maintaining impaired behaviour (e.g. social withdrawal) in individuals who develop emotional disorders. A potential advantage of the LODESTARS in the context of such studies is that it captures dispositional expectancies of social reward as well as social threat. Emotional disorders that arise due to reduced social reward expectancies can thus be distinguished from those that arise due to heightened social threat expectancies. In disorders where both play a role, the relative importance of these two dimensions could be assessed. Given that LODESTARS reward and threat expectancies were found to be negatively correlated in all studies reported in this thesis, it would be interesting to investigate whether altering levels of social threat expectancies, for instance by means of therapeutic interventions, has any impact upon reward expectancies and vice versa. Further, if it did prove possible to alter people's levels of social threat/reward expectancies, and if these effects were enduring, it would be interesting to investigate if the changes were reflected in altered brain structure. Longitudinal and/or causal designs such as this address the problems associated with correlational designs for purposes of making directional inferences.

With regard to the neural correlates of social reward and threat/punishment processing, examination of other stable individual differences in brain structure may be informative. In particular, the structural connectivity between brain regions, by way of white matter tracts, may vary with dispositional differences in expectancies for or reactivity to social rewards and threats or punishments. Like grey matter volume, individual differences in genetically determined aspects of structural connectivity in tandem with early social environment(s) and experiences, shape the development of individuals' social cognitive processing styles and interpersonal dispositions (Leppänen & Nelson, 2009). It is also possible that individual differences in brain chemistry associated with individual differences in social reward/punishment expectations and sensitivity could be detected using magnetic resonance spectroscopy (MRS). The inhibitory neurotransmitter γ-aminobutyric acid (GABA) has been shown to play a role in modulating reward signalling and motivational neural systems in rats (Laviolette & van der Kooy, 2001). Using MRS, it is possible to non-invasively measure regional GABA levels in the human brain (Mullins et al., 2013). Future studies could investigate if individual differences in reactivity to social reward and punishment are linked with differences in GABA levels.

7.5 Conclusion

This thesis has investigated the relationships between individual differences in social expectancies, motivation, and reactivity to social feedback. The neural correlates of these individual differences were examined, as well as their relationships to broader personality traits and to social integration outcomes such as individuals' sense of belonging.

Two novel measures were developed: a self-report measure of dispositional levels of social threat and reward expectancies (the LODESTARS) and a task-based measure of social motivation and reactivity to social reward and punishment (the SMID task). Rigorous validation studies were employed to ensure the validity and utility of these measures.

The research reported in this thesis employed multiple methods: self-report, task-based measures, and structural and functional (BOLD) neuroimaging. The studies reported here benefitted from large sample sizes and high statistical power, with the exception of the pilot fMRI study and the Cyberball study. The findings of all the studies conducted supported the key proposal that dispositional biases in expectancies of social reward and punishment are critical for understanding individual differences in reactivity to social feedback and social outcomes such as loneliness. It was proposed that expectancies exert their effects both by informing social approach and avoidance motivations and by directly influencing perceptions of and reactions to social cues. Convergent findings from multiple modalities were consistent with both these proposed mechanisms.

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Appendix 1.

Social Network Index adjusted for students – showing changes

Instructions: This questionnaire is concerned with how many people you see or talk to on a regular basis including family, friends, workmates, neighbours, etc. Please read and answer each question carefully. Answer follow-up questions where appropriate.

1. Which of the following best describes your ~~marital~~ relationship status?

_____ (1) currently married & living together, or living with someone in marital-like relationship

_____ (2) ~~never married & never lived with someone in a marital-like relationship~~ in a relationship and living together in shared accommodation with other people

_____ (3) ~~separated~~ in a relationship; not living together

____ (4) single but previously lived with someone in a marital-like relationship

_____ (5) ~~divorced or formerly lived with someone in a marital-like relationship~~ single & never lived with someone in a marital-like relationship

_____ (6) divorced, separated or widowed

2. ~~How many children do~~Do you have any children? (If you don't have any children, ~~check~~ click '0' ~~and skip to question 3.~~)

_____0 _____1 _____2 _____3 _____4 _____5 _____6 _____7 or more

2a. How many of your children do you see or talk to on the phone at least once every 2 weeks?

_____0 _____1 _____2 _____3 _____4 _____5 _____6 _____7 or more

3. Are ~~either of~~ your parents living? ~~(If neither is living, check '0' and skip to question 4.)~~

_____ (0) neither _____ (1) mother only _____ (2) father only _____ (3) both

3a. Do you see or talk on the phone to either of your parents at least once every 2 weeks?

_____ (0) neither _____ (1) mother only _____ (2) father only _____ (3) both

~~4. Are either of your in-laws (or partner's parents) living? (If you have none, check the appropriate space and skip to question 5.)~~

~~_____ (0) neither _____ (1) mother only _____ (2) father only _____ (3) both _____ (4) not applicable~~

4a. Do you see or talk on the phone to either of your partner's parents at least once every 2 weeks?
______ (0) neither ______ (1) mother only ______ (2) father only _____ (3) both

5. How many other relatives (other than your spouse, parents & children) do you feel close to? (If '0', check that space and skip to question 6.)
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

5a. How many of these relatives do you see or talk to on the phone at least once every 2 weeks?
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

6. How many close friends do you have? (meaning people that you feel at ease with, can talk to about private matters, and can call on for help)
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

6a. How many of these friends do you see or talk to at least once every 2 weeks?
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

7. Do you belong to a church, temple, or other religious group? (If not, check 'no' and skip to question 8.)
______ no ______ yes

7a. How many members of your church or religious group do you talk to at least once every 2 weeks? (This includes at group meetings and services.)
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

8. Do you attend university any classes (school, university, technical training, or adult education) on a regular basis? (If not, check 'no' and skip to question 9.)
______ no ______ yes

8a. How many fellow students or teachers do you talk to at least once every 2 weeks? (This includes at class meetings.)
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

9. Are you currently employed either full or part-time? (If not, check 'no' and skip to question 10.)
____ (0) no ______ (1) yes, self-employed ______ (2) yes, employed by others

9a. How many people do you supervise?
____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

9b. How many people at work (other than those you supervise) do you talk to at least once every 2 weeks?

____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

10. How many of your neighbours do you visit or talk to at least once every 2 weeks?

_____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

11. Are you currently involved in regular volunteer work? (If not, check 'no' and skip to question 12.)

_____ no _____ yes

11a. How many people involved in this volunteer work do you talk to about volunteering-related issues at least once every 2 weeks?

____0 ____1 ____2 ____3 ____4 ____5 ____6 ____7 or more

12. Do you belong to any groups in which you talk to one or more members of the group about group-related issues at least once every 2 weeks? Examples include social/sports clubs, recreational groups, trade unions, commercial groups, professional organizations, ~~groups concerned with children like the PTA or Boy Scouts,~~ groups concerned with community service, etc. (If you don't belong to any such groups, check 'no' and skip the section below.)

_____ no _____ yes

Consider those groups in which you talk to a fellow group member at least once every 2 weeks. Please provide the following information for each such group: the name or type of group and the total number of members in that group that you talk to at least once every 2 weeks.

Total number of group members

Group that you talk to at least once every 2 weeks

This scale was used for the following journal article:

Cohen, S., Doyle, W. J., Skoner, D. P., Rabin, B. S., & Gwaltney, J. M. Jr. (1997). Social ties and susceptibility to the common cold. Journal of the American Medical Association, 277, 1940-1944.

Appendix 2.

Post-Cyberball Need Threat Scale

Needs were assessed on a 5-point scale ranging from 1 (not at all) to 5 (extremely). Questions marked with an "(R)" were reverse-scored.

Belongingness

1. I felt as one with the other players.
2. I had the feeling that I belonged to the group during the game.
3. I did not feel accepted by the other players. (R)
4. During the game I felt connected with one of more other players.
5. I felt like an outsider during the game. (R)

Control

1. I had the feeling that I could throw as often as I wanted to the other players.
2. I felt in control over the game.
3. I had the idea that I affected the course of the game.
4. I had the feeling that I could influence the direction of the game.
5. I had the feeling that the other players decided everything. (R)

Self-Esteem

1. Playing the game made me feel insecure. (R)
2. I had the feeling that I failed during the game. (R)
3. I had the idea that I had the same value as the other players.
4. I was concerned about what the other players thought about me during the game. (R)
5. I had the feeling that the other players did not like me. (R)

Meaningful Existence

1. During the game it felt as if my presence was not meaningful. (R)
2. I think it was useless that I participated in the game. (R)
3. I had the feeling that my presence during the game was important.
4. I think that my participation in the game was useful.
5. I believed that my contribution to the game did not matter. (R)

Appendix 3.

Full inter-correlation tables for all self-report variables in each study

To access these tables in Excel format, please see the supplemental material that accompanies this thesis.

Appendix 4.

Pilot testing for SMID task

The stimuli used in the SMID task were developed in pilot studies 1, 2, and 2.1 reported here.

A4.1 Pilot Study 1: Development of monetary stimuli for the SMID task

A4.1.1 Methods

A4.1.1.1 Monetary Stimuli

Photographs of British coins, placed on a black velvet background, were taken using a Panasonic Lumix fz40 digital camera. The images were re-sized such that the coins in the final images are correctly proportioned with respect to themselves and each other. Some previous studies that have used images of money as outcome stimuli have presented the currency in the context of a wallet or other money container (e.g. Spreckelmeyer et al., 2009), whereas others have presented the money image on a plain background (e.g. Lin, Adolphs, & Rangel, 2011; Clithero, Smith, Carter, & Huettel, 2011). To ensure that the final stimuli for the present study were as realistic as possible but also that participants were minimally distracted by superfluous details, a pilot study was conducted in which participants viewed 7 potential versions of the monetary stimuli. Participants gave feedback on how realistic and easy to comprehend they found the stimuli, as well as whether they considered the stimuli to be gender-biased. In all stimuli, the amount of money gained or lost was shown by images of coins summing to that amount, with a red cross through them in the loss (punishment) trials (see Fig. A4.9). The amount gained or lost was displayed in green (for reward) or red (punishment) text, under the images (see Fig. A4.9). For neutral outcomes, an empty money container or blank space was shown, with 'No change' displayed in yellow text (see Fig. A4.9).

A4.1.1.2 Participants

Seven individuals completed this pilot study (5 postgraduate students and 2 undergraduates, all from Cardiff University).

A4.1.1.3 Measures

Participants recorded their responses in a computer-based questionnaire (presented in Microsoft Excel), by clicking on the appropriate response boxes to tick them. Participants answered the following questions for each version of the monetary stimuli (scores allocated to each answer for analysis are shown in square brackets; these were not visible to the participants):

Were the stimuli easy to comprehend, i.e. to take in, visually?

- Answer options: very easy[0], quite easy[1], quite difficult[2], very difficult[3]

Did you consider the money container to be gender-biased?

- Answer options: very gender-biased (masculine)[2], slightly gender-biased (masculine)[1], not gender-biased[0], slightly gender-biased (feminine)[1], very gender-biased (feminine)[2]

Were the stimuli sufficiently realistic?

- Answer options: very realistic[0], quite realistic[1], OK[2], quite unrealistic[3], very unrealistic[4]

Additionally, participants indicated their overall recommendation by answering the question "Which did you think was the best (most suitable)?" at the end of the questionnaire.

A4.1.1.4 Procedure

Participants received the Excel questionnaire, plus a PowerPoint presentation showing the potential monetary stimuli, via email. They were instructed to view the PowerPoint presentation running in full-screen mode, so that the stimuli would appear similarly to how they would in the RT task. They filled out the questionnaires and returned them by email.

A4.1.2 Pilot Study 1 Results

All participants answered all questions, yielding 8 ratings for ease of comprehension, gender bias and realism for each version of the monetary stimuli. All participants also answered the question of which version they thought was most suitable. 2 participants selected 2 options for this, yielding 9 votes for the most suitable. All 9 votes were given equal weight and were reverse-scored (see Table A4.1) such that, overall, the monetary stimuli version with the lowest score was considered most suitable. This total score takes into account the 3 ratings categories (ease of comprehension, gender bias, realism) and votes for the most suitable.

	Easy to comprehend?	Gender-biased?	Realistic?	Most suitable? (reverse scores)	Total score
Money container A	4	2	7	-1	12
Money container B	2	1	5	-3	5
Money container C	6	1	11	0	18
Money container D	5	6	12	0	23
No container	2	0	6	-4	4
Money container E	5	11	6	-1	21
Money container E1	3	11	5	0	19

Table A4.1: Results from questionnaires relating to potential versions of monetary stimuli.

As can be seen in Table A4.1, No Container had the lowest total score; therefore this was the format used for the monetary outcome stimuli in the RT task (see Fig. A4.9).

A4.2 Pilot Study 2: Development of social stimuli and testing the stimuli

The nature of the RT task was based on the monetary incentive delay (MID) paradigm originally developed by Knutson et al. (2000). Several authors have recently adapted this task to include social outcomes as well as monetary ones (e.g. Lin et al., 2011; Spreckelmeyer et al., 2009) and have found that social incentive delay (SID) trials give rise to robust and theoretically meaningful data.

A4.2.1 Methods

A4.2.1.1 Social Stimuli

Faces: Happy (reward), angry (punishment) and calm (neutral) faces were used from the NimStim (Tottenham et al., 2009) set of faces for the social outcome stimuli.

Words: Reward and punishment words were selected from the English Lexicon Project list of words (Balota et al., 2007) on the basis of 'happiness' ratings collected by Dodds, Harris, Kloumann, Bliss, & Danforth, (2011). Dodds et al. acquired their happiness ratings by asking users of Amazon's Mechanical Turk to rate how a given word made them feel on a nine point integer scale. They obtained 50 independent evaluations per word. Dodds et al.'s happiness ratings for the reward and punishment words trialled in this study are shown in Figure. As can be seen in Figure, none of the error bars (representing standard deviation) reach the midpoint of 'neither happy nor unhappy', indicating that the proposed reward words are almost invariably rewarding (elicit happiness) and the proposed punishment words are almost invariably punishing (elicit unhappiness). The words were presented in green (for reward) or red (punishment) text under the faces (see Fig. A4.9**Error! Reference source not found.**). Four different individuals' faces from the NimStim were used – 2 females and 2 males – so to minimise differences associated with intrinsic qualities of the faces, the reward and punishment words were paired on the basis of the mean reaction time to them (from the English Lexicon Project data, Balota et al., 2007) and their number of syllables. These pairs were then allocated to the angry and happy faces of the same individual. The pairs were as follows:

Yes	**No**
Great	**Stupid**
Good	**Bad**
Perfect	**Awful**
Splendid	**Worthless**
Brilliant	**Pathetic**
Superb*	**Dismal***
Wonderful	**Wrong**
Fantastic	**Idiot**

Excellent	**Terrible**
Fabulous	**Disgusting**
Marvellous*	**Inadequate**

*Happiness ratings (from Dodds et al., 2011) are not available for these words. However they are included because they seem likely to elicit similar responses and they complete a set of twelve pairs of words, meaning that each of the 4 individuals' faces are used the same number of times. The ratings taken in the current study will allow assessment of whether participants find these words to be rewarding or not (in conjunction with the faces).

There are very few words in the English language that confer neutral feedback – most feedback words are aimed at informing someone either that their performance is adequate or inadequate. Therefore the word OK (presented in yellow text) was used for all the neutral social stimuli (see Fig. A4.9). The neutral monetary outcome text was also the same in all trials ('no change') so the neutral outcomes are similar in that sense across all trial types (see Fig. A4.9**Error! Reference source not found.**).

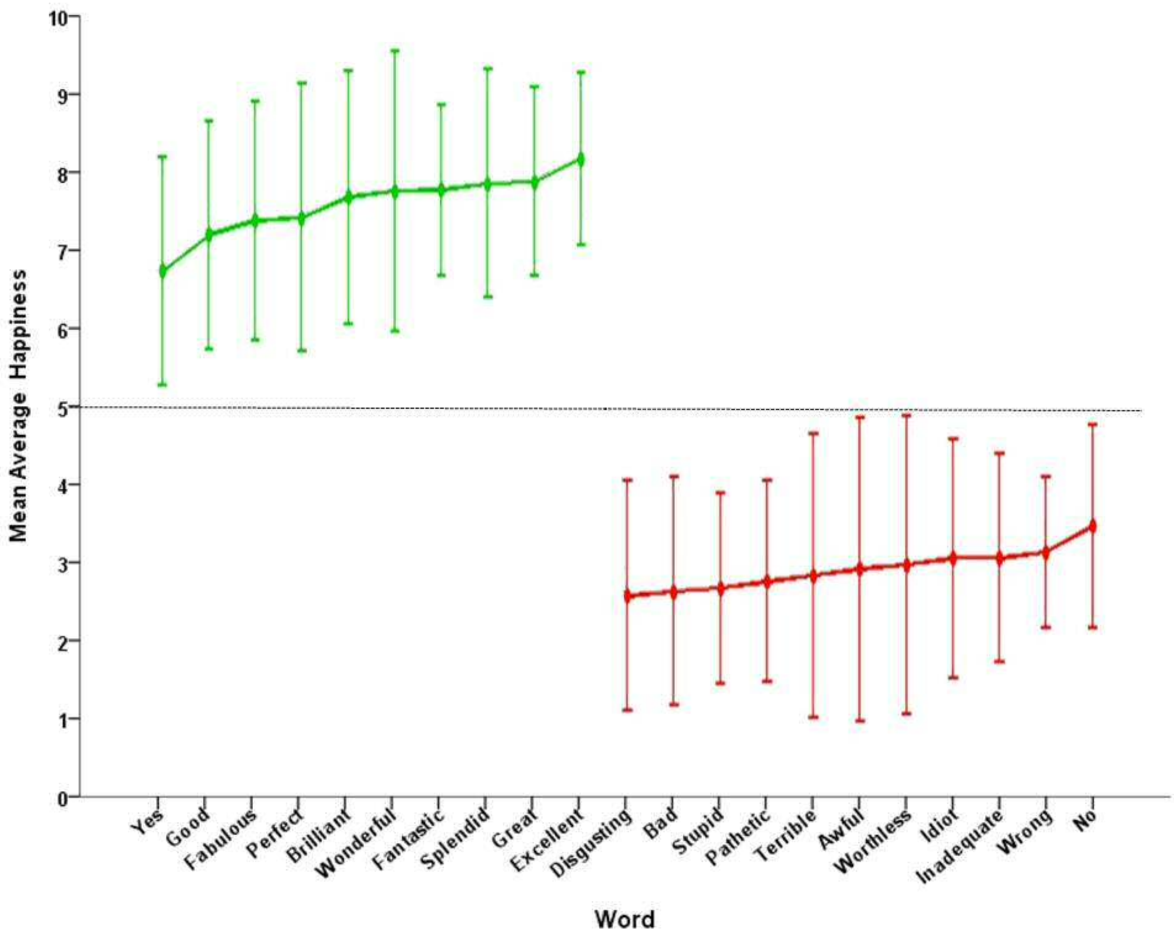

Figure A4.1: Mean happiness ratings (collected by Dodds et al., 2011) for reward and punishment words. Error bars represent ± 1 standard deviation. Ratings were collected on a 9-point integer scale, with 1 being the most unhappy and 10 being the most happy. Reference line at 5 = 'neither happy nor unhappy'.

Sounds: The main potential problem anticipated with the MID/SID task is that participants may fail to engage with it due to lack of salience or realism of the stimuli. It was thought that presenting auditory as well as visual feedback might improve the salience of the outcomes. Therefore some auditory cues were selected for pilot testing. The monetary reward, neutral and punishment cues were taken from non-vocal artificial sound stimuli produced by Capilla, Belin, & Gross (2012) (downloaded from http://vnl.psy.gla.ac.uk/resources.php). The social reward and neutral cues were taken from the pleasure and neutral stimuli, respectively, from the Montreal affective voices collection (Belin, Fillion-Bilodeau, & Gosselin, 2008) and the social punishment cues were taken from the anger and disgust stimuli in this dataset (downloaded from http://vnl.psy.gla.ac.uk/resources.php).

A4.2.1.2 Participants

21 individuals completed this pilot study (6 male). Their mean age was 21.86 years (range 18 – 25 years). They were recruited via email and word of mouth.

A4.2.1.3 Measures

Participants were asked to rate their responses to the visual stimuli using the self-assessment manikin (SAM) affective rating system as described by Bradley & Lang (1999).

A4.2.1.4 Procedure

Each participant attended a testing session in the Psychology building at Cardiff University. Participants were instructed to play a PowerPoint presentation displaying the visual stimuli and record their responses to each one on the SAM. Whether the monetary or social stimuli were presented first was counterbalanced.

Following this, participants were informed that we were also considering the addition of sounds to the stimuli. They were asked to view a sample selection of the stimuli again (displayed via Cogent 2000 (http://www.vislab.ucl.ac.uk/cogent.php) running in MATLAB 2012 (http://www.mathworks.co.uk/products/matlab), this time presented with the auditory cues. Participants were asked to provide verbal feedback on whether these improved, worsened, or made no difference to the salience and realism of the stimuli.

A4.2.2 Pilot Study 2 Results

Figures A4.2, A4.3 and A4. 4 show the mode SAM ratings for each of the three SAM scales (pleasure, arousal and dominance) for the monetary and social visual stimuli.

Table and Figure show overall mean SAM ratings, rounded to the nearest integer (rating) for the different trial types in the MID/SID RT task. Although ratings on the SAM are ordinal, and should therefore be described by the mode as the measure of central tendency, in this case the rounded mean gave a better estimate of participants' responses to the stimuli, as the rounded mean reflects all participants' ratings, not just the SAM rating selected by most participants. This was important, as in many cases there were two or three SAM ratings that were selected by similarly high numbers of participants.

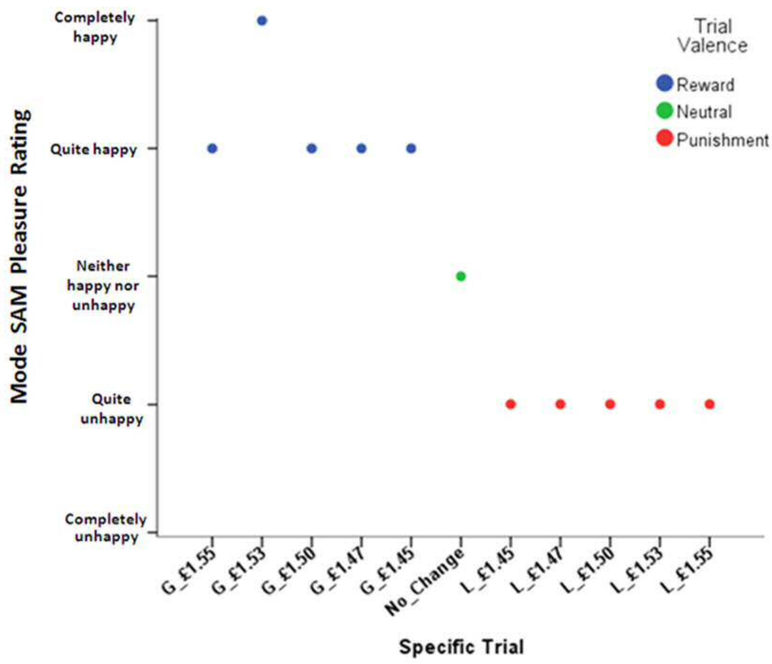

Figure A4.2: Mode SAM pleasure ratings for monetary trials.

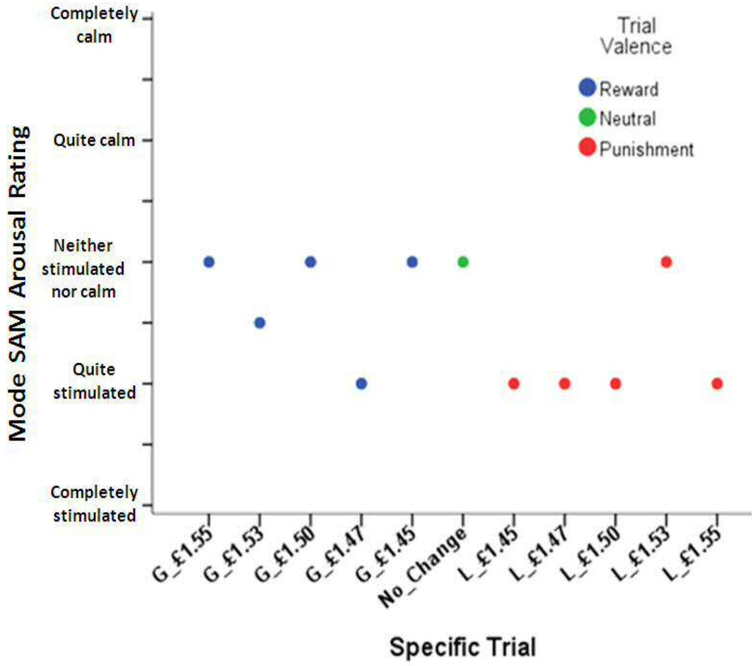

Figure A4.3: Mode SAM arousal ratings for monetary trials.

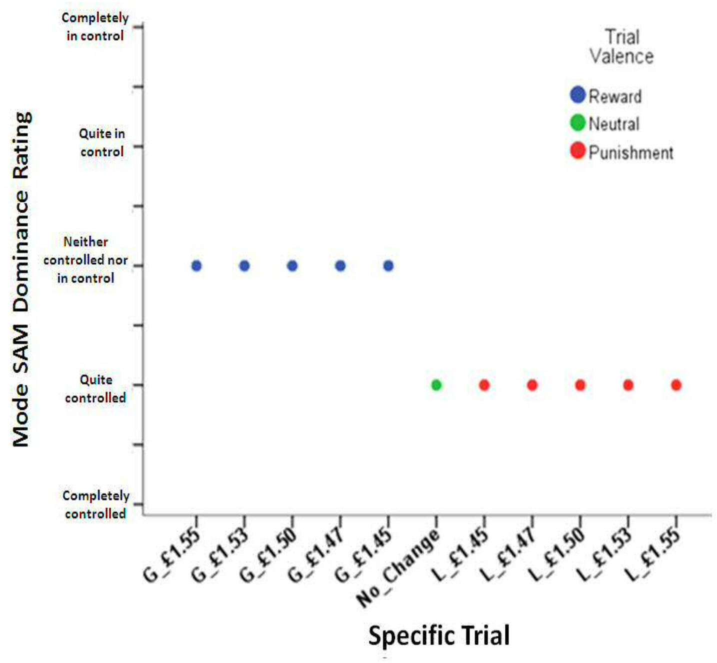

Figure A4.4: Mode SAM dominance ratings for monetary trials.

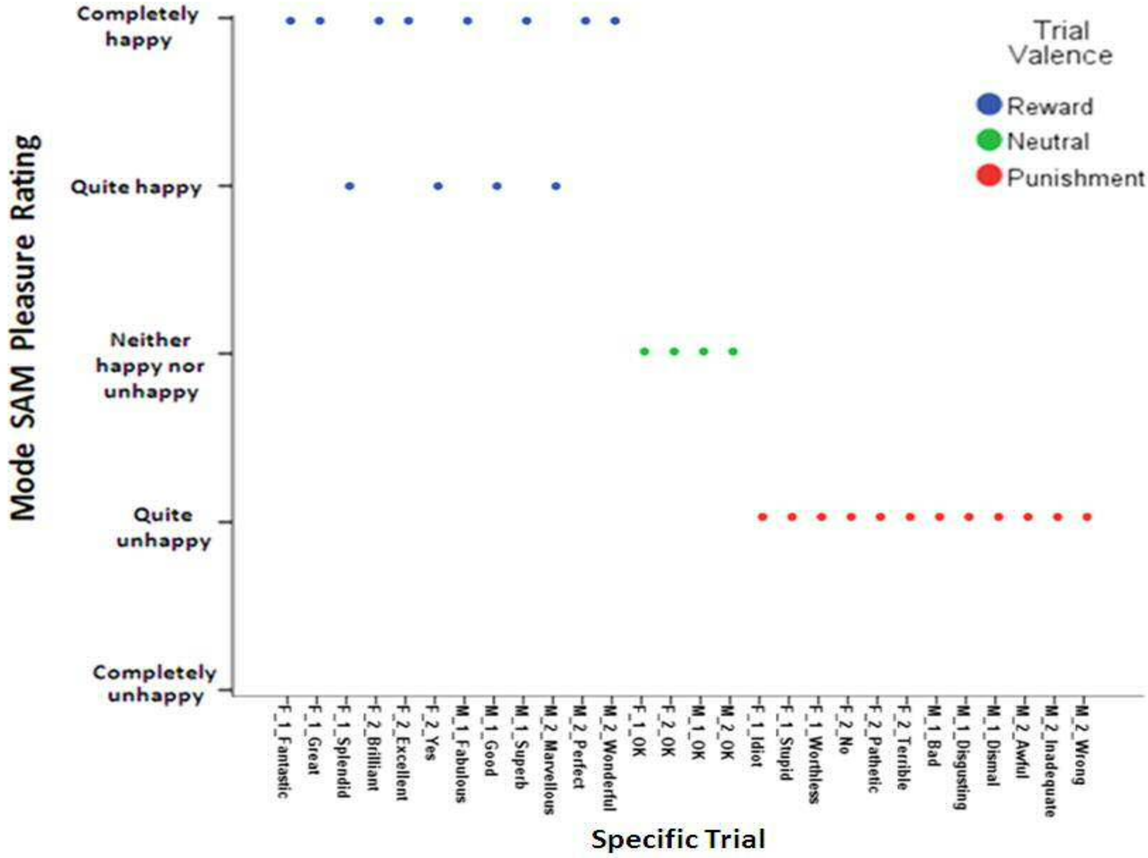

Figure A4.5: Mode SAM pleasure ratings for social trials.

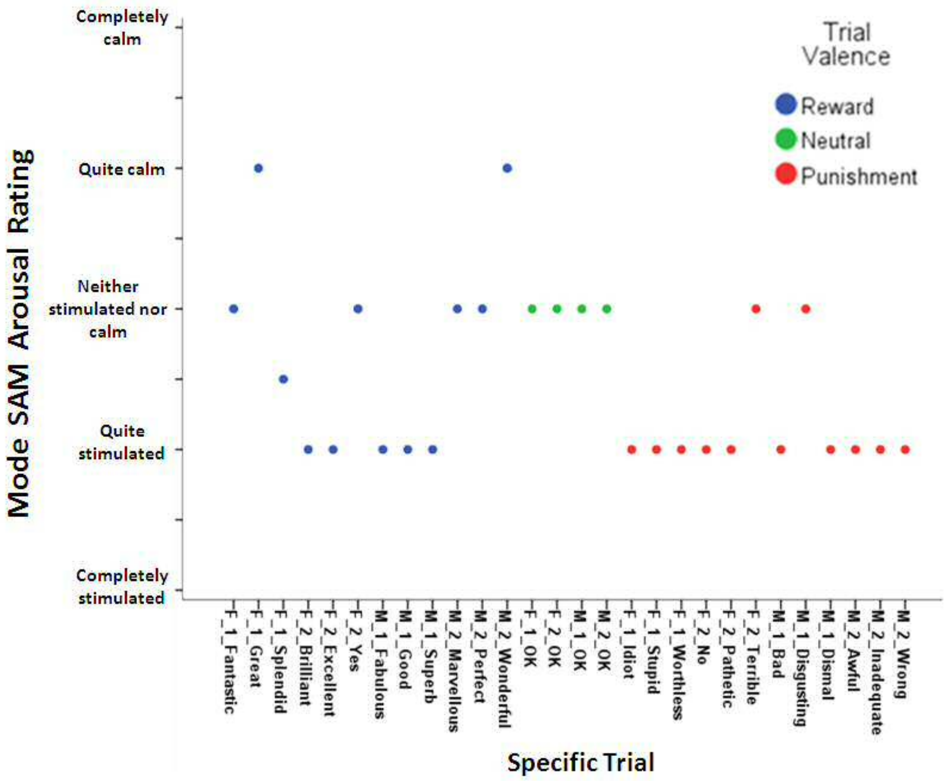

Figure A4.6: Mode SAM arousal ratings for social trials.

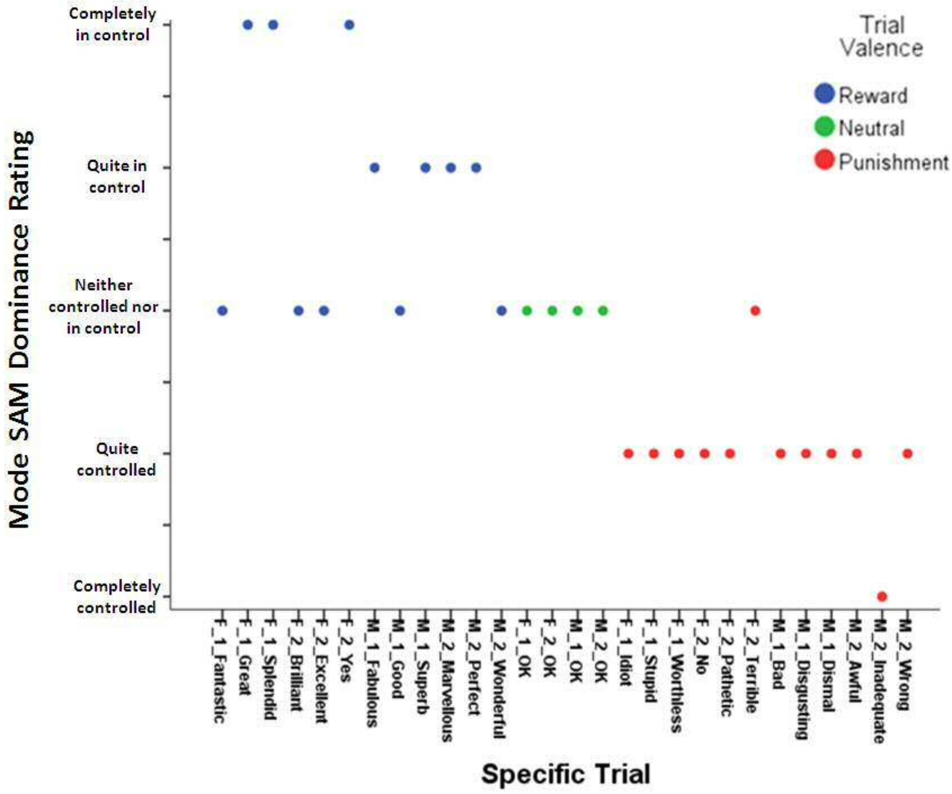

Figure A4.7: Mode SAM pleasure ratings for social trials.

Trial Type	Overall Mean SAM Rating, Rounded to Nearest Integer (Nearest Rating)		
	Pleasure	**Arousal**	**Dominance**
Monetary Reward	Quite Happy	Neither Stimulated Nor Calm	Slightly In Control
Social Reward	Extremely Happy	Neither Stimulated Nor Calm	Quite In Control
Monetary Neutral	Neither Happy Nor Unhappy	Slightly Calm	Neither Controlled Nor In Control
Social Neutral	Neither Happy Nor Unhappy	Slightly Calm	Slightly In Control
Monetary Punishment	Quite Unhappy	Slightly Stimulated	Slightly Controlled
Social Punishment	Quite Unhappy	Slightly Stimulated	Slightly Controlled

Table A4.2: Overall mean SAM ratings for the different trial types in the MID/SID RT task.

In general, the SAM ratings indicate that participants do find the reward trials to elicit positive affective responses (happy), the punishment trials to elicit negative affective responses (unhappy) and the neutral trials to elicit neutral affective responses (neither happy nor unhappy) (see Figure). As shown in Figure, the social and monetary trials in each of the three conditions (reward, neutral and punishment) elicit similar overall levels of pleasure, arousal and dominance, indicating that they are comparable. That is, differences in participants' responses to these different trial types should be due to whether the trial is monetary or social, not to differences in pleasure, arousal or dominance responses associated elicited by the stimuli.

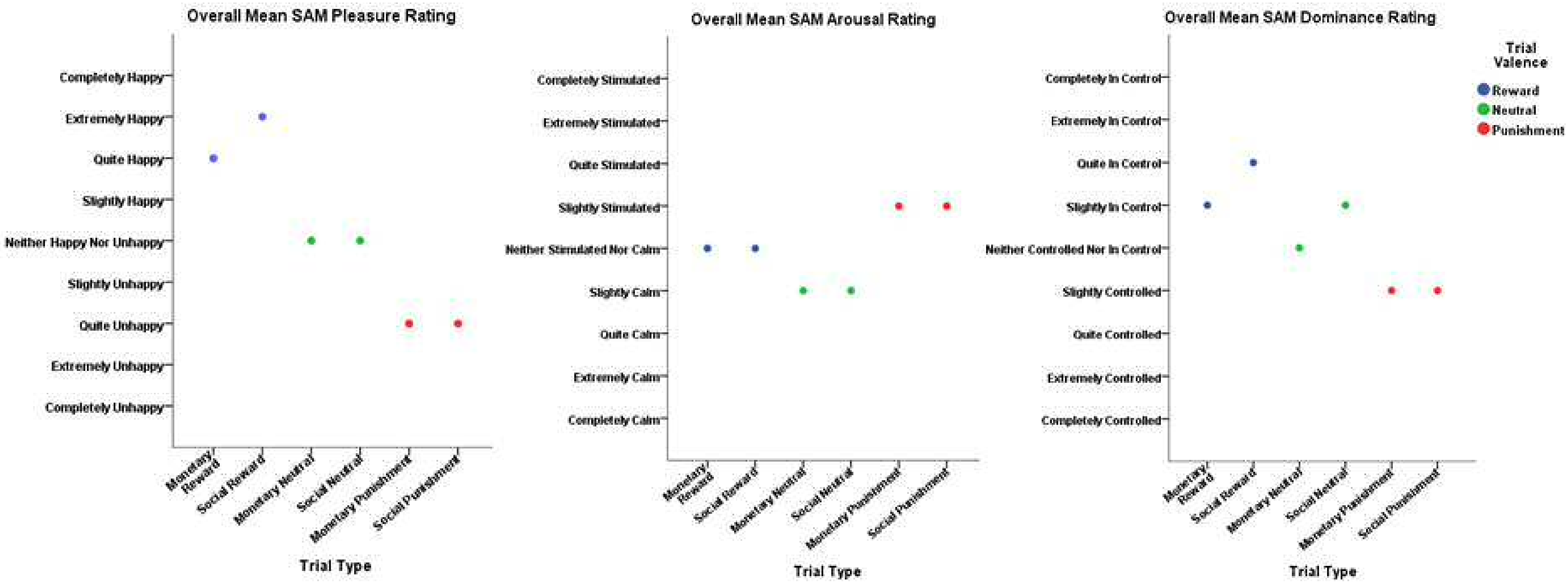

Figure A4.8: Overall mean SAM ratings, rounded to the nearest integer (rating) for the different trial types in the MID/SID RT task.

The full results of the pilot test of the auditory cues are shown in Table A4.3. In general, participants stated that auditory cues greatly increased the salience of the stimuli, but that the social sound stimuli, in particular the social reward sound stimuli, were unrealistic and distracting. Almost all participants stated that the money sounds were good as they were very obviously associated with reward and punishment. The feedback regarding the social sounds was generally that they were amusing and distracting, that they sounded a bit odd because they did not sound like audio cues relating to reward and punishment and were not realistic enough. In general, the participants did not associate the social stimulus sounds in this pilot study with reward and punishment audio cues.

Participant number	Feedback
1	Did not hear sounds
2	Improves - when just doing the task without the sounds, you could forget that you are actually being punished or rewarded because it just seems like a normal computer task but with the sounds, it really intensifies the feeling that you are being rewarded and punished.
3	Improves – although the social sounds did not seem to convey reward and punishment, they were a bit blasé.
4	Improves – did not really seem realistic that I was winning and losing money without the sounds.
5	Improves – definitely makes it more obvious.
6	Improves – the non-social sounds were amusing and so distracted from the stimulus but overall improved it.
7	Improves – made it more obvious when reward and punishment – especially negative money sound, which stood out a lot.
8	Improves - The sounds overall were really good and added to the experience of the stimulus. The non-social punishment sound was the most effective and stood out a lot more than the others in terms of salience.
9	Improves - Sounds were good for money but not good for faces, did not have the same impact as it did for the money, just sounded a bit odd and not like the sounds that people would do when being rewarded or punished.
10	Improves - sounds were good, social distracting as did not sound realistic and were a bit amusing, the money was good but overall improved.
11	Worsens – the sounds are distracting.

12	Improves - preferred the non-social to the social sounds but overall the sounds added to the experience
13	Worsens – the sounds are not realistic enough to add to the experience.
14	Improves - the social sounds were distracting but the money sounds worked really well. Overall, it improved the stimulus.
15	Improves - the female social sounds were really funny and did not really sound as if they were relating to a reward or punishment but overall it improved the task.
16	Improves - made it more realistic and intensified the stimulus
17	Improves – make it more salient, was getting a bit bored when it was just the visual stimulus, did not really affect how I felt.
18	Improves - the sounds were funny, especially for the social stimuli and so they did not work as well but the money ones really added to it. The sounds made sure you really understood whether it was a reward or a punishment.
19	Improves – just makes it more realistic and obvious.
20	Improves - sounds made it seem more realistic.
21	Did not hear sounds

A4.3 Pilot Study 2.1: Further development of the social stimuli

Because participants in Pilot Study 2 stated that the social reward auditory cues were unrealistic and distracting – but that overall auditory cues greatly increased the salience of the stimuli – it was decided that other, potentially more suitable sound stimuli would be tested.

A4.3.1 Methods

A4.3.1.1 Stimuli

These were the same as in Pilot Study 2, but the social reward cues were replaced by triumph/achievement sounds developed by Sauter & Scott (2007) (kindly provided by Sauter).

A4.3.1.2 Participants

Four of the participants who took part in Pilot Study 2 gave feedback on the new version of the stimuli with sounds, and how these compared to the same stimuli presented without sounds.

A4.3.1.3 Procedure

As in Pilot Study 2, each participant attended a testing session in the Psychology building at Cardiff University. Participants were shown a Cogent 2000 presentation of a sample selection of stimuli again, firstly without auditory cues, and then with the auditory cues. Participants were asked to provide verbal feedback on whether these improved, worsened, or made no difference to the salience and realism of the stimuli.

A4.3.2 Pilot Study 2.1 Results

All 4 participants stated that the auditory cues greatly increased the salience of the stimuli, and that they were sufficiently realistic.

A4.4 Discussion

The pilot testing reported here yielded a set of visual and auditory stimuli that most participants found to be salient and unambiguous social or monetary rewards, neutral outcomes or punishments. These were used to create the SMID task, as shown in Figure A4.9 and described in Chapter 6 of this thesis.

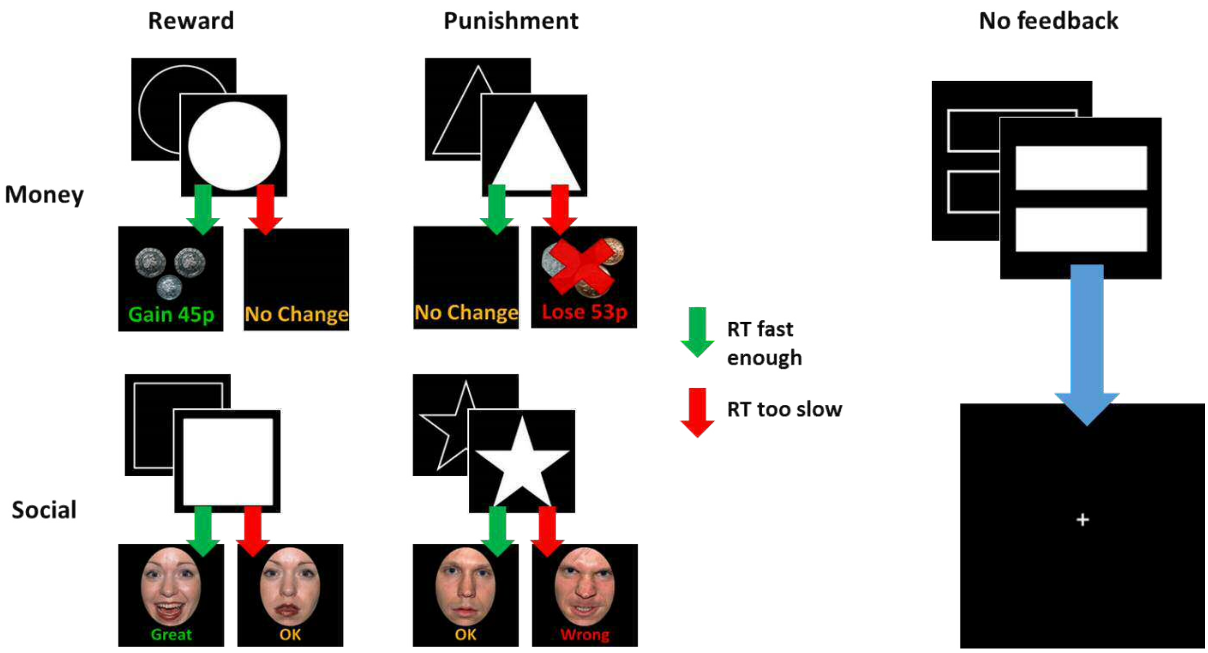

Figure A4.9: Experimental paradigm for the social and monetary incentive delay (SMID) reaction time task. Participants were instructed to hit a key (the space bar) as fast as possible when the cue (outline shape) turned white (target). The cue was presented for a variable duration; the cue durations were from randomly generated normal distributions in which the mean was 1000 msec and the standard deviation was 200 msecs.

Appendix 5.

Script for SMID task instructions

"It's a simple task, but there are a few different conditions – so I'll talk you through it first and then you'll do a practice session before the main task. So your basic task is that you'll see a series of shapes appear on the screen – these will be squares and triangles and things like that. First they'll appear as outlines of shapes, and then they'll turn solid white. Your task is to press the space bar as fast as you can when the shape turns solid white. So that's the basic task – it's very simple. But there are a few different conditions: there're reward conditions and punishment conditions. In the reward conditions, if you press the space bar fast enough, then you'll get a reward. In social reward conditions this is a positive face and a positive sound and a word like 'excellent' or something. In the money conditions it shows that you gain a small amount of money, which is added on to your overall total. In the reward conditions if you don't press the space bar fast enough, then you get a neutral outcome. Which is either a neutral face and sound in the social condition, or in the money condition you don't gain any money but you don't lose any either.

There are also punishment conditions: in these your aim is to avoid punishment. So in these conditions if you press the space bar fast enough, that's when you get a neutral outcome, and if you don't press the space bar fast enough, then you receive a punishment. Which is a negative face, a negative sound and a word like 'stupid' or something in the social condition. In the money condition you lose a small amount of money as punishment, which is subtracted from your overall earnings from the experiment – but not below £5.***Only say this if they're being paid for participating. Obviously if they're participating to earn course credits, don't say this.

So there are reward conditions and punishment conditions; social and monetary. But also randomly, throughout the task, no-feedback trials will pop up. And you'll know when it's a no-feedback trial because rather than the shape being a square or circle or whatever, it will be an equals sign. But it's exactly similar to the other trials: first you'll see a hollow equals sign and then it will turn solid white. You have to press the space bar as fast as you can when it turns solid white, but on these trials you don't get any feedback as to whether or not you pressed fast enough. It will just return to a blank screen with a cross in the middle and make some sort of random noise.

Is that OK? Are you ready to do a practice?"

****Run the practice session. Feel free to speak to them if they seem confused – the point of the practice is to make sure they're clear about the task. So remind them to press when the shape turns solid white if they prematurely press etc. And say "that's one of the no-feedback trials" when the first equals sign appears.

After the practice task end screen, when the screen remains black for a few seconds, start talking to them:

“Was that OK? Do you want another practice or are you ready to go on the main task?”

****If they want another practice let them, just make a note of it. But they hardly ever do! So to get going on the task:

“OK, so I’ll set you up for the main task now. It’s exactly similar to the practice, it’s just longer. There are 10 trials of each type in a row rather than 2, and the whole thing takes about 20 minutes. The amount of money you win and lose will be added to your total, but you can’t go below £5”. ***Again, only say this if they’re being paid for participating, not if they’re participating to earn course credits.

“If you occasionally slip and press the button too soon, don’t worry about it. But if you were to sit there going [mime pressing the space bar over and over repeatedly] the computer would decide that you’re cheating and stop the task. So only press when you see the shape turn solid white.”*** You can say this whenever it seems appropriate, e.g. if they do press prematurely during the practice you might want to say this directly after they’ve completed the practice.

****Set up for main task. Tell them where you’ll be when they’ve finished and wish them good luck as you leave the room.

****Task runs, they come and fetch you. Show them (highlight using the mouse) how much they earned. Then tell them there are a couple of final questionnaires:

“There are two very short final questionnaires for you to do and then I’ll pay you. One is the same as one of the questionnaires you did before; we’re just interested in before and after. It’s just in here

**Show them into where the post-task questionnaire’s ready and waiting on the computer, remind them to enter their participant number which is blu-tacked to the monitor

Appendix 6.

Post-SMID task questions probing affective responses to the task

Think about the computer-based task you completed a few minutes ago. Please answer the questions below by moving the slider to the postition on the scale that best represents how you felt during the task.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	
	0 10 20	30 40	50 60	70 80	90 100	
I enjoyed the task						0
I felt angry during the task						0
Participating in the task made me feel good about myself						2
Participating in the task made me feel insecure						0

Still thinking about the computer-based task you completed a few minutes ago, please indicate how motivated you were by the different types of outcomes by using the slider scale below.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	
	0 10 20	30 40	50 60	70 80	90 100	
I found the money rewards to be motivating						0
I found the social rewards to be motivating						0
I found the money punishments to be motivating						0
I found the social punishments to be motivating						0

Thinking about the social reward outcomes, please select the option below that best describes the facial expression of the faces shown

The presentation order of these three options was randomised.

- ◯ Joyful
- ◯ Happy
- ◯ Pleased
- ◯ Other (please specify)

Thinking about the social punishment outcomes, please select the option below that best describes the facial expression of the faces shown

The presentation order of these three options was randomised.

- ◯ Contemptuous
- ◯ Angry
- ◯ Disapproving
- ◯ Other (please specify)

Appendix 7.

Full correlations of post-SMID affect response questions with all other self-report variables and with SMID RT indices

To access this table in Excel format, please see the supplemental material that accompanies this thesis.

Appendix 8.

A preliminary study of the neural correlates of exposure to social and monetary incentives in the SMID task

The social and monetary incentive delay (SMID) task described in Chapter 6 of this thesis was designed such that it could be administered to participants in an MRI scanner. By having participants engage in this task during a functional neuroimaging experiment, neurobiological substrates of responses (reactions) to social reward and punishment can be probed. Behavioural, self-report and brain imaging data can then be examined to see if and how they relate to each other and to individual differences at other levels of the model proposed in this thesis, e.g. participants' dispositional social expectancies (LODESTARS scores). This approach has the potential to reveal a much deeper and more nuanced representation of the cognitive, affective and neural mechanisms underlying the experience of social reward and threat.

A pilot study was conducted in which 22 female participants were scanned using BOLD fMRI while engaging in the SMID task. As the full counterbalancing of the task stimuli and block presentation order requires 24 participants (or multiples thereof) it is not justified at this point to conduct analyses separately on social reward and punishment outcomes. However, within the pilot-study data that have been acquired, the stimuli and presentation order were counterbalanced at the level of monetary versus social conditions. This appendix therefore reports the results of some preliminary analyses conducted at this level. It is informative to compare brain responses to social and monetary outcomes presented within the same task, as it is currently unclear whether there exist systematic differences in the networks of brain regions that are recruited during the experience of valenced social versus non-social outcomes.

Previous studies have suggested considerable overlap for rewards, with both types of reinforcement associated with increased activity in ventromedial prefrontal cortex (vmPFC) and ventral striatum (Izuma et al., 2008; Lin et al., 2011). However, other researchers have suggested that the experience of social reward is partially mediated by regions of the brain that are perhaps specific to social cognition (that is, theory of mind regions; Krach, Paulus, Bodden, & Kircher, 2010). Less work has been conducted regarding the neural correlates of social punishment.

A8.1.1 Methods

Twenty-two healthy females (mean age 27.6 years, range 18-52 years) underwent fMRI while engaged in the social and monetary incentive delay (SMID) task described in Chapter 6 of this thesis. Each participant completed 240 trials of the SMID task across 2 runs (with a break of approximately 3 minutes in between). 80 trials involved monetary (mon) outcomes (gain, loss or no change) and 80 involved social (soc) feedback (positive, negative or neutral). Additionally 80 no feedback (nfb) trials were interspersed semi-randomly throughout the task. Forty of these appeared during social blocks and 40 during monetary blocks:

40 x monetary reward 40 x monetary punishment	mon
40 x social reward 40 x social punishment	soc
40 x 'monetary' no-feedback 40 x 'social' no-feedback	nfb

Blood-oxygenation level dependent (BOLD) fMRI data were acquired using a 3-T General Electric HDx MRI scanner at the Cardiff University Brain Research Imaging Centre (CUBRIC). Imaging data were pre-processed in FSL (Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012) and analysed using FEAT v5.98 (FMRIB expert analysis tool; www.fmrib.ox.ac.uk/fsl).

Average group statistical maps were generated using mixed effects higher-level analysis. A cluster-based correction of the z-statistic images was performed and thresholded at z scores > 2.3. For each resulting cluster of spatially connected voxels surviving the z threshold, a cluster probability threshold of $p < 0.05$ was applied, to correct for multiple comparisons.

A8.1.2 Results

Tables A8.1 – A8.6 show all activations that survived cluster level correction ($P<0.05$ FWE corrected; threshold of $z > 2.3$ [$p < 0.01$] used to define the clusters) for the following contrasts (all collapsed across reward and punishment trials):

1. mon > nfb
2. nfb > mon
3. soc > nfb
4. nfb > soc
5. mon > soc
6. soc > mon

For each cluster is shown: the coordinates of the maximum activation voxel in MNI space; the number of voxels; the maximum z-statistic (i.e. the value of the maximum activation or "intensity" within the cluster); and the p-value of the cluster after FWE correction.

Table A8.1: Contrast 1. mon > nfb

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Cerebellum and occipital lobe	R (but cluster extends bilaterally)	7.24	38	-76	-22	55774	<0.001
Insula	L	4.58	-38	16	-8	1102	<0.001
Precentral gyrus	L	3.49	-58	6	34	907	<0.001
Middle temporal gyrus	L	3.48	-68	-38	0	595	<0.001
Middle cingulate cortex	R	3.62	2	-26	30	449	<0.001

Table A8.2: Contrast 2. nfb > mon

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Postcentral gyrus (somatosensory cortex)	R (predominantly, but cluster does extend bilaterally)	4.45	32	-42	60	9059	<0.001
Insula	R	4.17	40	-18	12	1040	<0.001
Occipital lobe (middle occipital gyrus)	L	3.98	-34	-86	34	638	<0.001

Table A8.3: Contrast 3. soc > nfb

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Occipital lobe (V1)	R (but cluster extends bilaterally)	7.21	20	-102	2	166638	<0.001
Hippocampus	L	4.93	-20	-30	-10	7343	<0.001
Middle temporal gyrus	R	6.71	52	-32	-4	6514	<0.001
Superior medial gyrus (mPFC)	R	4.75	6	64	20	2888	<0.001
Hippocampus	R	4.89	22	-32	-6	358	<0.001

Table A8.4: Contrast 4. nfb > soc

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Precuneus, postcentral gyrus (somatosensory cortex), posterior cingulate cortex, inferior parietal cortex, cluster extends into middle frontal gyrus bilaterally, down into medial anterior occipital cortex bilaterally (calcarine gyrus), also thalamus bilaterally	R (but cluster extends bilaterally)	5.06	8	-56	54	28184	<0.001

A8.1.2.1 Overlapping responses (mon and soc versus no feedback)

Regions in which BOLD responses to both monetary and social outcomes were significantly greater than responses to no feedback outcomes can be seen in Fig. A8.1. Overlap was observed in the following areas:

- right superior mPFC (for soc > nfb only the cluster extends to left mPFC; however cluster in right mPFC is larger and extends into right ACC for mon > nfb only);
- bilateral inferior frontal gyrus;
- right middle temporal gyrus (some overlap on left as well, though cluster for soc > nfb, which is mirrored bilaterally, is much larger on left than is mon > nfb. Cluster for soc > nfb is a bit larger on the right as well, and extends further anteriorly);
- bilateral hippocampus,
- bilateral occipital cortex extending into cerebellum.

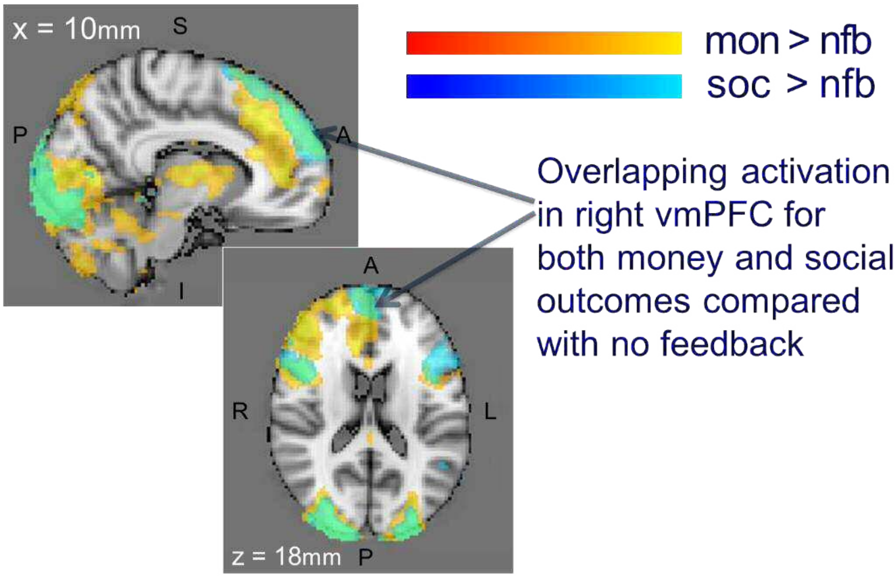

Figure A8.1: Overlay of mon > nfb and soc > nfb contrasts, showing regions in which BOLD responses to both monetary and social outcomes were significantly greater than responses to no feedback outcomes.

Regions in which BOLD responses to no feedback outcomes were significantly greater than responses to both monetary and social outcomes can be seen in Fig. A8.2. Overlap was observed in the following areas:

- right postcentral gyrus (somatosensory cortex);
- bilateral precuneus,
- bilateral posterior cingulate cortex (though posterior cingulate activation is more extensive for nfb > soc than for nfb > mon);
- bilateral medial anterior occipital cortex (calcarine gyrus);
- left middle occipital gyrus.

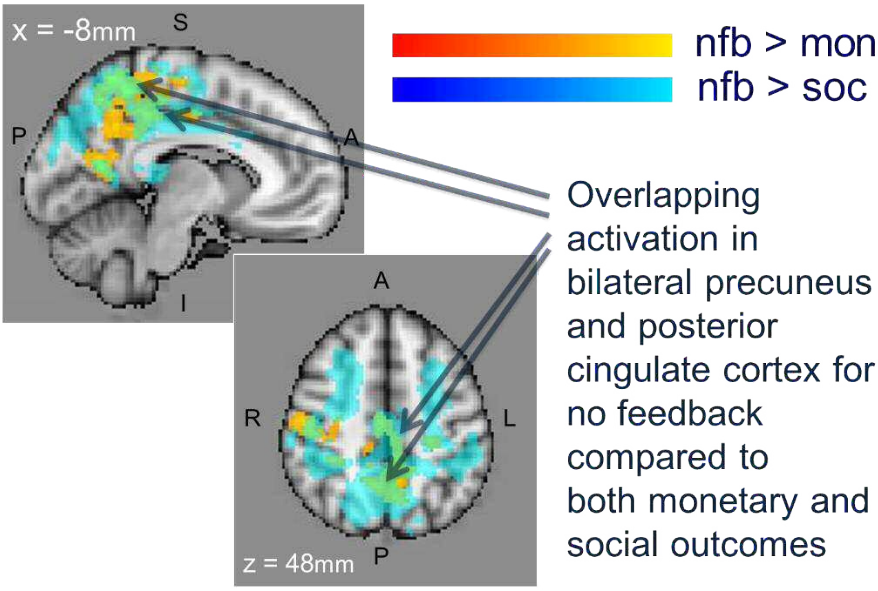

Figure A8.2: Overlay of nfb > mon and nfb > soc contrasts, showing regions in which BOLD responses to no feedback outcomes were significantly greater than responses to both monetary and social outcomes.

A8.1.2.2 Distinct responses to money outcomes (> social)

The brain regions in which BOLD was significantly greater in response to monetary outcomes compared with social feedback are summarised in Fig. A8.3. Full results are given in Table A8.5.

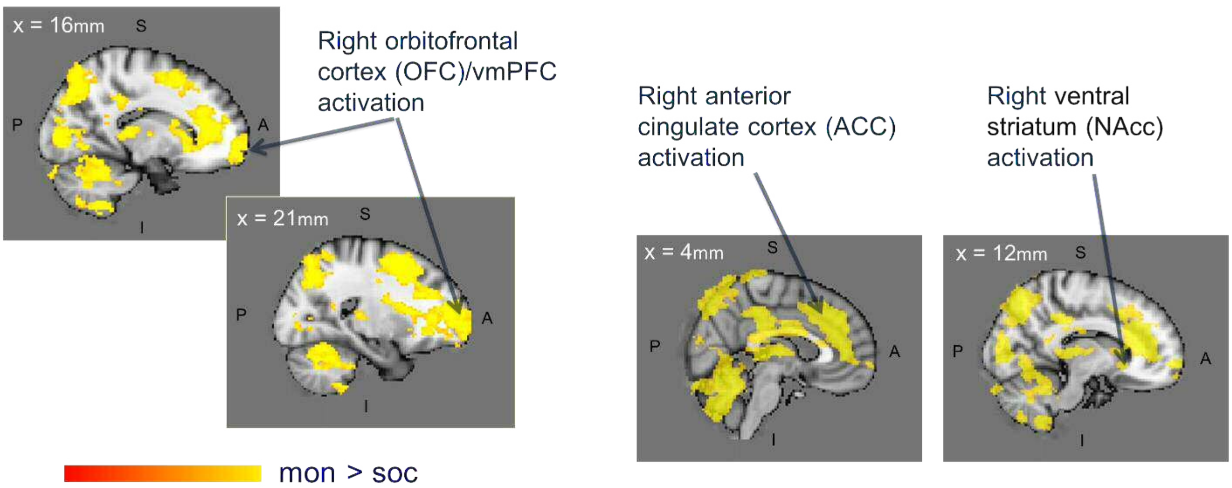

Figure A8.3: Results of contrast soc > mon, that is brain regions in which BOLD was significantly greater in response to social feedback compared with monetary outcomes.

Table A8.5: Contrast 5. mon > soc

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Inf. parietal lobule, supramarginal gyrus (NB extends back to just above temporoparietal junction but is superior to it)	R (but cluster extends bilaterally)	5.84	50	-46	48	28739	<0.001
Anterior cingulate cortex, prefrontal cortex (middle/lateral), ventral OFC, ventral striatum (NAcc)	R	5.41	4	32	36	14014	<0.001
Sup. frontal gyrus	L	3.76	-24	0	44	1302	<0.001
Inf. temporal gyrus	R	4.43	64	-32	-14	884	<0.001

A8.1.2.3 Distinct responses to social outcomes (> money)

The brain regions in which BOLD was significantly greater in response to social feedback compared with monetary outcomes are summarised in Fig. A8.4. Full results are given in Table A8.6.

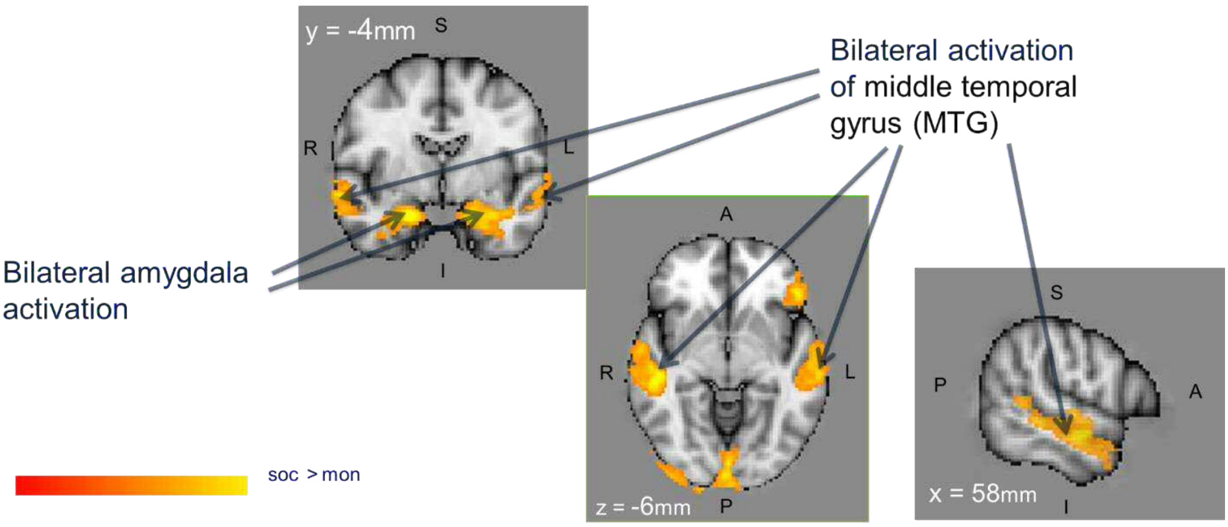

Figure A8.4: Results of contrast soc > mon, that is brain regions in which BOLD was significantly greater in response to social feedback compared with monetary outcomes.

Table A8.6: Contrast 6. soc > mon

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Amygdala & hippocampus, extending along the sup. temporal sulcus (predominantly middle temporal gyrus), possibly up as far as temporoparietal junction, though cluster ends very slightly too far inferior & anteriorly – but only by about 4 voxels). Also extends to the inf. frontal gyrus	L	5.44	-22	-10	-20	3601	<0.001
Amygdala & hippocampus, extending along the sup. temporal sulcus (predominantly middle temporal gyrus), possibly up as far as temporoparietal junction, though cluster ends a bit too far inferior & anteriorly)	R	5.51	20	-8	-24	2737	<0.001
Occipital cortex (V19)	R	5.37	10	-102	2	1927	<0.001

A8.1.3 Discussion

We observed greater activation of the middle temporal gyrus (MTG) and superior temporal sulcus (STS) during the experience of social, compared with money, outcomes. This is consistent with the results of many other previous brain imaging studies that have indicated involvement of this region in social perception. For example, this region is important for conscious explicit appraisal of socially important facial expressions (Critchley et al., 2000) and for binding this information with that from vocal modalities (Campanella & Belin, 2007).

Greater amygdala activation was also present during social, compared with monetary, outcomes. This is consistent with the role of the amygdala in automatic implicit appraisal of salient facial expressions (Critchley et al., 2000; Frith, 2007). The amygdala is also involved in the attachment of value (both positive and negative) to stimuli (Frith, 2007). While this would be expected to occur in both monetary and social conditions of the SMID task, the amygdala is thought to represent a 'hub' in several systems (including valuation) relating to social perception and cognition (Bickart, Dickerson, & Feldman Barrett, 2014). The salience of valenced social outcomes in provoking amygdala activity may therefore be stronger than that of monetary outcomes (Vrtička, 2012).

In the present study, money outcomes, compared to social, were more closely associated with activity in traditional valuation regions, such as the orbitofrontal cortex (OFC) and ventral striatum/nucleus accumbens (NAcc; Diekhof et al., 2012).

Greater BOLD activity in the precuneus and posterior cingulate was observed in response to no-feedback outcomes compared with both monetary and social outcomes. These regions are important components of the so-called default mode network, which activates 'by default' when participants are not involved in a task (Fransson & Marrelec, 2008).

A8.1.4 Implications

The present work demonstrates overlapping value-related responses during receipt of social and money outcomes in vmPFC, providing further evidence that this brain region is involved in signalling the value of outcomes, including social, irrespective of the nature of the reinforcer.

The differential activations for social versus money outcomes reported here suggest, however, that brain networks involved in processing these two types of outcomes may be more distinct than has previously been suggested (e.g. by Lin et al. 2011).

A8.2 Links between social feedback-related BOLD activation and motivation for social incentives and autism-like social traits

Thus far the analyses reported in this appendix have looked at group-level contrasts – i.e. do the brains of the participants activate on average in response to the stimulus contrasts (mon > soc etc.) specified at the first-level.

In this section, the role of individual differences is considered. Specifically, whether there are any observable additional effects of participants' relative motivations for monetary versus social outcomes, as indexed by their reaction times during the SMID, and their social characteristics, as measured by the broad autism phenotype questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007).

In previous work, emotional intelligence has been found to correlate positively with BOLD activity in the posterior part of the MTG/STS during social signals from voices and faces (Kreifelts, Ethofer, Huberle, Grodd, & Wildgruber, 2010). Such results suggest that this brain region may interface between social information perception and social cognition by interpreting the social significance of perceived stimuli.

I investigated whether social motivation and autistic-like social traits correlate with activation in response to self-relevant social feedback in the brain. It was hypothesised that activity in posterior MTG/STS would correlate negatively with autistic-like social traits, in line with the findings of Kreifelts et al. (2010).

A8.2.1 Methods

Relative motivational indices (RMIs) were calculated for each participant using their reaction times (RTs): RMI = RT_mon / RT_soc (ratio score).

Autism-like social traits were measured using the 'Aloof personality' and 'Pragmatic language problems' sub-scales of the broad autism phenotype questionnaire (BAPQ; Hurley et al., 2007):

- Aloof personality = a lack of interest in or enjoyment of social interaction.
- Pragmatic language problems = deficits in the social aspects of language, resulting in difficulties communicating effectively or in holding a fluid, reciprocal conversation.

These were combined to form BAPQ-Social, a procedure previously implemented by Sasson et al., 2013. Integrating the social and communication aspects of the BAP is also in line with the diagnostic criteria of ASD in the DSM-5, which conceptualises these domains as inseparable.

Covariate analyses (with BAPQ-Social, RMIs) were conducted on 2 of the 6 contrasts set up at first-level, namely:

mon > soc
soc > mon

For each the following covariate contrasts were run. After all thresholding, each of these were masked by C1 (group mean for the first-level contrast in question). Contrast masking by the mean effect limits results to only those regions with a significant mean activation.

BAPQ-Social
NEG_BAPQ-Social
RMI_overall
NEG_RMI_overall

The following F-tests were run. The F-tests were masked by C1 (group mean for the first-level contrast in question).

F-test_BAPQ+RMI
F-test_NEG_BAPQ+RMI

A8.2.2 Results

As predicted, responses to social feedback in posterior MTG/STS correlated negatively with BAPQ-social scores and positively with higher motivation for social compared to monetary outcomes, as indicated by faster reaction times during the task. These results are shown in Figs. A8.5 and A8.6, respectively. Full results of the covariate analyses are given in Tables A8.7 - A8.10. These tables show clusters within mon > soc and soc > mon activations in which the level of BOLD activation was significantly associated with BAPQ-Social or RMI_overall. All results that survived cluster level correction (P<0.05 FWE corrected; threshold of $z > 2.3$ [$p < 0.01$] used to define the clusters) are reported. For each cluster is shown: the coordinates of the maximum activation voxel in MNI space; the number of voxels; the maximum z-statistic (i.e. the value of the maximum activation or "intensity" within the cluster); and the p-value of the cluster after FWE correction.

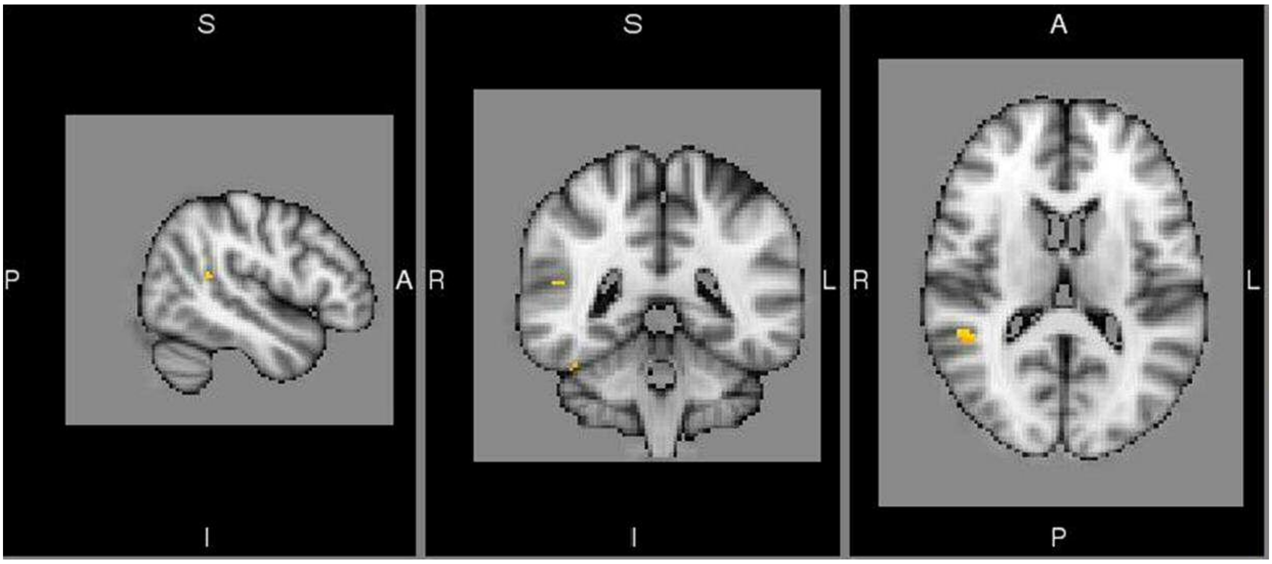

Figure A8.5: soc > mon, covariate RMI_overall. Higher RMIs (indicating greater relative motivation for social outcomes) are correlated with greater activation in right posterior MTG/STS in response to social feedback.

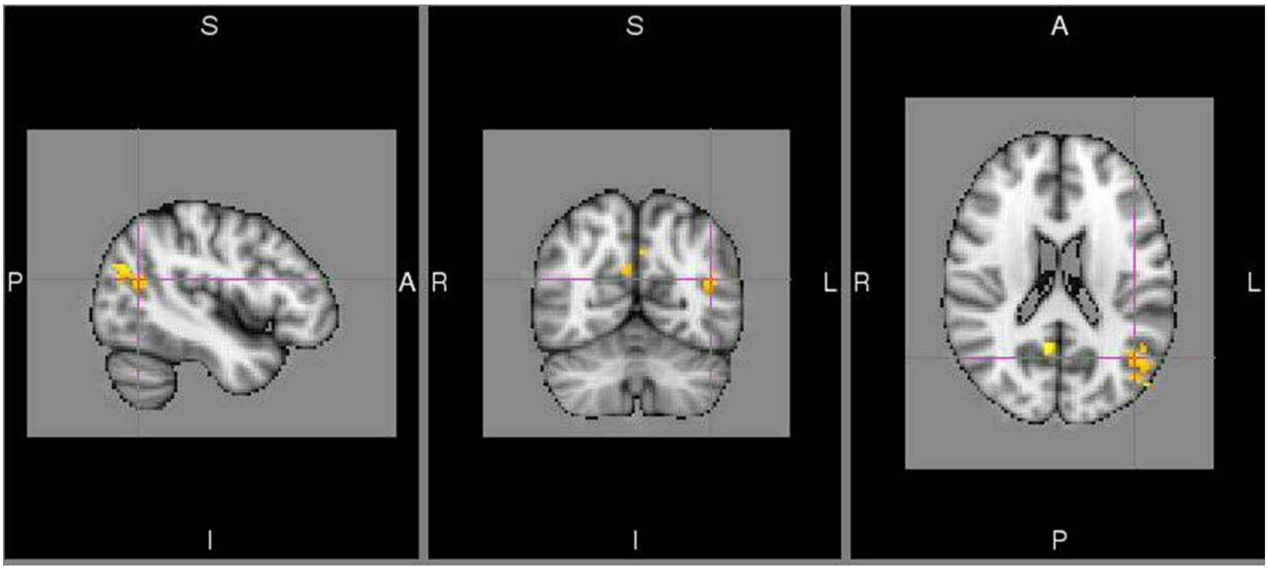

Figure A8.6: soc more_than mon, cov NEG_BAPQ-Social. Higher scores on BAPQ-social (indicating greater autistic-like social traits) correlated with lower activation in left posterior MTG/STS in response to social feedback

Table A8.7: Contrast 5. mon > soc, cov: BAPQ-Social

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
		4.94				329	<0.001
		3.92				198	<0.001
		3.62				157	<0.001
		3.95				136	<0.001
		3.74				109	<0.001
Posterior cingulate cortex	R	3.82	2	-44	38	49	<0.001
Angular gyrus (NB: involved in number processing)	L	3.18	-44	-62	46	46	<0.001
Inf. temporal gurus	L	3.47	-52	-44	-14	38	<0.001
		3.47				34	<0.001
		3.91				22	<0.001
		4.02				17	<0.001
		2.75				16	<0.001
		3.07				16	<0.001
		3.31				14	<0.001
OFC	R	3.09	10	60	-6	14	<0.001
		3.16				12	<0.001
		3.19				11	<0.001
		3.55				9	<0.001
Posterior cingulate cortex	R	3.34	8	-38	30	9	<0.001
		3.02				8	<0.001
		3.12				7	<0.001
		2.94				5	<0.001
		2.91				5	<0.001
		3.13				4	<0.001
		2.51				4	<0.001
		2.84				2	<0.001
		2.76				2	<0.001
		2.61				2	<0.001
OFC	R	2.73	12	64	-10	2	<0.001
		2.55				2	<0.001
		2.54				1	<0.001
		2.37				1	<0.001
		2.31				1	<0.001
		2.38				1	<0.001
		3.1				1	<0.001
		3.34				1	<0.001
		2.43				1	<0.001
		2.3				1	<0.001

Contrast 5. mon > soc, cov: NEG_BAPQ-Social: No significant activations

Contrast 5. mon > soc, cov: RMI_overall: No significant activations

Table A8.8: Contrast 5. mon > soc, cov: NEG_RMI_overall

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Cerebellum	R	4.05	18	-52	-28	2420	<0.001
Cerebellum	R	3.97	2	-66	-14	2420	<0.001
Cerebellum	L	3.88	-26	-58	-40	2420	<0.001
Cerebellum	R	3.84	10	-88	-22	2420	<0.001
Cerebellum	L	3.75	-2	-66	-42	2420	<0.001
Cerebellum	R	3.56	34	-40	-38	2420	<0.001
Caudate nucleus	L	3.91	-18	-8	18	78	<0.001
Precentral Gyrus, extending into IFG	L	3.85	-44	2	28	42	<0.001
Angular Gyrus	R	3.75	36	-54	24	231	<0.001
Supramarginal Gyrus	R	3.57	50	-40	40	231	<0.001
Cerebellum	L	3.54	-18	-46	-50	110	<0.001
Amygdala/thalamus	L	3.43	-10	-14	8	160	<0.001
Cerebellum	L	3.40	-36	-84	-28	74	<0.001
Precentral Gyrus	L	3.39	-36	-6	60	374	<0.001
SMA	L	3.11	-14	-4	52	374	<0.001
Middle Frontal Gyrus	L	3.08	-28	12	52	374	<0.001
Angular Gyrus/STG	R	3.21	54	-44	26	8	<0.001
white matter	R	3.13	28	-40	20	24	<0.001
SMA	L	3.02	-2	-6	54	22	<0.001
Cerebellum	L	2.84	-40	-78	-22	3	<0.001
Occipital cortex (linual gyrus)	R	2.81	20	-94	2	9	<0.001

Postcentral Gyrus	L	2.76	-44	-24	44	2	<0.001
Cerebellum	R	2.74	50	-64	-36	6	<0.001
Thalamus	R	2.73	20	-22	16	12	<0.001
Cerebellum	L	2.70	-38	-80	-24	1	<0.001
Occipital cortex	R	2.65	36	-66	6	8	<0.001
Occipital cortex	R	2.62	36	-64	22	2	<0.001
Cerebellum	R	2.60	6	-44	-20	1	<0.001
Occipital cortex	R	2.59	36	-74	2	2	<0.001
Cerebellum	L	2.55	-20	-96	-24	4	<0.001
Postcentral Gyrus	L	2.55	-42	-36	54	3	<0.001
Sup. occipital cortex	R	2.54	38	-64	32	3	<0.001
Occipital cortex	R	2.51	38	-76	4	2	<0.001
Brainstem (pons)	L	2.46	-6	-36	-30	1	<0.001
Occipital cortex	R	2.45	36	-60	28	2	<0.001
Cerebellum	R	2.43	8	-72	-32	1	<0.001
white matter	R	2.40	30	-36	12	1	<0.001
Cerebellum	L	2.37	-22	-84	-30	1	<0.001
Supramarginal Gyrus; STG	R	2.37	54	-38	20	1	<0.001
Brainstem (pons)	R	2.35	10	-26	-16	1	<0.001
Cerebellum	L	2.33	-32	-54	-42	1	<0.001
Cerebellum	R	2.31	2	-56	-42	1	<0.001
white matter	R	2.31	34	-48	12	1	<0.001

Contrast 6. soc > mon, cov: BAPQ-Social

No significant activations

Table A8.9: Contrast 6. soc > mon, cov: NEG_BAPQ-Social

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
Precuneus	L	4	0	-50	36	163	<0.001
Middle Temporal Gyrus (posterior)	L	3.97	-44	-62	20	126	<0.001
SMA	R	4	6	60	-10	89	<0.001
Precuneus	R	4.68	8	-56	20	88	<0.001
Sup. frontal gyrus	L	2.5	-16	46	42	2	<0.001
Middle Temporal Gyrus	L	2.55	-58	-26	-12	1	<0.001
Superior medial gyrus (mPFC)	R	2.32	6	48	6	1	<0.001

Table A8.10: Contrast 6. soc > mon, cov: RMI_overall

Brain area	L/R	Max z score	MNI Coordinates x	y	z	No. of voxels	Cluster p value
		3.43				41	<0.001
		3.44				26	<0.001
		3.52				24	<0.001
		3.76				15	<0.001
Sup. Temporal Gyrus	R	3.03	52	-42	14	12	<0.001
		2.64				8	<0.001
		3.22				3	<0.001
		2.82				2	<0.001
		2.97				2	<0.001
		2.62				1	<0.001
		2.34				1	<0.001

Contrast 6. soc > mon, cov: NEG_RMI_overall: No significant activations

A8.2.3 Discussion

Compared with monetary outcomes, social outcomes were associated with greater BOLD activity in brain regions linked to theory of mind and social information processing, including bilateral MTG/STS.

As predicted, responses to social feedback in posterior MTG/STS correlated negatively with BAPQ-social scores and positively with higher motivation for social compared to monetary outcomes, as indicated by faster reaction times during the task.

A8.3 <u>Brain structure analysis</u>

If the pMTG/STS serves a core function in social cognition and motivation, then trait-like individual differences in these, as measured by BAPQ-social, might be associated with variation in grey matter volumes in this region.

I investigated this hypothesis by means of voxel-based morphometry (VBM), a technique introduced in Chapter 3 and employed in Chapter 5 of this thesis.

A8.3.1 Results

After accounting for age, gender and intracranial volumes, significant negative associations were found between self-reported autism-related social traits and grey matter volumes in posterior MTG/STS ($p < 0.01$) bilaterally:

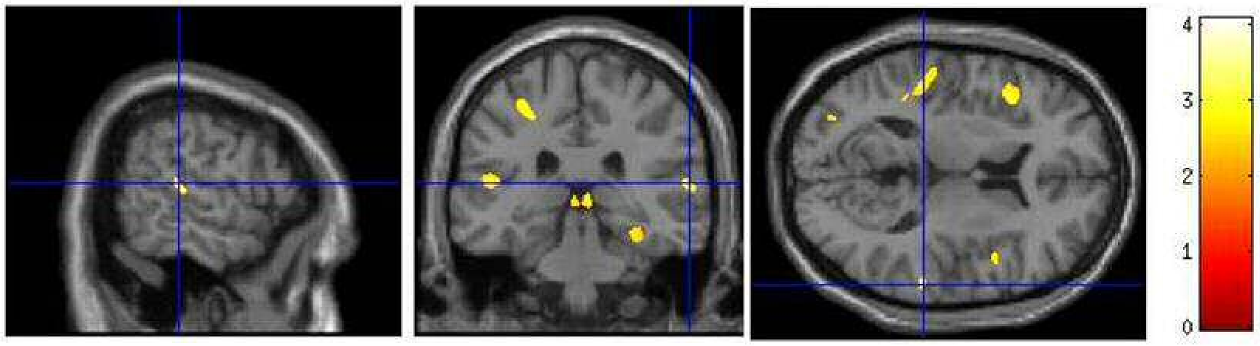

Figure A8.7: Higher scores on BAPQ-social (indicating greater autistic-like social traits) are associated with lower grey matter volumes in posterior MTG/STS

A8.4 <u>Conclusion</u>

Social outcomes in the SMID task were associated with greater activity in brain regions linked to theory of mind and social information processing, including bilateral MTG and STS, compared with monetary outcomes. Moreover, this activation in posterior regions of the MTG/STS correlated negatively with self-reported autistic-like social characteristics and positively with higher motivation for social compared to monetary outcomes as indicated by faster reaction times during the task. This suggests that greater motivation for social incentives and lower expression of autism-like social traits are linked with greater reactivity of the posterior MTG/STS (pMTG/STS) to social feedback.

Our results support the hypothesis that the pMTG/STS serves as an interface between perception of social information and social cognition. Our findings add to previous work by indicating that this region may also play a role in social motivation. The pMTG/STS may play a critical role in analysing socially relevant perceptual information, evaluating its implications and orienting attention accordingly, in line with the individual's present affective state and social goals.