THE INFLUENCE OF DIMENSIONAL PSYCHOPATHOLOGY ON SOCIAL REWARD PROCESSING

A Thesis Submitted for the Degree of Doctor of Philosophy

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July 2021

Thesis Abstract

Social reward processing is a key mechanism underpinning human social interaction. The feelings of reward attached to social interaction help to motivate future social behaviour and inform preferences for different types of social contact. As with other forms of reward, there is increasing evidence to suggest that psychopathology affects social reward processing, leading to the atypical interpersonal behaviour that defines some psychopathologies. This thesis, therefore, aimed to develop the findings of previous research and examined associations between social reward processing and dimensional psychopathology.

It addressed five research questions. (1) *Is atypical social reward processing a transdiagnostic characteristic of psychopathology?* To answer this question, a systematic review and meta-analysis of existing research investigating social reward processing in clinical versus healthy control groups was conducted (Chapter 3). (2) *Do clinical versus control group differences in social reward processing translate dimensionally within the normative population?* To probe this, associations between psychopathology and measures of social reward processing were investigated in a general population sample (n = 154; Chapter 4). (3) *Are dimensions of psychopathology differently related to the behavioural processing of various social reward subtypes (Admiration, Negative Social Potency, Passivity, Sociability)?* This was also examined in a general population sample (n = 42). (4) *Are these dimensional relationships detectable in forensic psychiatric service users?* This was explored in a pilot sample (n = 15) using the same approach as used in the general population sample (Chapter 6). (5) *How does intranasal oxytocin administration influence social reward processing in dimensional psychopathology?* This question was addressed using a within-subjects, placebo-controlled design (n = 17) with double-blind acute administration of oxytocin to healthy adults (Chapter 7).

The presented findings suggest that psychopathology is associated with atypical social reward processing. Reduced processing of social rewards linked to schizophrenia spectrum and autism spectrum dimensions was observed in multiple chapters, with several psychopathological dimensions also showing an increased preference for antisocial rewards involving witnessing or enacting cruelty to others. Furthermore, Chapters 3 and 4 demonstrated the potential utility of transdiagnostic approaches in social reward research and, collectively, the findings presented across this thesis highlight the importance of including social reward subtypes within characterisations of social reward processing. As such, these studies provide new insight into links between psychopathology and social reward processing and provide a theoretical and methodological foundation for larger work investigating social reward processing in psychopathology.

Acknowledgements

I would first like to thank Professor Veena Kumari. You have been an exceptional supervisor and I feel honoured to have worked with you. Thank you for sharing your expertise and enthusiasm for psychological science with me. I hope we have many more years of collaboration ahead of us. Second, thank you to Dr Jaap Munneke. Thank you for all your words of encouragement over the last three years and for your guidance in the analysis and write-up phases of this PhD project. I really appreciate it.

I have also received great support from many other experts throughout the course of my PhD. Thank you to Dr Ignazio Puzzo for your consistent support throughout the highs and lows of the last three years. I have learned a lot from you and look forward to seeing where our shared academic interests take us next. Dr Rachel Bennetts, thank you for always finding the time to meet with me to discuss my ideas and for sharing your love of data analysis approaches and psychology jargon (shout out psychopharmacogenetics). Dr Nicholas Stokes, I am grateful for your work facilitating data collection within the West London Forensic Service, and thank you to Dr Lucy Foulkes and Dr Hedwig Eisenbarth for your advice and guidance throughout the last three years.

I have been very lucky to complete my PhD alongside my doctoral colleague and office buddy (both in-person and online), Martina Vanova. Thank you for being motivated to make our PhD work the best it could be, and for being a great friend and colleague. I wish you all the best with the next steps in your career and please keep in touch.

I owe a lot to the many students who have helped me with data collection and participant recruitment, with special thanks to Leonie Elbers for your efforts during your time working as part of our team. Thanks also to the PGR team, Malcolm Overton, Ari Lingeswaran, and the many other academic, clinical, and technical staff who have contributed to this PhD project. Of course, a massive thank you must go to all the participants who took part in this research.

Outside of work, thank you to my amazing family and friends. Mum, Henry, Lydia – thank you all for always inspiring me and for always being there when I need you. It means so much. Dad, I know you are smiling down on us, and I am proud to be following in your footsteps as I move forward in my career in psychology. I am also lucky to have a cracking group of friends who never fail to entertain me – and I know the last three years would have been a lot harder without our socials and niche banter. Thank you all.

Table of Contents

Table of Tables

Table of Figures

List of Abbreviations

ACIPS	Anticipatory and Consummatory Interpersonal Pleasure Scale
ADHD	Attention-Deficit/Hyperactivity Disorder
ANOVA	Analysis of Variance
AQ	Autism Quotient
AQ-10	Autism Quotient 10 Item Version
ASD	Autism Spectrum Disorder
BIS/BAS	Behavioural Inhibition System/Behavioural Approach System
BPD	Borderline Personality Disorder
BPQ	Borderline Personality Questionnaire
bvftD	Behavioural Variant Frontotemporal Dementia
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
DASS-21	Depression, Anxiety and Stress Scale
DSM	Diagnostic and Statistical Manual of Mental Disorders
EEG	Electroencephalogram
EFA	Exploratory Factor Analysis
ERPs	Event-Related Potentials
fMRI	Functional Magnetic Resonance Imaging
HiTOP	Hierarchical Taxonomy of Psychopathology
ICD	International Classification of Diseases
IRAS	Integrated Research Application System
IU	Intranasal Unit
MDD	Major Depressive Disorder
MDMA	3,4-Methylenedioxymethamphetamine
MDMQ	Multidimensional Mood State Questionnaire
Ms	Milliseconds
MSIDT	Monetary and Social Incentive Delay Task
OFC	Orbitofrontal Cortex
O-Life	Oxford-Liverpool Inventory of Feelings and Experiences
PCL-R	Psychopathy Checklist - Revised
PHQ-9	Patient Health Questionnaire
PID-5	Personality Inventory for DSM-5
PTSD	Post-Traumatic Stress Disorder
RA	Response Accuracy
RDoC	Research Domain Criteria

RMSEA	Root Mean Square Error of Approximation
RT	Reaction Time
SAD	Social Anxiety Disorder
SD	Standard Deviation
SPIN	Social Phobia Inventory
SPQ-BR	Schizotypal Personality Questionnaire - Brief
SRP-4-SF	Self-Report Psychopathy Scale 4 Short Form
SRQ	Social Reward Questionnaire
SRS-IDT	Social Reward Subtype Incentive Delay Task
SSRI	Selective Serotonin Reuptake Inhibitors
TEPS	Temporal Experience of Pleasure Scale
TLI	Tucker–Lewis Index
vmPFC	Ventromedial Prefrontal Cortex
VTA	Ventral Tegmental Area

1. Introduction to Social Reward Processing and Psychopathology

1.1. Chapter Aims and Overview

The opportunity to obtain and experience rewards is a key motivational factor within human behaviour (McClure et al., 2004). This chapter first describes the psychological and neurobiological mechanisms involved in reward processing before focusing specifically on the reward value of social stimuli. It then introduces the subtypes of social reward described by Foulkes, Viding, et al. (2014) and outlines their subjective, behavioural, and neural correlates. The chapter then moves to define psychopathology, discuss recent approaches in its conceptualisation and assessment, before highlighting the interpersonal features of psychopathology which may be associated with atypical social reward processing.

1.2. Reward Processing Mechanisms

Rewards are defined as incentives that promote the initiation and maintenance of behaviour (Wise, 2002). The pursuit and achievement of rewards is associated with positive changes in affective experience, such as heightened feelings of pleasure (Berridge & Kringelbach, 2008), which increase the likelihood of a behaviour being repeated (Chau et al., 2004). The opportunity to obtain rewards is linked to increased motivation, and the availability of rewards is often key to the success of learning, reinforcement, and decision-making paradigms. Reward is a multidimensional construct that can be split into multiple classes, including primary rewards (sex, food; Noori et al., 2016) and secondary rewards (monetary, social; Rademacher et al., 2010).

Much research (e.g., Liu et al., 2011; Martins et al., 2021; Oldham et al., 2018; Wilson et al., 2018; Zald & Treadway, 2017) has focused on delineating the psychological and neurobiological mechanisms involved in reward processing. It is suggested that reward processing has two distinct and dissociated temporal phases (Dichter et al., 2012; Dillon et al., 2008; Smith et al., 2011), namely reward anticipation and reward consumption.

1.2.1. Reward Anticipation

Reward anticipation (also referred to as reward motivation or reward wanting; Oldham et al., 2018) is the first phase of reward processing, where the prospect of a reward is encountered and resources are allocated towards obtainment (Oldham et al., 2018). Reward anticipation can be assessed using self-report, behavioural, and/or neuroimaging methods. The anticipation domain of the Temporal Experience of Pleasure Scale (TEPS; Gard et al., 2006) assesses how much participants want and anticipate experiences that are considered pleasurable (e.g., *"when ordering something off the menu, I imagine how good it will taste"*) – with higher scores indicating increased reward anticipation. Although they are related, it is

important to note that the anticipation phase of reward processing is phenomenologically different to other similar constructs, such as approach motivation and BIS/BAS (Gray, 1981), as reward anticipation specifically concerns the pleasure experienced during the imagination and anticipation of a reward or stimulus (Berridge & Robinson, 2003). Several studies have shown that self-reported reward anticipation is associated with a range of individual difference characteristics, such as psychopathology (e.g., Loas et al., 2014; Mote et al., 2014).

Reward anticipation is often indexed behaviourally using incentive delay tasks. These tasks assess anticipatory reaction times and/or anticipatory response accuracy towards a salient cued target, with faster reaction times and greater response accuracy indicating increased reward anticipation. Previous work examining the behavioural bases of reward anticipation has found that behavioural anticipation is greater towards rewards versus non-rewards or neutral stimuli (e.g., Dillon et al., 2008) and, as with self-report assessments of reward anticipation, this is related to individual difference factors like psychopathology (e.g., Gu et al., 2017), gender (e.g., Spreckelmeyer et al., 2009), and age (e.g., Rademacher et al., 2013).

The neural correlates of reward anticipation were first described in Knutson et al. (2000; 2001). They found, relative to neutral stimuli, that monetary reward anticipation is associated with increased activation within the dorsal (caudate and putamen) and ventral (nucleus accumbens) regions of the striatum. Following the findings of Knutson et al. (2001), the neurobiological bases of reward anticipation has attracted significant research interest, with two large meta-analyses (Oldham et al., 2018; Wilson et al., 2018) showing that reward anticipation elicits increased activation within the ventral striatum, the salience network (including the anterior insula and anterior cingulate cortex), the ventral tegmental area, amygdala, and thalamus. Furthermore, Dichter, Damiano, et al. (2012) posit that dopaminergic activity within, and across, these areas (the mesolimbic pathway; Li et al., 2015) mediates reward anticipation. The degree to which these brain areas are activated during anticipation is modulated by the magnitude of the reward that is anticipated and the probability of obtaining it (Liu et al., 2011), as well as the individual difference factors listed above (e.g., Balodis & Potenza, 2016; Bjork et al., 2010; Veroude et al., 2016).

1.2.2. Reward Consumption

After the feelings of pleasure associated with the anticipation phase of reward processing, reward consumption is the second phase of reward processing and is characterised by the experience of pleasure and satisfaction during reward receipt. Whilst correlated with the anticipatory phase (Chan et al., 2012), the feelings of reward extracted during the

consumption phase are subjectively (Gard et al., 2006), behaviourally, and neurobiologically (Berridge et al., 2009) distinct from the anticipation phase. Subjective reward consumption can be assessed through self-report scales of reward consumption, such as the consummatory domain of the self-report TEPS (Gard et al., 2006) and the Fawcett-Clark Pleasure Scale (Fawcett, et al., 1983). These measures assess self-reported consumption of rewards by asking participants to rate the hedonic value of typically rewarding experiences (such as "*the smell of fresh grass is enjoyable to me*"). These scales positively correlate with openness and extraversion personality dimensions (Gard et al., 2006) and negatively correlate with traits associated with reduced reward processing, such as alexithymia (Yinghui et al., 2018).

As with the anticipation phase, the consumption phase of reward processing is measurable via behavioural and neuroimaging methods. Behaviourally, this often involves indicating the hedonic value of visual stimuli (e.g., Aharon et al.,.2001; Costa et al., 2010) or rating feelings of pleasure/enjoyment after receiving an anticipated reward (Chan et al., 2018; Peters & Büchel, 2010). The brain areas implicated in the reward consumption phase include the orbitofrontal cortex (OFC) and ventromedial prefrontal cortex (vmPFC) (Levy & Glimcher, 2012) which are described as responsible for the encoding and representation of reward values (Gläscher et al., 2009; Hiser & Koenigs, 2018). Furthermore, Oldham et al.'s (2018) meta-analyses found that increased OFC, vmPFC, and posterior cingulate cortex activity is observed in the reward consumption phase only (rather than in both the consumption and anticipation phase) which indicates a neural dissociation of both phases. Behavioural and neural responses during the reward consumption phase are adjusted depending on the mode and type of reward outcome, with more pronounced responses during consumption of unexpected rewards or rewards of larger magnitude (Diekhof et al., 2012).

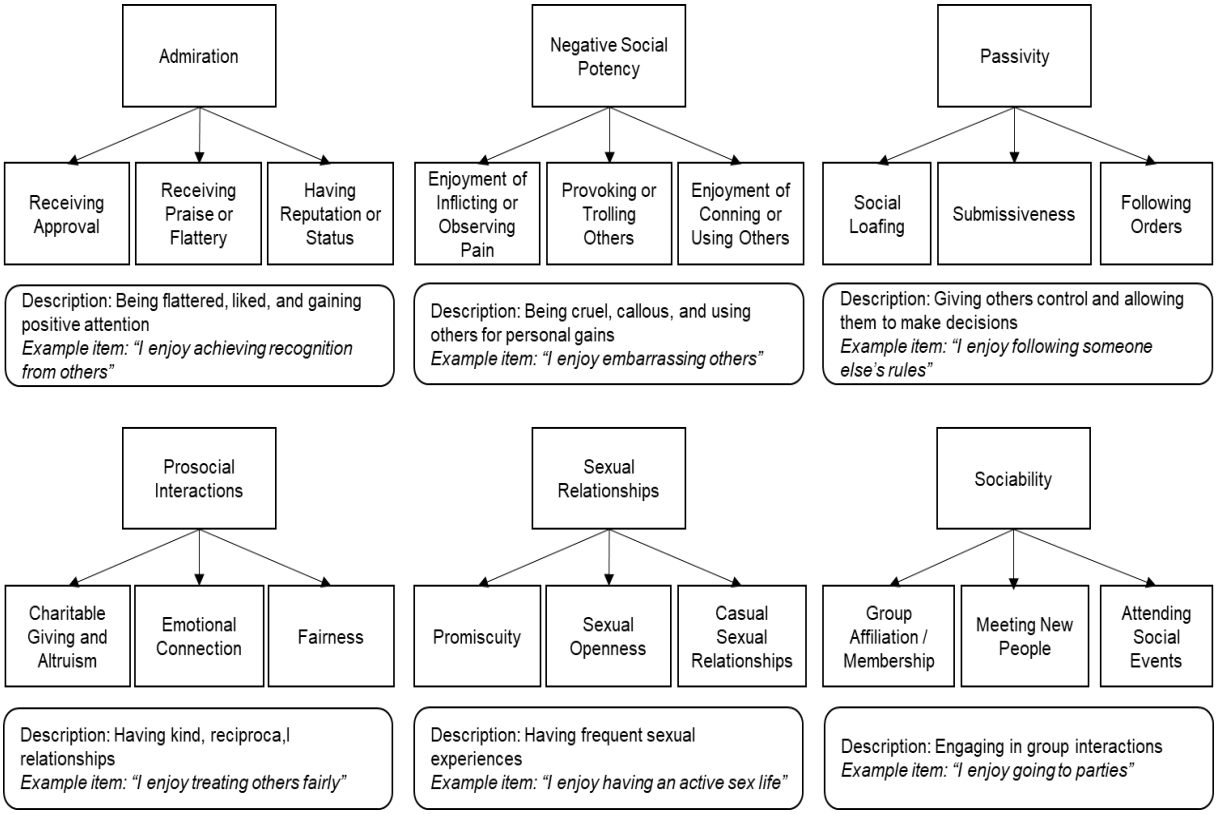
1.3. Social Reward Processing

Much of the evidence cited above is from research investigating the anticipation and consumption of monetary rewards or primary rewards (e.g., food). However, social rewards too have a meaningful impact on behaviour (Tamir & Hughes, 2018) and yet are comparatively under investigated (Ait Oumeziane et al., 2017; Fareri & Delgado, 2014; Fulford et al., 2018). A better understanding of the mechanisms involved in social reward processing will inform models of social motivation and interpersonal behaviour, with the potential to contribute knowledge on how social reward processing influences the atypical social behaviours that characterise various psychopathologies, such as social anhedonia (Barkus & Badcock, 2019). The influence of psychopathology on social reward processing is the focus of this thesis but, prior to examining relationships between psychopathology and

social reward processing (Chapter 3 onwards), it is important to clearly define social reward processing and its subjective, behavioural, and neural correlates.

In their classification of social reward, Foulkes, Viding, et al. (2014) define six subtypes of social reward: Admiration (receiving flattery and positive attention), Negative Social Potency (enjoyment of witnessing or causing cruelty to others), Passivity (letting others have control of a social interaction), Prosocial Interactions (mutual kind relationships), Sexual Relationships (frequent sexual experiences) and Sociability (being part of social situations). Their classification of social rewards is displayed in Figure 1.1.

Figure 1.1. Diagram of Social Reward Subtypes Defined by Foulkes, Viding, et al. (2014)



Their classification was developed following descriptions of the rewarding nature of human interaction (Buss, 1983) and the review of striatal activity during social behaviour given in Báez-Mendoza and Schultz (2013). Assessed using the Social Reward Questionnaire (Foulkes, Viding, et al., 2014), this classification of social rewards has good test-retest reliability and demonstrates good concurrent validity with other measures of social reward behaviour, such as the Interpersonal Goal Inventory (Dryer & Horowitz, 1997) and the Anticipatory and Consummatory Interpersonal Pleasure Scale (Gooding & Pflum, 2014). The coming section succinctly synthesises experimental evidence on the reward value of the six social reward subtypes and their features.

1.3.1. Admiration: Being Flattered, Liked, and Gaining Positive Attention

Receiving approval from others or being liked is a core feature of Admiration (Izuma et al., 2008). In an experimental context, this is increasingly illustrated through paradigms which mimic social media and the 'Liking' of photos. Sherman et al., (2016) explain that receiving a 'Like' is an inherently social experience and that a 'Like' is frequently used to indicate peer approval or endorsement (Hayes et al., 2016). As such, studying subjective, behavioural, and neural reward responses to 'Likes' enables researchers to investigate the reward value of social rewards involving Admiration and the receival of approval from others. In keeping with work illustrating the value of social rewards more generally (Gu et al., 2019), Ait Oumeziane et al. (2017) showed that social media 'Like' anticipation is associated with greater behavioural responses and event-related potentials (ERPs) than neutral stimuli anticipation. They also showed that 'Likes' and monetary rewards have similar anticipatory value, with these reward types eliciting similar ERP latencies and scalp topographies during the reward anticipation phase. In addition to increased anticipation, 'Likes' elicit reward network responses during the consumption phase, including increased bilateral nucleus accumbens activation when viewing photos of self with more 'Likes' in comparison to photos with less 'Likes' (Sherman et al., 2018). Moreover, achieving those 'Likes' is then associated with increased subjective feelings of reward and positive affect (Rosenthal-von der Pütten et al., 2019).

Receiving praise or flattery is another core feature of Admiration which, as a social reward, is often administered through positive visual or verbal feedback. Opportunities for praise produce similar anticipatory behavioural responses to monetary rewards (Wang et al., 2017, 2020) and receiving praise in a social context (via positive adjectives) elicits stronger hemodynamic responses in the brain areas implicated in reward consumption than neutral feedback or when praise is computer-generated (Schindler et al., 2019). At a subjective level, receiving a certificate of praise has been subjectively rated as more motivating/rewarding than receiving monetary rewards (Wang et al., 2017) and the subjective feelings of competence and positive affect that are associated with praise as a social reward reinforce its reward value (Dhillon, 2017). Some research (e.g., Foulkes & Blakemore, 2016; Wang et al., 2020) has identified that social rewards involving praise may be more meaningful for, and elicit greater subjective, behavioural, and neural responses in, children and adolescents in comparison to adults. Indeed, the Sensitivity to Threat and Affiliative Reward model (STAR) (Waller & Wagner, 2019) posits that sensitivity to social praise is heightened in adolescence (Altikulaç et al., 2019; Jarcho et al., 2012) and thus social rewards involving praise may be particularly salient for younger individuals.

Having a reputation is a third core feature of Admiration as a social reward (Izuma, 2012; Milinski, 2016). Reputation refers to a person's character as agreed or perceived by a social group (Jazaieri et al., 2019) and has implications for an individuals' social status and power (Hayes, Hogan & Emler, 2016). To examine the reward value of social rewards involving reputation, Wake and Izuma (2017) asked participants to view words or phrases that they believed were taken from others' impressions of them whilst undergoing functional magnetic resonance imaging (fMRI). Using correlation and classifier-based multivariate-pattern-analysis of the reward consumption phase, results revealed linear increases in left caudate nucleus activation in-line with increases in the magnitude of perceived reputation (none-low-high), in addition to significant correlations between neural responses towards reputation and monetary rewards (Wake & Izuma, 2017). Similarly, at a subjective level, Sebastian and Crossler (2019) attribute the risky sharing of photos on social media as an attempt to obtain a reputation and the positive subjective feelings of reward that follow. Following this assertion that risky social media use may in part be driven by a desire for reputation, Admiration scores on the Social Reward Questionnaire predict problematic (risky or addictive) social media behaviour (Meshi et al., 2020), indicating that obtaining a reputation may be a socially rewarding (and thus a socially motivating) experience.

1.3.2. Negative Social Potency: Being Cruel, Callous, and Using Others for Personal Gain

Although antisocial in nature, Negative Social Potency has the potential to be rewarding for some individuals (Buckels et al., 2013). Commonly referred to as everyday sadism (Buckels et al., 2013; Paulhus & Dutton, 2016), inflicting, observing, or initiating physical and psychological pain in others can lead to increases in subjective feelings of reward (Foulkes, 2019) that are reflected behaviourally and neurobiologically. Chester and DeWall (2016) measured proclivity for aggressive responding in healthy individuals by monitoring whether participants responded to provocation with aggression during fMRI. In keeping with the notion that Negative Social Potency can be rewarding, they found that, after provocation, nucleus accumbens activity significantly predicted the magnitude of participants' aggressive responses – which they interpreted as evidence of reward-related anticipation of inflicting pain in others. Similarly, at a self-report level, they found that sadistic traits positively correlated with subjective feelings of pleasure during the anticipation and consumption of administering pain to others (Chester et al., 2019).

Another feature of Negative Social Potency is being deliberately provocative or trolling. Like the explanation of everyday sadism given above, trolling is an online antisocial behaviour concerned with causing harm to others, characterised by attempts to start malicious arguments online and/or the posting of deliberately inflammatory or provocative content

(Sanfilippo et al., 2017). It has been suggested that practicing online trolling could be rewarding as 'trolls' enjoy anticipating and consuming the distress and outrage caused in their targeted online community (Owen et al., 2017). Indeed, the Negative Social potency subscale of the Social Reward Questionnaire (Foulkes, Viding, et al., 2014) positively correlates with self-reported tendency towards, and enjoyment of, internet trolling (March, 2019) and is more predictive of trolling behaviour than self-report measures of sadism and antisociality (Craker & March, 2016). Similarly, Buckels et al. (2019) showed that internet trolling tendency positively correlates with subjective feelings of pleasure experienced when viewing images of others in pain, which they interpreted as evidence that enjoyment of Negative Social Potency may increase inclinations towards internet trolling. Whilst still in its infancy (Marsh, 2019) and in combination with the research by Chester and DeWall (2016), work on the rewarding nature of internet trolling highlights that everyday antisocial, sadistic, or aggressive behaviour may have an anticipatory and consummatory reward value for some individuals.

1.3.3. Passivity: Giving Others Control and Allowing Them to Make Decisions

Passivity refers to extracting feelings of reward from situations in which others take the lead and assume control, with scores on the Passivity subscale of the Social Reward Questionnaire positively correlating with self-reported submissiveness (Foulkes, Viding, et al., 2014). In addition to submissiveness, a second feature of Passivity is social loafing or social free riding; as individuals may extract pleasure from others doing the work for them (Foulkes, McCrory, et al., 2014). The success of rewards in reducing social loafing at an organisational level has been demonstrated repeatedly (e.g., Pearsall et al., 2010) but whether social loafing, and Passivity more generally, is a rewarding experience in and of itself is yet to be specifically investigated empirically.

1.3.4. Prosocial Interactions: Having Kind, Reciprocal, Relationships

Prosocial Interactions are characterised by kind or helpful behaviours that have the intention of benefiting someone else rather than oneself (Lockwood et al., 2020). Prosocial Interactions can be rewarding for both the recipient and the person who performs the prosocial act (Aknin et al., 2018). Indeed, the warm-glow hypothesis of altruism (Andreoni, 1990) acknowledges that many altruistic behaviours are in part motivated by the feelings of reward associated with being altruistic (Zaki et al., 2016).

Charitable giving is a pertinent example of prosocial behaviour (Bhanji & Delgado, 2014). To establish the reward value of charitable giving, Cutler and Campbell-Meiklejohn (2019) conducted a meta-analyses of neuroimaging studies investigating the reward bases of altruistic (genuine) versus strategic (own benefit involved e.g., promotion) charitable giving.

They showed that, relative to not donating, both altruistic and strategic donating activated reward-related brain areas, illustrating the reward value of charitable giving. They also found that the vmPFC was involved in the delivery of both reward types, which fits with the description of the brain areas responsible reward consumption described above (Smith et al., 2011), but found that the subgenual anterior cingulate cortex was specifically implicated in the consumption of altruistic giving only. Lahvis (2016) argues that charitable giving is also a subjectively rewarding experience and that the anticipated feeling of pleasure following delivery of the reward is a key motivating factor within charitable giving.

Emotional closeness is a second key feature of Prosocial Interactions as a social reward. Using an affiliation task, Inagaki et al. (2016) showed that hemodynamic responses within the ventral striatum increase when viewing photos of emotionally close friends/relatives. Furthermore, in an ecological momentary assessment and reward fMRI study (Flores et al., 2018), individuals who demonstrated greater right posterior superior temporal sulcus/temporoparietal junction activity reported greater feelings of real-life emotional closeness to others, and simultaneously reported greater subjective feelings of current and expected future happiness (Flores et al., 2018). This shows that real-life emotional closeness and its subjective effect on wellbeing may be related to prosocial reward processes. This may also translate to the prosocial act of including others who were previously excluded. For example, as illustrated in a Cyberball task, including others who were previously being excluded activates brain areas that are associated with reward consumption, like the anterior medial prefrontal cortex and precuneus (Kawamichi et al., 2019; Van Der Meulen et al., 2016), indicating that including others may also have a prosocial rewarding effect. In combination, these examples illustrate the rewarding nature of emotional closeness as a feature of Prosocial Interactions.

Fairness is a key third feature of Prosocial Interactions. Current models of fairness propose that it involves the balancing of equity, compensation for effort, social good, and consequences for acting unfairly (Tabibnia & Lieberman, 2007). Experimentally, fairness is frequently assessed using exchange paradigms (such as the ultimatum game; Güth et al., 1982) in which participants must choose how different financial outcomes will be distributed between players, including fair and unfair offers. In such paradigms, fair offers are associated with increased reward processing, indicated by higher subjective feelings of happiness and increased activation within the ventral striatum and OFC (Tabibnia et al., 2008). Therefore, initiating and engaging in fairness may have a social reward value (Foulkes, 2015).

1.3.5. Sexual Relationships: Having Frequent Sexual Experiences

Research (Gola et al., 2016; Klein et al., 2020; Noori et al., 2016) has consistently shown that visual sexual stimuli elicit behavioural and neural (e.g., ventral striatum) responses that are consistent with increased reward processing. Of course, this is somewhat inevitable given that sex is a primary reward (Paredes, 2009). However, it is less clear how sexual relationships are rewarding within a social context. The Foulkes, Viding, et al. (2014) definition of Sexual Relationships includes having a casual attitude to sexual relationships that might include multiple partners, an open attitude to sex, and promiscuity. Investigating this experimentally, risky sexual behaviour in adolescence (like multiple lifetime sexual partners, first sexual experience prior to age 15) is associated with increased processing of social rewards at a neural level (Eckstrand et al., 2017). Similarly, Anders et al. (2020) examined the subjective reward value of casual sexual relationships through qualitative focus groups with college students. They showed that anticipatory and consummatory feelings of reward (interestingly including sense of status; see section on Admiration above) have a strong influence on motivation to engage in casual sexual relationships. Woerner and Abbey (2017) also showed that sexual assertiveness positively predicted self-reported sexual pleasure, which in turn was related to positive affect. Together, these examples show how greater anticipation and consumption of sexual rewards may lead to increased casual sexual behaviour and enjoyment of social rewards involving Sexual Relationships.

1.3.6. Sociability: Engaging in Group Interactions

Engaging in group social scenarios and participating in group events is rewarding for many individuals (Chevallier et al., 2012). Foulkes, Viding, et al. (2014) capture this enjoyment of group interaction within the Sociability subscale of the Social Reward Questionnaire. Scores on this subscale are positively correlated with personality measures of extraversion (Foulkes, Viding, et al., 2014; Foulkes & Blakemore, 2016) and those higher in extraversion rate real-life social interactions as more subjectively rewarding than those who are less extraverted (Duffy et al., 2018). This increased processing of reward during social interaction also translates to online behaviour, with higher scores on the Sociability subscale of the Social Reward Questionnaire positively correlating with self-reported amount of social media use (Meshi et al., 2020).

1.3.7. Considerations within this Definition of Social Rewards

The section above synthesised evidence for the reward value of the different social reward subtypes described by Foulkes, Viding, et al. (2014). Although they have been outlined separately, an important consideration is that there is likely to be some overlap between the interpersonal behaviours captured by each of the social reward subtypes, for example with

Prosocial Interactions and Sociability, which makes it difficult to precisely identify their independent reward values. This also applies to the features of each of the subtypes described above, such as praise versus reputation in Admiration. Therefore, whilst a comprehensive overview of the social reward subtypes has been offered, it could be important for future research to consider if the features of each of the reward subtypes, and the subtypes themselves, may co-vary or diverge at subjective, behavioural, and neural levels.

A second consideration, which has implications for understanding the psychological and neurobiological mechanisms involved in social reward processing, is that opportunities for monetary and social reward are likely to relate to one another (Saxe & Haushofer, 2008). For example, increased financial worth is likely to bring-in more opportunities for Admiration and status, whilst increased Sociability may lead to more opportunities for monetary gain. Finally, the reward value of the different subtypes is likely dependent on willingness to expend effort (for example with Prosocial Interactions; Lockwood et al., 2017) and may vary depending on culture or the receiving/giving of rewards between in-group and out-group (Hackel et al., 2017).

1.4. Section Summary

The research summarised thus far suggests that social interaction can be rewarding (Krach et al., 2010). The feelings of reward attached to social interaction are likely to vary depending on the type of social interaction available, with the Foulkes, Viding et al. (2014) classification suggesting six subtypes of social reward: Admiration, Negative Social Potency, Passivity, Prosocial Interactions, Sexual Relationships and Sociability. Furthermore, existing evidence suggests that the processing of these social reward subtypes is likely influenced by a range of individual difference factors, including age, gender, and psychopathology.

The coming section focuses on one of these individual difference factors, namely psychopathology, and summarises recent debate regarding its conceptualisation and measurement. This is with the aim of providing a foundation from which to investigate the core topic of this thesis: Social reward processing in dimensional psychopathology.

1.5. Psychopathology

Psychopathology is a heterogenous term typically used to describe alterations in mood, perception, cognition, or behaviour in the context of mental health experiences (Andersen & Bienvenu, 2011). However, in contrast to other psychiatric phraseology, such as mental disorder or abnormal psychology, use of the term ‘psychopathology’ acknowledges a continuum of mental health experiences, in which psychopathology can sometimes be

expressed in a non-dysfunctional or non-distressing way, perhaps more akin to personality than abnormality (Widiger et al., 1999). From a diagnostic perspective, all categories featured in the DSM-5 and ICD-11 fall under the broader category of psychopathology, which has led some (e.g., Caspi et al., 2014) to argue that the structure of all psychiatric categories could be captured in one general psychopathology factor – the 'p' factor (e.g., Allegrini et al., 2020; Gluschkoff et al., 2019; Levin-Aspenson et al., 2021).

The empirical chapters of this thesis will focus on five psychopathologies, namely schizophrenia spectrum traits, affective symptoms, psychopathic traits, borderline personality disorder traits, and autism spectrum disorder traits. The main dimensions and behavioural features of these psychopathologies are summarised in Table 1.1. The use of 'traits' and 'symptoms' reflects the dimensional approach which will be adopted throughout this thesis, which prioritises grading severity and complexity through continuum approaches rather than clinical cut-off scores (see section 1.5.1.). This thesis focuses on these five psychopathologies because their dimensions capture a range of interpersonal behaviours which might be associated with atypical social reward processing and, as psychopathological spectra, they encompass many of the traits/symptoms/behaviours which make-up current dimensional models of psychopathology (e.g., Michelini et al., 2021).

Table 1.1. Psychopathologies of Interest

Psychopathology	Dimensions	Behavioural Features
Schizophrenia Spectrum Traits	Cognitive-Perceptual	Ideas of Reference
		Suspiciousness
		Magical Thinking
		Unusual Perceptions
	Interpersonal	No Close Friends
		Constricted Affect
		Social Anxiety
	Disorganised	Eccentric Behaviour
		Odd Speech
Affective Symptoms	Depression	Lack of Meaning
		Low Self-Worth
		Less Experience of Positive Emotions
	Anxiety	Noticeable Physical Changes
		Difficulty Relaxing

	Stress	Heightened Emotional Arousal
	Social Phobia	Social Inadequacy
		Fragile Self-Esteem
		Physiological Experience
		Social Inferiority
		Avoidance of Attention to Oneself
Psychopathic Traits	Interpersonal	Deceitfulness
		Manipulativeness
		Grandiosity
	Affective	Callousness
		Enjoyment of Violence
		Shallow Affect
	Lifestyle	Sensation-Seeking
		Rebelliousness
		Risk-Taking
	Antisocial	Previous Criminal Behaviour
		Disregard for Social Norms
Borderline Personality Disorder Traits	Impulsivity	Lack of Premeditation
		Use to Excess
	Affective Instability	High Affect Intensity
		Rapid Mood Cycling
	Abandonment	Fear of Abandonment
		Belief in Abandonment
		Lonesomeness
	Relationships	Interpersonal Instability
		Disappointment
	Self-Image	Inferiority
		Self-Doubt
	Suicide/Self-Mutilation	Self-Harm
		Suicide Attempt(s)
	Emptiness	Lack of Current or Future Purpose
		Loneliness
	Intense Anger	Less Able to Control Anger
		High Reactivity

		Easily Angered
	Quasi-Psychotic States	Unusual Perceptual Experiences
		Magical Thinking
Autism Spectrum Disorder Traits	Social Skills	Less Enjoyment of Social Interaction
		Reduced Social Proficiency
		Preference Towards Non-Social Activities
	Details/Patterns	Routines and Repetitive Behaviours
		Attention to Detail and Patterns
	Communication/Mindreading	Difficulty Interpreting the Intentions of Others
		Difficulties with Imagination

1.5.1. Transition from Categorical to Dimensional Approaches

Categorical conceptualisations of psychopathology propose that different mental health diagnoses fall into distinct diagnostic categories based on diagnostic criteria. This approach will label an individual as having a diagnosis if a sufficient number of diagnostic criteria are met, and conversely no diagnosis will be given if insufficient criteria are met (Kraemer et al., 2004). In contrast to this taxonomic, cut-off-based approach, dimensional approaches posit that mental health experiences lie on a continuum, so that an individual might be assessed across several symptom or personality dimensions simultaneously (Simonsen, 2010). It is argued (e.g., Hudziak et al., 2007; Krueger et al., 2005) that viewing psychopathology dimensionally helps understand symptoms based on severity rather than presence/absence (Simonsen, 2010) and proponents of dimensionality argue that dimensional approaches are more psychometrically and quantitively comprehensive than traditional categorical approaches (e.g., Krueger & Piasecki, 2002; Markon et al., 2011). In addition to these measurement advances, the dimensional approach also prioritises framing mental health symptomatology within the context of individual differences and possible human experience, and thus may be less stigmatising than categorical perspectives which underline differences between people with and without mental illness (Buckwitz et al., 2020).

Whilst the debate between categorical and dimensional approaches has been ongoing for some time, the last decade has seen a tremendous shift away from categorical approaches towards dimensional approaches. Indeed, the latest diagnostic frameworks, the DSM-5 and ICD-11, both include dimensionality more than previous versions (e.g., Kreuger & Bezdjian, 2009; Lebeau et al., 2012; Möller, 2009; Narrow & Kuhl, 2011) and particularly within the personality disorder literature there is a growing transition towards dimensional approaches

through the Alternative Model of Personality Disorders (Krueger & Hobbs, 2020) and the PID-5 (Calvo et al., 2016). Chapters 4-7 of this thesis, therefore, contribute to this transition away from categorical approaches; they adopt a continuum view of psychopathology and assess dimensions of psychopathology via self-report measures. Each of the psychopathologies investigated in this thesis (schizophrenia spectrum traits, affective symptoms, psychopathic traits, borderline personality disorder traits, and autism spectrum disorder traits) are frequently conceptualised and assessed dimensionally within normative and clinical populations (e.g., Abu-Akel et al., 2019; Ahmed et al., 2011; Hopwood et al., 2018; Kwapil & Barrantes-Vidal, 2015; Sellbom et al., 2018), and their proposed dimensions are presented in Table 1.1.

1.5.2. Transdiagnostic Frameworks

The dimensional approach described above has recently been extended to include a transdiagnostic component. For example, several large consortium frameworks (e.g., HiTOP, Kotov et al., 2017; RDoC; Cuthbert, 2014) have been established with the aim of promoting the transition from traditional psychiatric nosology to structured dimensional transdiagnostic frameworks. These frameworks identify the traits, behaviours, and neurobiological correlates which cover multiple psychiatric categories, rather than studying psychiatric classes in isolation (Michelini et al., 2021). These transdiagnostic frameworks are growing in popularity, as both researchers and clinicians find their hierarchical structure useful when understanding symptom presentation and complexity (Michelini et al., 2021). Although not the core focus of this thesis, Chapters 3 and 4 include a transdiagnostic component which, with further investigation, might provide insight into the transdiagnostic nature of social reward processing in psychopathology. As such, dimensional approaches are being expanded to not only include continuum perspectives on clinical diagnoses, but also a transdiagnostic focus which explores how dimensions might cross-over traditional diagnostic boundaries (Forbes et al., 2016).

1.5.3. Clinical Implications of Dimensional Approach

In their recent review of dimensional models of psychopathology, Lahey et al. (2021) outline a series of advantages to applying a dimensional approach within clinical practice. They argue that adopting a dimensional approach makes clinical care more accessible: rather than requiring individuals to meet binary clinical thresholds to obtain help, dimensional approaches allow clinicians to identify sub-clinical psychopathology which might be linked to harm or distress, and thereby offer support to those who fall outside traditional diagnostic criteria (Lahey et al., 2021). Furthermore, as indicated above, dimensional models clarify complexity, as individuals seeking mental health support often present with symptoms and

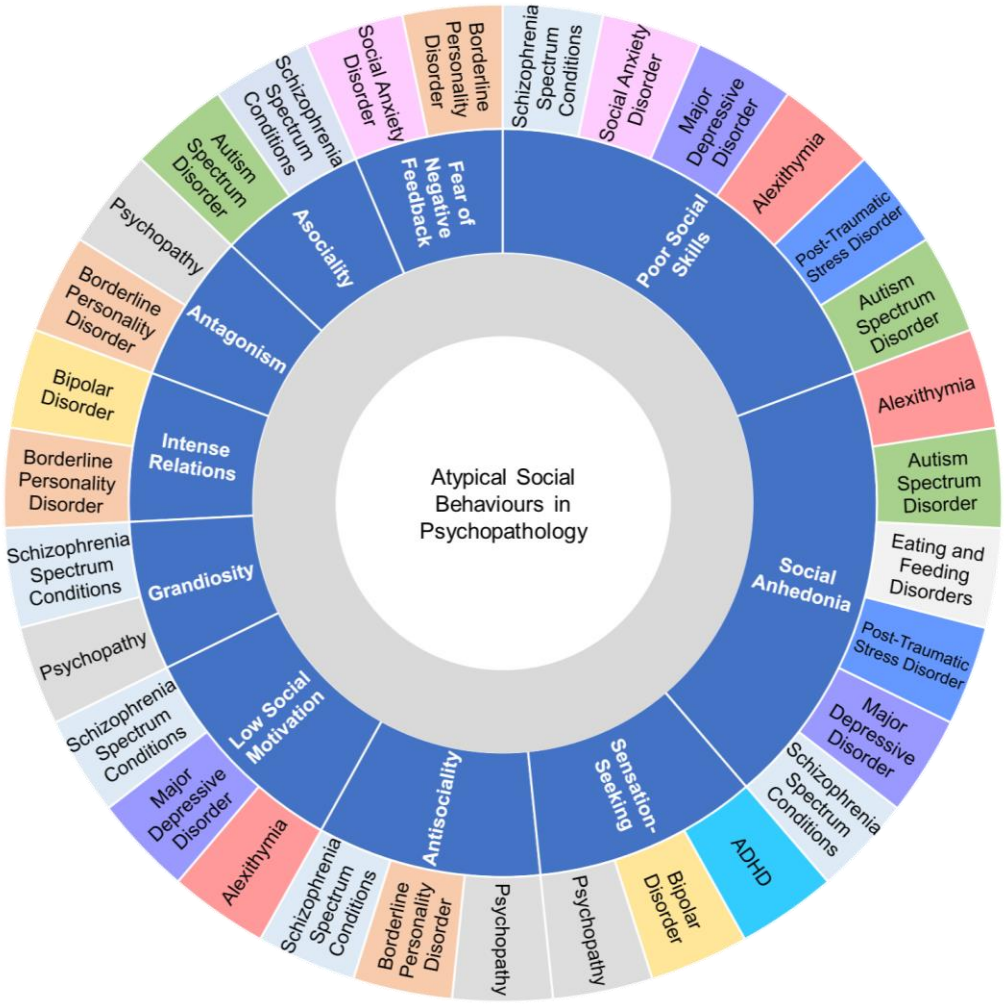
behaviours which might meet several diagnostic criteria – often referred to as comorbidity (First, 2005). Instead of viewing this co-occurrence of symptoms as comorbidity, Forbes et al. (2016) and Ruggero et al. (2019) explain that it is perhaps inevitable that multiple dimensions of psychopathology will be elevated simultaneously, and thus clinicians can garner a more holistic insight into symptom presentation (and potentially shared aetiology; Kendler et al., 2011) by adopting a dimensional approach.

Despite these advantages, the dimensional approach is not yet fully integrated within clinical practice. Some argue that clinicians are less familiar with dimensional models and thus might find them difficult to implement in practice without additional clinical expertise being developed or without simplification of current complex, psychometrically driven, dimensional models (e.g., Kraemer, 2007; Pilkonis et al., 2011; Zachar & First, 2015). Furthermore, others (e.g., First, 2005) suggest that adopting dimensional approaches will increase administrative load, as clinicians are required to tally multiple assessment tools and case-records. Finally, Cradock and Mynors-Wallis (2014) explain that categorical diagnoses serve multiple important functions which might be lost if replaced by a dimensional approach. They suggest that diagnoses help shape the clinician-patient interaction and provide the clinician with important guidance regarding potential treatment approaches and prognoses. They also argue that psychiatric diagnoses can often be helpful for patients – diagnosis might reassure the patient that their experiences are recognisable and treatable, for example. Integrating dimensional approaches within clinical practice might, for these reasons, not have a wholly positive effect on practitioner and patient experience of clinical care (First, 2005) and thus further clinical consultation is required before completely embedding dimensional approaches within clinical practice (Ruggero et al., 2019).

1.5.4. Atypical Interpersonal Behaviour in Psychopathology

The above discussion of dimensional approaches in psychopathology also has specific implications for understanding the interpersonal characteristics of psychopathology. As suggested in the final column of Table 1.1., several psychopathologies have behavioural features which might link to atypical social behaviour (Ethridge & Weinberg, 2018; Krach et al., 2010), and examples of such behaviour are presented in Figure 1.2. The figure was created for the purposes of this chapter and was informed by transdiagnostic conceptualisations of social behaviour in psychopathology given in Barkus and Badcock (2019) and Michelini et al. (2021). Figure 1.2. highlights that many of the atypical social behaviours which characterise psychopathology are observed across traditional diagnostic categories, and thus a dimensional approach is likely to be helpful in delineating associations between symptomatology and atypical social behaviour.

Figure 1.2. Atypical Social Behaviours in Psychopathology



Following Figure 1.2., this thesis aims to examine whether adjustments in social reward processing might contribute to these atypical social behaviours. To do so, Chapter 3 provides a comprehensive review of existing studies investigating social reward processing in clinical versus control groups, and then Chapters 4-7 adopt a dimensional approach and explore associations between self-reported dimensional psychopathology and social reward processing.

1.6. Chapter Summary

This chapter has summarised existing research on social reward processing. It has highlighted that reward processing is split into anticipatory and consummatory phases and has outlined the findings of previous research which has investigated these phases using self-report, behavioural, and neuroimaging methods. This chapter has explained the Foulkes, Viding, et al. (2014) definition of social reward and has discussed the reward value of each of the six social reward subtypes: Admiration, Negative Social Potency, Passivity,

Prosocial Interactions, Sexual Relationships, and Sociability. It has also provided an overview of current debates in psychopathology research and has introduced the notion that the interpersonal features of some psychopathologies may be associated with atypical social reward processing. The next chapter adopts the Foulkes, Viding, et al. (2014) definition of social reward and introduces the Social Reward Questionnaire as a self-report measure of social reward processing. It also provides a critique of current experimental measures of social reward processing and details the development of two novel tasks designed to measure social reward processing experimentally.

2. Assessing Social Reward Processing via Self-Report and Experimental Methods

2.1. Chapter Aims and Overview

The previous chapter highlighted that social reward is a multidimensional construct encompassing several subtypes of social interaction. It explained that the feelings of reward extracted from social scenarios are often dependent on the type of social interaction available and introduced the notion that atypical social behaviour in psychopathology may be associated with adjusted social reward processing mechanisms. This chapter applies the definition of social reward given in the previous chapter and provides an overview of existing self-report and experimental measures of social reward processing. This is with the aim of introducing the methodological approach that will be adopted throughout this thesis, including the development of the modified Monetary and Social Incentive Delay Task (MSIDT) and the Social Reward Subtype Incentive Delay Task (SRS-IDT). The chapter begins with a discussion of the Social Reward Questionnaire, before describing the format of existing experimental tasks, and finally the development of the modified MSIDT and SRS-IDT.

2.2. Self-Report Measures of Social Reward Processing

2.2.1. Social Reward Questionnaire

The Social Reward Questionnaire (SRQ; Foulkes, Viding, et al., 2014) assesses subjective processing of the social reward subtypes described in Chapter 1, section 1.3, page 17. It has 23 items, such as *"I enjoy treating others fairly"* and *"I enjoy going to parties",* which are rated on a seven-point Likert scale from 1 = Strongly disagree to 7 = Strongly agree. Scores are generated for each of the social reward subtypes (Admiration - 4 items, Negative Social Potency – 5 items, Passivity – 3 items, Prosocial Interactions - 5 items, Sexual Relationships – 3 items, Sociability – 3 items) with higher scores indicating greater hedonic experience. By assessing subjective processing of the different social reward subtypes, the SRQ provides a comprehensive insight into the different aspects of social interaction that individuals find rewarding.

All items on the SRQ begin with *"I enjoy"*, to ensure sure they capture the hedonic value of the social reward subtypes (Foulkes, Viding, et al., 2014). However, the questionnaire does not explicitly distinguish between anticipatory and consummatory phases of reward processing, with several of the items (e.g., *"I enjoy many people wanting to invite me to their social events"*) likely involving both an anticipatory and consummatory component.

The SRQ subscales – which assess the six subtypes of social reward - demonstrate good internal consistency (mean $\alpha = 0.82$, ± 0.04, range = 0.77-0.87) with acceptable

homogeneity (*M* = 0.56, ± 0.05, range = 0.51-0.65) (Foulkes, Viding et al., 2014). Furthermore, the SRQ has good construct validity, with SRQ scores correlating with a range of related measures, such as the Anticipatory and Consummatory Interpersonal Pleasure Scale (ACIPS; Gooding et al., 2015) and the Dark Tetrad (Craker & March, 2016). The items included in the SRQ have been translated and tested in Dutch (Altikulaç et al., 2019) and Iranian (Arab-Mohebi-Shahrabi et al., 2017) samples. There is also an adolescent version of the SRQ, the SRQ-A, which is like the SRQ but does not assess Sexual Relationships (Foulkes et al., 2017). The SRQ was used in this thesis, rather than the SRQ-A, as all sampled participants were over the age of eighteen.

The SRQ was thus selected because it is the most comprehensive self-report measure of social reward processing currently available. Indeed, the SRQ offers more of a nuanced assessment of subjective social reward processing than alternative measures, for example the ACIPS (Gooding & Pflum, 2014), Social Anhedonia Scale (SAS; Chapman et al.,1976), the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001). The SRQ specifically assesses the reward value of different types of social interaction, rather than collapsing across subtypes as per the ACIPS. It is also more specific to social reward processing than the SAS, which it includes items like "*People sometimes think that I am shy when I really just want to be left alone"* and "*My relationships with other people never get very intense"*, capturing multiple interpersonal factors rather than purely hedonic experience. Likewise, SHAPS and SPSRQ include some items relevant to the reward value of interpersonal behaviour (SHAPS: *"I would enjoy seeing other people's smiling faces"*; SPSRQ: *"When you are in a group, do you try to make your opinions the most intelligent or the funniest"*), but neither measure traditionally generates scores which capture social reward processing specifically. A final strength of the SRQ is that it is scored using Likert responses which provide a more dimensional insight into reward processes than dichotomous measures (such as SAS and SPSRQ).

Therefore, following this brief review of the few self-report measures of social reward processing that are currently available, it appears that the SRQ demonstrates good construct validity and reliability and, from a conceptual standpoint, is perhaps the most specific self-report assessment of social reward processing currently available. The SRQ thus has potential utility in identifying links between subjective social reward processing and dimensional psychopathology. The empirical investigations presented in Chapters 4 and 6 follow this assertion and explore associations between SRQ scores and dimensional psychopathology in normative and clinical samples.

2.3. Experimental Measures of Social Reward Processing

Having identified the SRQ as a suitable measure of subjective social reward processing, this chapter will now describe experimental paradigms which have previously been used to assess social reward processing.

2.3.1. Incentive Delay Task

2.3.1.1. Task Format

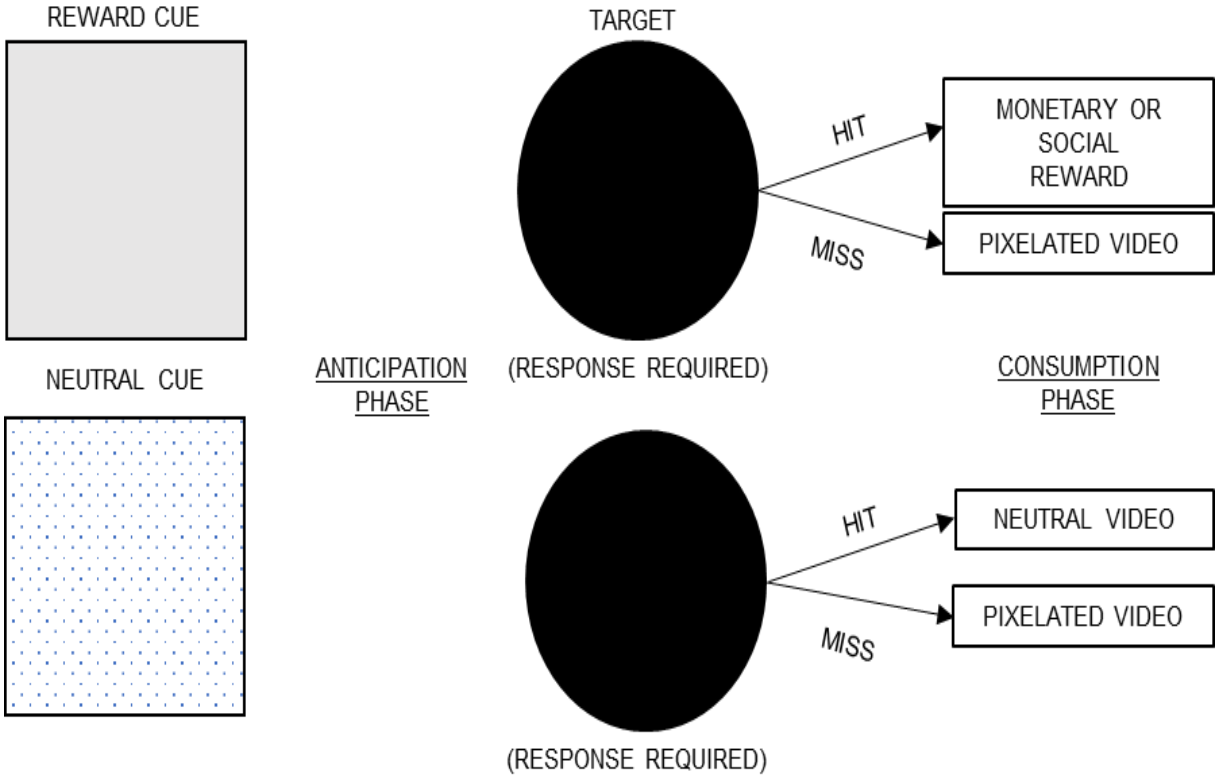
The incentive delay task was first outlined in Knutson et al. (2000; 2001) and is one of the more dominant experimental tasks used to measure behavioural and neural responses during reward processing (Oldham et al., 2018). The task presents participants with a cue, which indicates the type of reward that is available, followed by a target. The participant is required to respond to the target via a key press. The participant can obtain rewards during the task, depending on the speed and accuracy of their response towards the target. A diagram of the general format of the incentive delay task is provided in Figure 2.1.

The time-course of each trial in the original Knutson et al. (2000) incentive delay task was as follows: the cue (500ms), a jittered interstimulus interval (delay; 4000-4500ms), the target (variable; 160-260ms), and reward feedback (500ms) stating if money had been won and the participants' cumulative total of rewards won up to that point. In the Knutson et al. (2000) reward task, rewards ($1.00) were available on 20% of trials and achievement of the reward was dependent on the participant responding faster than the mean reaction time threshold that they set during the practice trials.

Since it was first published, the incentive delay task has been adapted to include multiple modifications, including:

i) Altering the probability of reward being available (e.g., Foulkes, McCrory, et al., 2014)
ii) Adjusting the magnitude of the available reward (e.g., Gola et al., 2017)
iii) Including images and videos as feedback rather than text (e.g., Gossen et al., 2014)
iv) Monitoring the reaction time threshold so that it changes dynamically on a trial-by-trail basis in response to participant performance (e.g., Buckholtz et al., 2010)
v) Including simultaneous reward-win and reward-lose trials (e.g., Perry et al., 2015)
vi) Using different stimulus presentation times (reviewed in Oldham et al., 2018).

Figure 2.1. Example Incentive Delay Task Format



2.3.1.2. Integrating Social Rewards

The incentive delay task has traditionally been used with monetary rewards but has been adapted (e.g., Rademacher et al., 2010) to also include social rewards. Within this, most paradigms employ blocked designs and collect data on monetary and social reward responses separately. Human faces are typically employed as social rewards (with positive facial expressions, like smiling or nodding) but others have also trialled indicators of social approval, such as a 'Like' (e.g., Sherman et al., 2016) or positive social adjectives displayed next to the face of the participant (e.g., Makowski et al., 2016).

2.3.2. Comparing the Social Incentive Delay Task with Similar Tasks

Brief descriptions of other formats of reward task that have been used to assess social reward processing experimentally are provided in Table 2.1.

Table 2.1. Alternative Social Reward Processing Tasks

Name	Format	Processing Phase	Example of Studies Used
Guessing Game	Participant is presented with two response options and	Anticipation Consumption	Ding et al. (2017)

	guesses which is correct to obtain reward		Stavropoulos & Carver (2014) Stavropoulos & Carver (2018)
Incentivised Go/No-Go	Same as incentive delay task but with added no-go cue to assess ability to withhold response to obtain reward	Anticipation Consumption	Demurie et al. (2016) Kohls et al. (2011) Pankert et al. (2014)
Learning Task	To obtain a reward this task requires the participant to learn associations between a cue and the correct response option	Anticipation Consumption	Hanssen et al. (2020) Lee et al. (2019) Scott-Van Zeeland et al. (2010)
Passive Viewing Task	Examines participant reward responses (often using fMRI) whilst viewing socially rewarding stimuli	Consumption	Pelletier-Baldelli et al. (2020) Sepeta et al. (2012) Sweitzer et al. (2018)
Trust Game	Participants interact with simulated social partners, with whom they exchange points	Anticipation Consumption	Campellone et al. (2016) Campellone et al. (2018)

There are several advantages to examining social reward processing using the incentive delay task in comparison to those included in Table 2.1. First, more complex social reward paradigms, such as learning or trust-based tasks, rely on multiple cognitive processes simultaneously which can make it difficult to parse social reward processing from more general cognition. In contrast, the incentive delay task does not rely on learning processes or decision-ability, and so minimises the risks of cognitive confounds (Knutson & Greer, 2008). Furthermore, in comparison to tasks where participants passively view social rewards (e.g., Pelletier-Baldelli et al., 2020), the incentive delay task includes clear reward anticipation and reward consumption phases (Oldham et al., 2018; Ait Oumeziane et al., 2017) which is useful in separating the behavioural and neural bases of the two phases. Finally, Haber and Knutson (2010) highlight that the incentive delay task is consistently effective and robust in eliciting striatal activation, a core part of the reward-circuit which can be difficult to measure via fMRI (O'Doherty, 2009).

2.3.3. Considerations within Existing Social Reward Tasks

The first important consideration within existing tasks is the ecological validity of the social rewards used. For example, whilst happy faces are an important social reward, the tendency to depend on them as a social reward could be problematic. Although happy facial stimuli may be indicative of positive social interaction, and thereby socially motivating, they may not fit precisely into one of the social reward subtypes described above. Instead, these emotional faces might cross-over several subtypes of social reward (e.g., Admiration, Prosocial Interactions, Sociability; see Chapter 1, section 1.3., page 17) and so there could be a need for an experimental social reward task that more closely examines the different subtypes of social reward (see section 2.4.2., page 40).

Second, a primary reason for examining social reward processing is to translate the findings to clinical populations who might demonstrate atypical social reward processing (Izuma et al., 2010). However, difficulties with emotion recognition characterise a range of psychopathologies, and so the use of emotional faces as social rewards (Guyer et al., 2007; Hoertnagl & Hofer, 2014) may not be entirely appropriate without accounting for any potential difficulties with emotion processing (Chevallier et al., 2012).

Finally, much of the research in this area has employed blocked designs where monetary and social rewards are presented separately. Whilst this maximises simplicity and power when modelling monetary versus social reward processing, a blocked design could be vulnerable to habituation and anticipation effects (Liu et al., 2001) which could negatively influence reward responses. There is, therefore, a need to trial intermixed stimuli designs within social reward processing tasks.

2.4. Developing New and Novel Behavioural Tasks to Assess Social Reward Processing

This evaluation of existing paradigms has highlighted some of the challenges associated with current experimental assessments of social reward processing. This thesis aims to respond to these challenges by developing two novel tasks designed to assess social reward processing behaviourally, namely the modified Monetary and Social Incentive Delay Task (MSIDT) and the Social Reward Subtype Incentive Delay Task (SRS-IDT).

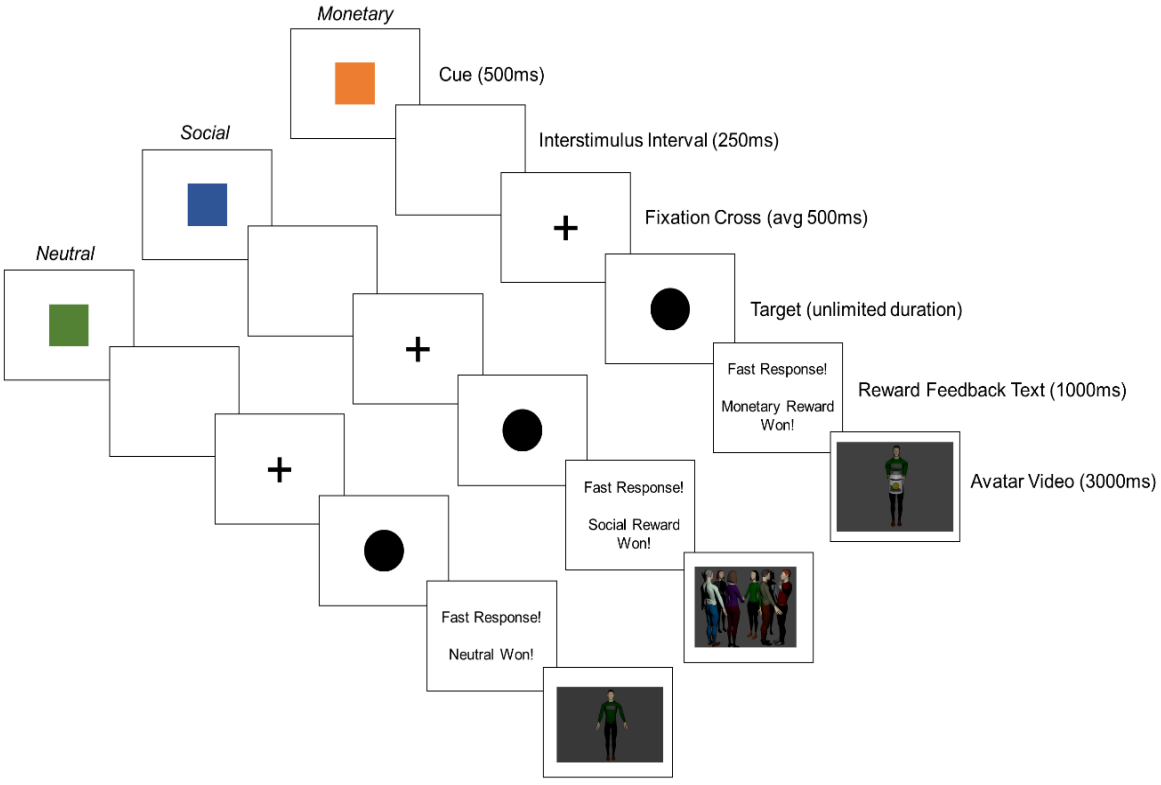
As described above, the incentive delay task has undergone many evolutions since first used in Knutson et al. (2000; 2001) – and this thesis continues this trend by making some important adjustments to the typical incentive delay format. From a theoretical standpoint, these adjustments have been informed by Fulford et al. (2018) and Matyjek et al. (2020), who recommend viewing social reward processing as a multi-faceted construct which captures several aspects of social interaction – rather than purely anticipation or

consumption of happy faces, for example. Thus, the two tasks used across this thesis (MSIDT and SRS-IDT) include novel avatar-based reward stimuli which are designed to represent the Foulkes, Viding et al. (2014) subtypes of social reward, and thereby provide a more multi-faceted assessment of social reward processing.

Furthermore, the previous chapter highlighted the atypical interpersonal behaviours which are sometimes associated with psychopathology. To explore whether these interpersonal behaviours are linked to atypical social reward processing, it is important to that the MSIDT and SRS-IDT i) represent the complexity of the social environment through interactive videos, rather than static stimuli (Fulford et al., 2018), ii) are engaging and accessible for clinical populations, and iii) assess processing of specific subtypes of social reward, rather than treating social reward as a singular construct. The development of the two tasks is detailed in sections 2.4.1. and 2.4.2., with the process of developing the reward stimuli explained in section 2.5.

2.4.1. Developing the modified Monetary and Social Incentive Delay Task

Figure 2.2. Format of Monetary and Social Incentive Delay Task



This version of the MSIDT was developed to assess behavioural processing of monetary and social rewards. It mirrors the task presented in Figure 2.1. by assessing reward anticipation following the presentation of a cued target, with faster RTs towards the target indicating greater reward processing. As shown in Figure 2.2., the task has a six-part

sequence with a 500ms intertrial interval: 1) cue (orange square = monetary trial; blue square = social trial; green square = neutral trial), 2) interstimulus interval, 3) fixation cross, 4) target (black circle), 5) written feedback, 6) reward video.

The task includes 12 trials per reward type (monetary, social, neutral) which are presented in a pseudorandomised sequence rather than in a blocked design (see above, page 37, for rationale for this). Like the original Knutson et al. (2000) task, participant task performance is calibrated with individual reaction time by calculating a reaction time threshold – an average of reaction times provided during the recorded practice trials. This follows other studies (e.g., Wang et al., 2017) which have set a bespoke reaction time threshold, rather than setting it trial-by-trial or at a precise value (e.g., 500ms; Demurie et al., 2011). Participants make all responses using the spacebar.

To address the issue raised above regarding the use of emotional faces as social rewards, avatar reward stimuli were developed for use in this task. Information on how the reward stimuli were developed and presented is included in section 2.5., page 41. All rewards are administered via video with a duration of 3000ms. Participants obtain the reward if they respond to the target within their individual reaction time threshold, and pixelated videos are shown following any misses.

All reward stimuli are hypothetical, with no real financial or social incentives included in the task. In keeping with other research comparing monetary and social reward responses (e.g., Rademacher et al., 2013), hypothetical rewards are used to make sure that the social and monetary rewards feel equally valuable to the participant. Whilst each participants' payment could be supplemented with their monetary earnings on the task, to find a social counterpart to this is more difficult (Foulkes, McCrory, et al., 2014).

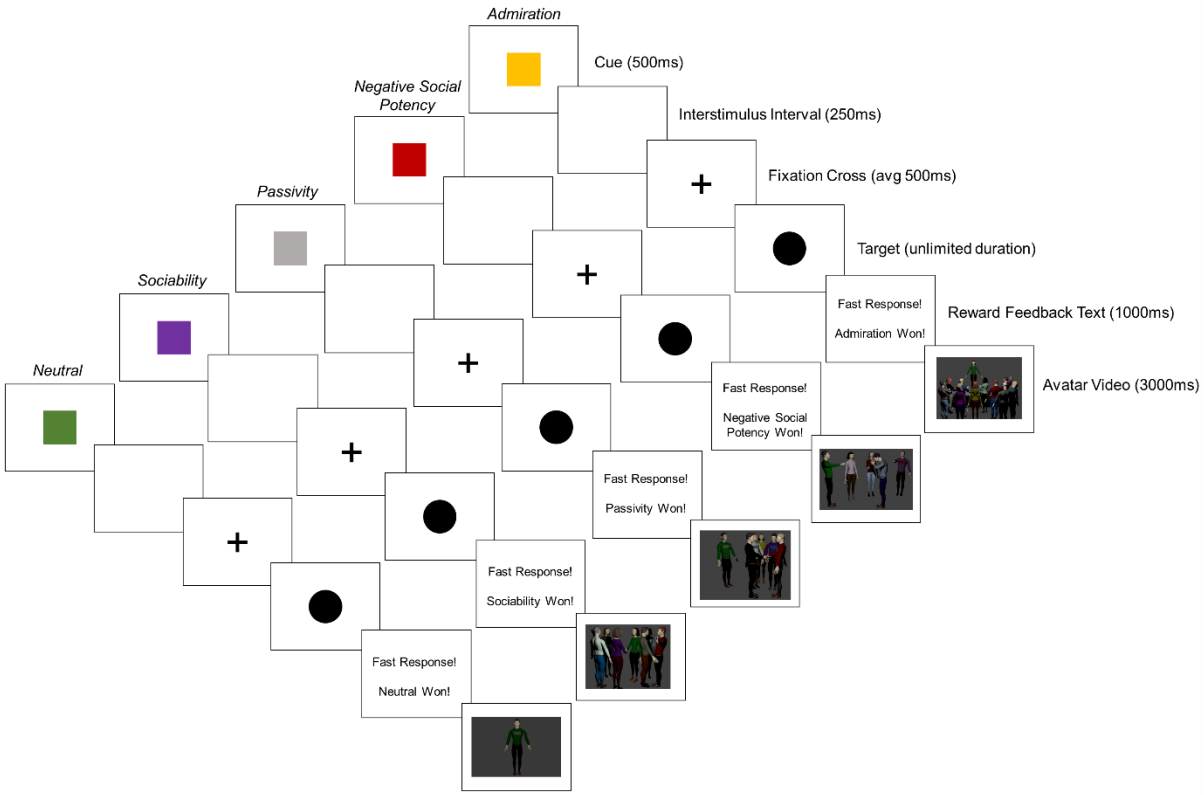
Except for the unlimited target duration, all stimuli presentation times used in this MSIDT are similar to other research examining social reward processing in psychopathology (e.g., Demurie et al., 2016; Gossen et al., 2014; Kohls et al., 2011). The target duration is set as unlimited to ensure that participant responses can be collected on all trials (having a fixed presentation time might mean that some participants provide no response on some trials) and to make the task accessible for clinical mental health populations who might exhibit psychomotor slowing as part of their illness (e.g., Morrens et al., 2007).

Full instructions are presented to the participant before the start of the first trial and all participants can practice the task before the recording of their reaction times.

2.4.2. Developing the Social Reward Subtype Incentive Delay Task

Following the MSIDT, the Social Reward Subtype Incentive Delay Task (SRS-IDT) was developed. The task was developed with the aim of providing a behavioural measure of the processing of the different social reward subtypes.

Figure 2.3. Format of Social Reward Subtype Incentive Delay Task



The format of the SRS-IDT is like the MSIDT, in that participants are required to respond as quickly as possible to a cued target. The task includes 12 trials per social reward subtype (Admiration, Negative Social Potency, Passivity, Sociability) and 12 neutral trials (72 trials in total – pseudorandomised). Like in the MSIDT, participants respond to the target (via key press) within their reaction time threshold to obtain the rewards. Again, the reaction time threshold is set using reaction times recorded during the practice trials. Pixelated stimuli are presented following any misses.

As presented in Figure 2.3., the SRS-IDT has a six-part sequence as per the MSIDT: 1) cue (500ms), 2) interstimulus interval (250ms), 3) fixation cross (jittered duration, average 500ms), 4) target (unlimited duration), 5) reward feedback text (1000ms), 6) reward feedback video (3000ms). A 500ms interval is inserted between trials. To ease accessibility and decrease working memory demands, the social reward subtype linked to the cue (e.g.,

Admiration) is also written on the cue. The stimuli presentation times are the same as the MSIDT to ensure consistency across tasks.

Full instructions are available to the participant prior to the start of the task, and they can first practice the task without their reaction times being recorded.

2.4.3. Piloting

Both tasks were piloted during development to ensure they provided a valid behavioural assessment of social reward processing. This piloting also helped to make sure that, from the participant perspective, the tasks were engaging and accessible. After examining the task set-up of previous studies using incentive delay paradigms (e.g., Knutson et al., 2001) the tasks were initially created with 24 trials per reward type (72 trials in total). However, given that the tasks were designed for use within mental health services, committee and service user feedback (as part of IRAS Ethics approval process; National Research Ethics Service) suggested that task durations should be shortened to make them feel more engaging and less time-consuming. Piloting the tasks revealed that reducing the tasks to 12 trials per reward type was still sufficient to detect reward versus neutral differences and mean accuracy rates of 64.39%. Therefore, the shortened versions of the tasks are employed in all subsequent studies.

Piloting the tasks also provided the opportunity to obtain spontaneous qualitative feedback from participants regarding the tasks. Participants reported that the tasks were engaging and that the stimuli were well-made, adding validity to the task development process. Indeed, pilot participant feedback highlighted that the modifications made to the tasks increased their engagement value and accessibility.

2.5. Creating the Reward Stimuli

Avatar videos (3000ms duration) were created to provide an engaging and more ecologically valid depiction of monetary and social reward scenarios. The reward stimuli were created and rendered using Blender® (Community, 2018) and were created for monetary, social, and neutral reward types. To account for the different social reward subtypes (Admiration, Negative Social Potency, Passivity, Prosocial Interactions, Sexual Relationships, Sociability; see Chapter 1 section 1.3., page 17), multiple social reward animations were created for all subtypes and then subsequently rated for relevance and identifiability.

The rating process was conducted via a panel meeting, which included two doctoral researchers, a research assistant, and two academic members of staff. Panel members watched the stimuli and were then asked to identify which of the Foulkes, Viding et al. (2014) subtypes were being represented by the stimuli and were asked to rate their relevance to the

Foulkes, Viding et al. (2014) definition. They were also asked an open question regarding their perspective on the stimuli and their accuracy. This process ensured that only stimuli which accurately represented the Foulkes, Viding et al. (2014) classification were included in the tasks. This process thus adds construct validity to the tasks as behavioural assessments of social reward processing, as the stimuli had to be judged to adequately represent the Foulkes, Viding et al. (2014) classification before being incorporated into the tasks. University and NHS ethics committees were also consulted during the stimuli development and rating process to ensure that the stimuli were being developed and selected appropriately within ethical guidelines.

Reward stimuli for four of the subtypes were selected following this process: Admiration, Negative Social Potency, Passivity, and Sociability. Prosocial Interactions and Sexual Relationships were not chosen for use.

Sexual Relationships stimuli were not used in the tasks as they were deemed inappropriate for use by the NHS ethics committee. As explained earlier, the tasks were developed for use within clinical settings (specifically forensic psychiatric services) and, given that many service users receiving care within these services have a complex sexual history – including sexual offending and/or sexual abuse – it was deemed not ethically justifiable to include the stimuli in this research. However, desire for, and initiation of, sexual interaction is of interest in psychopathology research, for example dating and sexual coercion research in psychopathy (e.g., Brazil & Forth., 2020; Harris et al., 2007). It is therefore important for future research to address this and develop stimuli to accurately (and ethically) assess the reward value of sexual relations in psychopathology.

Similarly, stimuli denoting Prosocial Interactions were not included in the tasks. This decision was made following the rating process, where Prosocial Interactions stimuli were rated as difficult to interpret and were frequently misidentified as Sociability by some panel members. Like with Sexual Relationships, it will therefore be important for future research to develop realistic simulations of Prosocial Interactions and, following the Foulkes, Viding et al. (2014) classification, these stimuli could portray actors/avatars engaging in warm, reciprocal, social interactions.

All stimuli were displayed via video and are accompanied by a corresponding sound. Information on the content of the reward stimuli is provided in Table 2.2. Example still images of the reward stimuli are displayed in Figure 2.4. All pixelated stimuli (presented following any misses) were generated in Blender® and accompanied by the sound of radio static.

All stimuli were rendered as 1920px X 1080px resolution with a frame rate of 24fps. The aspect ratio was the same for all stimuli. All stimuli were exported as .avi video files. The sounds accompanying the animations were downloaded from the collaborative database Freesound (www.freesound.org) under the creative commons license and then edited as required.

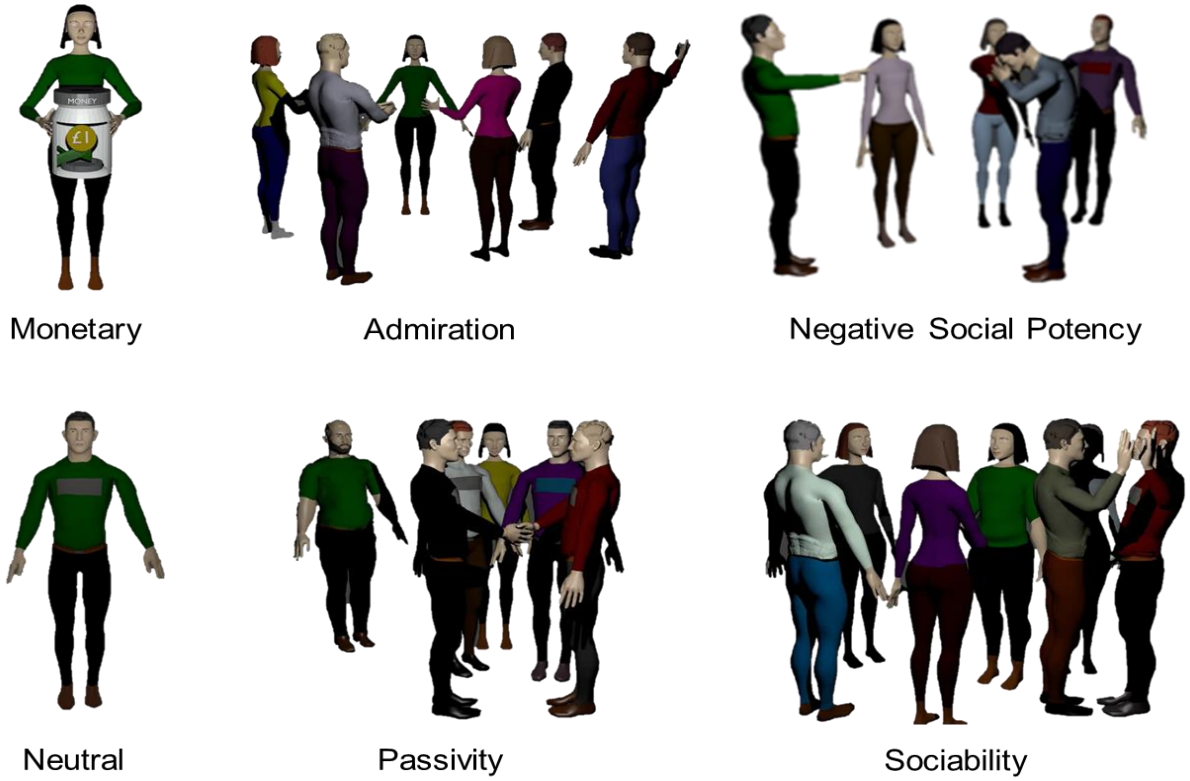
Table 2.2. Social Reward Stimuli Video Content

Reward Type	Animation	Sound
Social		
Admiration	Shows the participants' avatar as the centre of attention whilst receiving applause and recognition from other avatars	Accompanied by the sound of cheering and clapping
Negative Social Potency	Shows the participants' avatar bullying others by jeering and laughing whilst pointing at a crying avatar	Accompanied by the sound of laughter and soft crying
Passivity	Shows the participants' avatar on the peripheries of a social interaction, watching others take the control and the initiative	Accompanied by the sound of whispering, to give the impression the participants' avatar is not involved in the group interaction
Sociability	Shows the participants' avatar engaging in a large group social interaction	Accompanied by the sound of chatter and social activity
Monetary	Shows the participants' avatar receiving a large gold coin into a money jar	Accompanied by the sound of a cash register
Neutral	Shows the participants' avatar standing in the centre of the screen in a neutral stance	Accompanied by a neutral tone

Prior to completing the MSIDT or SRS-IDT, participants were asked to select an avatar from a choice of four (two male avatars and two female avatars, all dressed in green) and were told that they would have the opportunity to win rewards for that specific avatar. This was to try and encourage them to identify with the avatar as much as possible. Participants were

prompted to imagine the position of the avatar and were encouraged to win as many rewards for the avatar as possible.

Figure 2.4. Example Still Images of Reward Stimuli



2.6. Chapter Summary

This chapter has provided an overview of subjective and experimental measures of social reward processing. It has also introduced and justified the novel modifications that have been made to the standard incentive delay task to assess social reward processing experimentally through the MSIDT and SRS-IDT. Following these two introductory chapters, the next chapter focuses on social reward processing in psychopathology and presents the results of a systematic review and meta-analysis of existing studies investigating social reward anticipation in clinical versus healthy control groups.

3. Social Reward Processing in Psychopathology: Systematic Review and Meta-Analysis of Clinical and Control Group Differences

3.1. Chapter Aims and Overview

The description of social reward processing given in the previous two chapters highlights the multiple ways in which social interaction can be rewarding. However, if the mechanisms of reward processing are interrupted or adjusted, it could mean that social rewards are experienced in an atypical way, potentially leading to atypical interpersonal behaviour. Indeed, as described in Chapter 1, section 1.5.4., page 29, it is possible that atypical social reward processing may contribute to the maladaptive interpersonal behaviours that characterise a range of psychopathologies, such as social anhedonia, social withdrawal, or difficulty maintaining social relationships. This chapter focuses on the anticipation phase of social reward processing and provides systematic and meta-analytic evidence of atypical social reward processing as a transdiagnostic characteristic of psychopathology. The chapter begins with an introduction to reward processing in psychopathology, before detailing the results of the systematic review and meta-analysis. It finishes with a critical evaluation of current evidence and identifies directions for future research[1]. Although schizophrenia spectrum traits, affective symptoms, psychopathic traits, borderline personality disorder traits, and autism spectrum disorder traits are the main continua investigated across the course of this thesis, the review detailed in this chapter takes a broader approach and aims to provide a state-of-play review of the field by examining social reward processing across DSM-5 diagnostic categories.

3.2. Introduction

Atypical reward anticipation is a feature of many psychopathologies (Barkus & Badcock, 2019; Dichter, Damiano, et al., 2012; Hägele et al., 2015), with individuals diagnosed with schizophrenia (Gard et al., 2007), autism spectrum disorders (Kohls et al., 2011), and affective disorders (Olino et al., 2014) demonstrating reduced anticipation of monetary rewards at behavioural and neural levels. This reduced anticipation of rewards is also called hypoanticipation. Clinical conceptualisations suggest that this hypoanticipation of monetary rewards is linked to reduced approach motivation and less experience of feelings of pleasantness (e.g., Gard et al., 2007). Conversely, psychopathologies characterised by more impulsive, reckless, behaviours (such as antisocial personality disorder, attention-deficit/hyperactivity disorder) are associated with increased anticipation (hyperanticipation) of monetary rewards (Blair, 2010; Carré et al., 2013) – suggesting that hyperanticipation of

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monetary rewards may be linked to some elements of externalising symptomatology (Kohls, Peltzer, et al., 2009)

As highlighted above, mechanisms of non-social reward anticipation in different diagnostic groups are generally well investigated; with hypoanticipation as a characteristic of withdrawn or anhedonic psychopathologies, and hyperanticipation as a feature of illnesses with a prominent impulsive or novelty-seeking component. What is less understood, however, is whether this atypical reward anticipation translates to social rewards. In addition, whilst evidence of atypical reward processing has been found in different groups separately, minimal work to-date has taken a broader perspective and compared social reward anticipation across diagnoses. To this end, a more dimensional approach is needed whereby the links between social reward anticipation and shared continuous traits and symptoms (e.g., anhedonia, impulsivity) are examined across, rather than within, diagnostic groups.

3.3. Objectives of Review

This review had three objectives.

1. Investigate the extent to which atypical social reward anticipation is a feature of psychopathology when a clinical group is compared to a group of healthy controls.
2. Compare social reward anticipation across clinical groups and clarify whether atypical social reward anticipation is a transdiagnostic characteristic of psychopathology.
3. Consider the implications of atypical social reward anticipation for clinical practice and identify potential directions for future research.

3.4. Methods

3.4.1. Study Selection

A literature search was conducted using PubMed, PsychInfo, and Web of Science computerised literature databases. The search was conducted in February 2020. The search was focused on social reward anticipation in psychopathology, using 36 relevant search terms. Search terms were combined, and field-codes, MeSH terms, and wildcards were included, to increase the accuracy of the search. The full search strategy is given in the appendices (see Appendix 1, page 262). Research articles cited within each of the search results were also screened for relevance and included in the analysis if appropriate. Similarly, work that cited the searched articles was considered. A review of grey literature (via the Open Grey database) was also conducted but none of the material searched was

specific enough to the given research objectives and so no grey literature was included. The search was conducted in accordance with DSM-5 criteria, and so all diagnostic groups included in the DSM-5 were searched for. The full list of DSM-5 diagnostic chapters that informed the search is given in the appendices (see Appendix 1, page 262).

To be eligible for inclusion in this review, articles had to be focused on the anticipation phase of social reward processing, defined as wanting or seeking opportunities to obtain social rewards. Subjective, behavioural, and neuroimaging methods were all eligible for inclusion provided that social reward anticipation was included as a primary outcome measure. As explained in the previous chapter, the incentive delay task paradigm (Knutson et al., 2000) is the most dominant experimental method of assessing reward anticipation and so studies that included an incentive delay task paradigm with social rewards were searched first. An illustration of a standard incentive delay task paradigm with social rewards is given in the previous chapter (see Chapter 2, section 2.3.1., page 34).

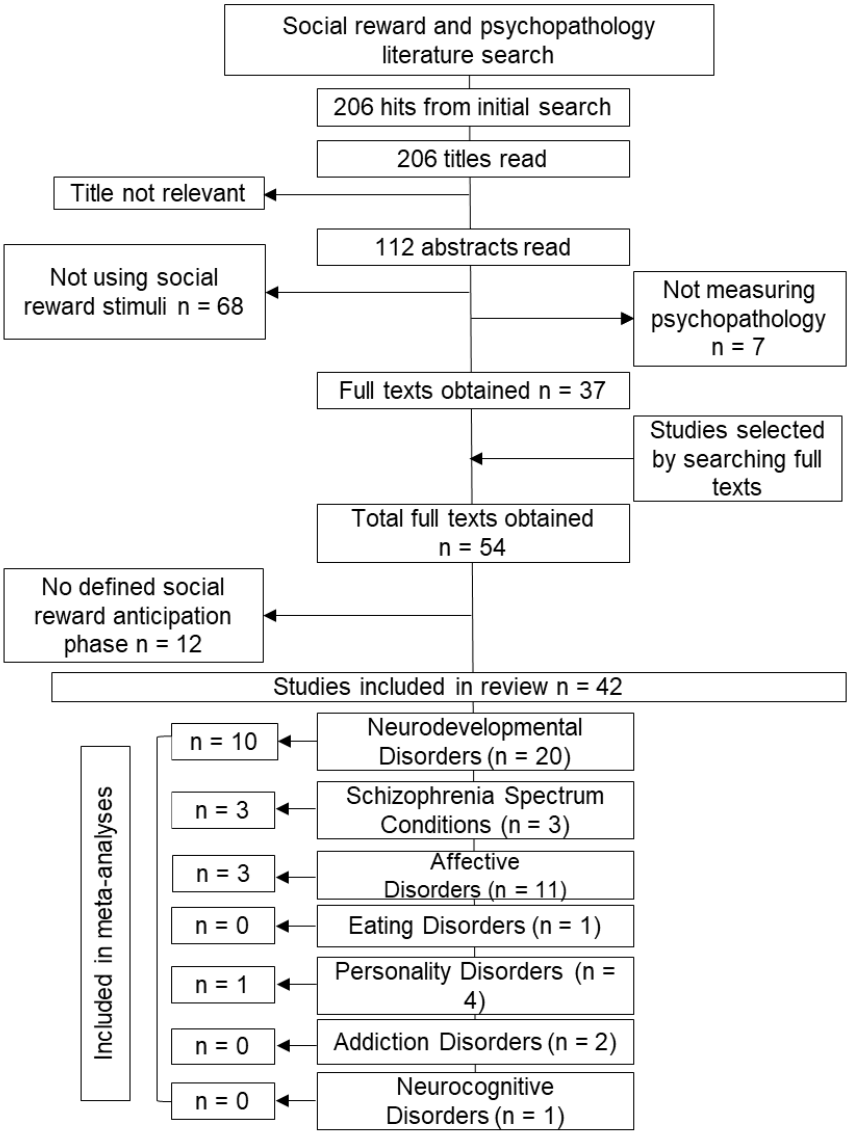
Other experimental paradigms were eligible for inclusion if they had a defined reward anticipation period. More complex social reward paradigms, such as trust or decision-making paradigms, were not included if they did not have an anticipation component. As described in Chapter 2 (see section 2.3.1.2, page 35) these more difficult paradigms often involve multiple complex cognitive functions, rather than reward anticipation specifically, which can make it difficult to parse reward anticipation from other functions. In contrast, the incentive delay paradigm has the benefit of measuring reward anticipation without depending on the participants' capacity to learn or make decisions.

Studies were excluded if they only focused on the outcome phase of reward processing, for example neuroimaging studies that measured reward-circuit activity whilst participants passively viewed socially rewarding stimuli. If studies included anticipation and outcome phases, only data relevant to the anticipation phase were extracted given the focus of this review. If studies included a reward-win and reward-lose (punishment) manipulation, only the reward-win data were extracted and reviewed. All studies had to include social rewards, but no restrictions were made as to the nature of the social rewards other than they had to fit into one or more of the social reward subtypes described by Foulkes, Viding, et al. (2014). Rewards of any sensory modality were eligible for inclusion. Studies taking categorical and dimensional approaches to psychopathology were both considered. Studies on more general personality traits (e.g., the five-factor model of personality; McCrae & Costa, 1987) were not eligible as those traits are not specifically psychopathological in nature. Studies included in the review could use samples with a range of diagnoses (provided the data per diagnosis

group were reported) and so could contribute to more than one section of the analysis. All identified articles had to be published in English.

The screening and selection of studies was conducted by two of the authors. A flowchart of the study selection process following PRISMA guidelines is presented in Figure 3.1.

Figure 3.1. Flowchart of Study Selection Process



3.4.2. Data Extraction and Analysis

All data were analysed descriptively, and all eligible studies were also submitted for meta-analysis. Between-groups meta-analyses comparing experimental reward anticipation in clinical and control groups were computed via Review Manager 5.3 Software - RevMan (Review Manager (Revman), 2014). To be eligible for inclusion in these analyses, studies had to compare reward anticipation between two groups and include mean and standard deviations of task performance (reaction time, response accuracy) for both groups. Two

meta-analytic comparisons were run. First, clinical and healthy control groups were compared on anticipatory reaction times towards social rewards. Second, the two groups were compared on anticipatory response accuracy towards social rewards. Included studies were coded and rated by two authors independently (see Appendix 2, page 264). After rating, both authors compared codes, discussed each study and all disagreements, the inter-coding reliability was entered as percentage of agreement (threshold set at 80%), and authors reached a joint consensus on the studies that would be included in the meta-analyses. Publication bias was formally assessed via funnel plot inspection and the Egger (Egger et al., 1997) and Begg (Begg & Mazumdar, 1994) tests of publication bias. Random effect models using standard mean difference scores were computed for each meta-analysis. Heterogeneity was estimated via I^2.

3.5. Results

Forty-two studies were included in this review, including studies investigating social reward anticipation in: Attention-Deficit/Hyperactivity Disorder (n = 4), Autism Spectrum Disorder (n = 15), Conduct Disorder (n = 1), Schizophrenia Spectrum Conditions (n = 3), Bipolar Disorder (n = 2), Major Depressive Disorder (n = 3), Alexithymia (n = 2), PTSD (n = 1), Social Anxiety Disorder (n = 3), Eating Disorders (n = 1), Borderline Personality Disorder (n = 1), Psychopathy (n = 3), Paraphilia and Sex Addiction (n = 1), Pathological Gambling (n = 1) and Behavioural Variant Frontotemporal Dementia (n = 1). The extracted data for the reviewed studies are tabularised in the appendices (see Appendix 3, page 265). Full information on psychotropic medication use in the reviewed studies is given in the appendices (see Appendix 4, page 276).

The results are presented per diagnostic category. The forest plots of the between-group meta-analyses are presented in Figures 3.2. and 3.3. The correlation coefficients for the self-report data are plotted in the appendices (Appendix 5, page 285) for illustrative purposes only; these data were not submitted for meta-analysis. The tests of publication bias identified no significant evidence of publication bias (funnel plot symmetry; all test values $p > .05$).

Figure 3.2. Forest Plot Comparing Clinical and Healthy Control Groups on Social Reward Anticipation Reaction Times. More Positive Scores Indicate Hypoanticipation (Longer Reaction Times) In the Clinical Group in Comparison to Healthy Controls

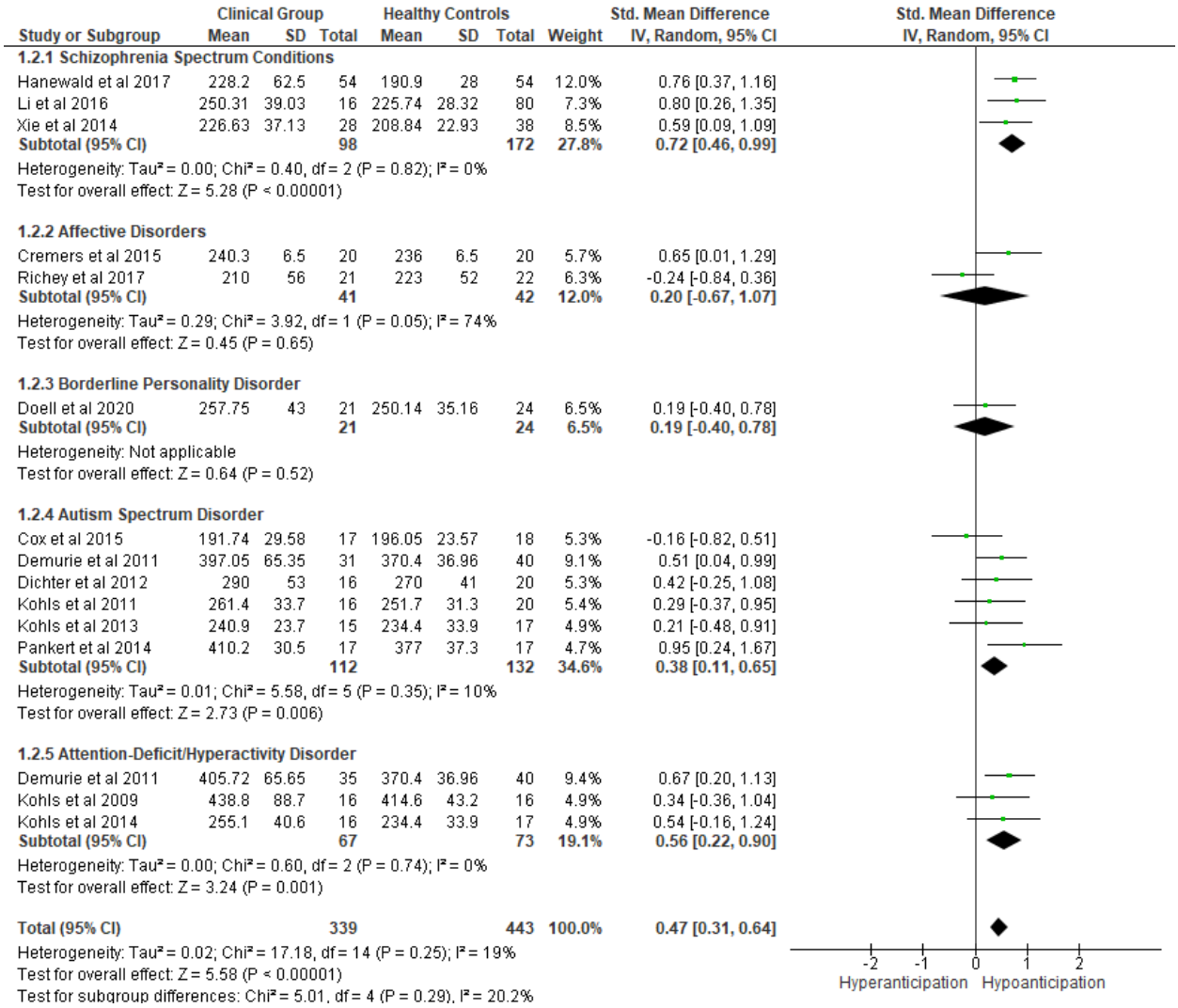
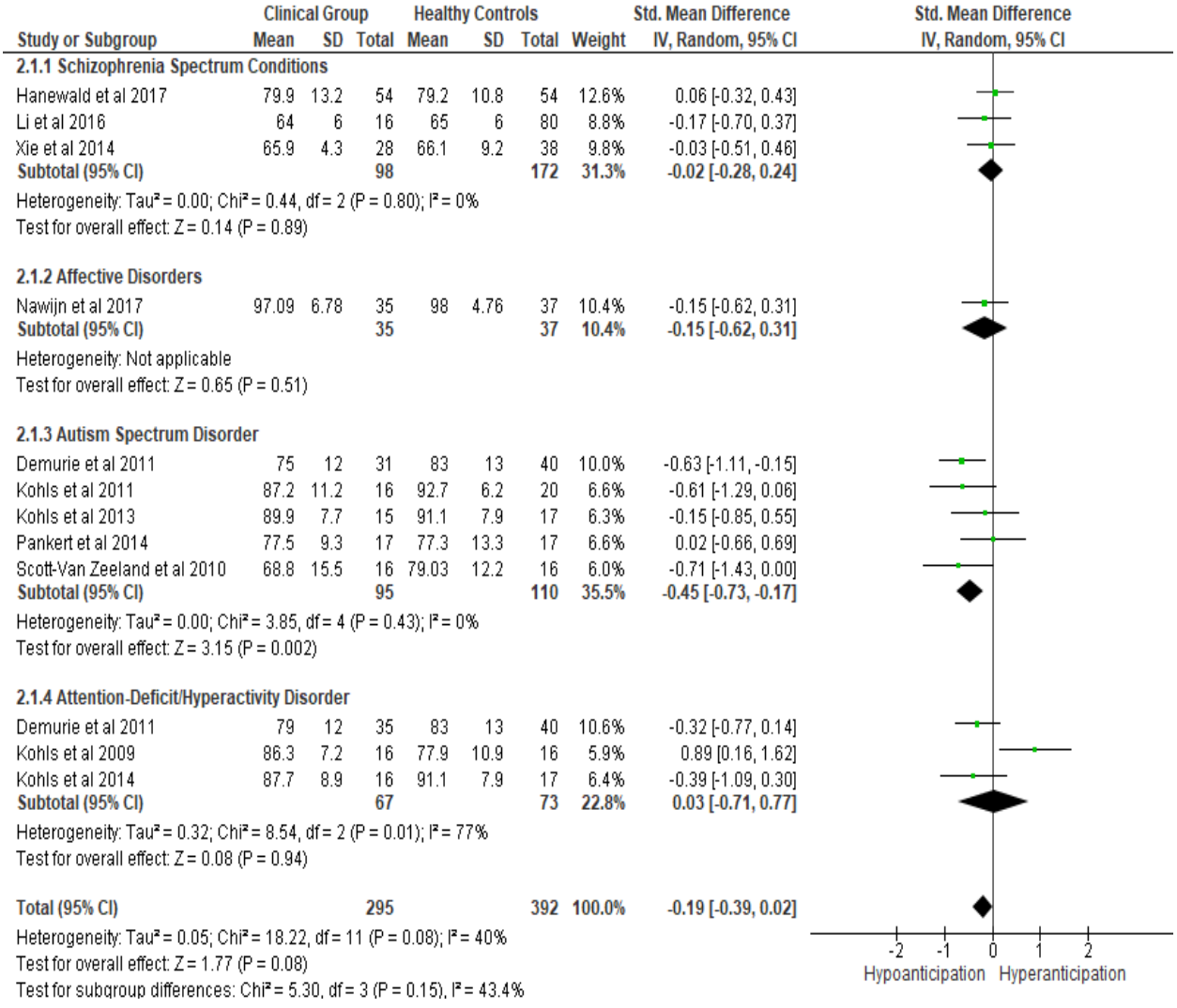


Figure 3.3. Forest Plot Comparing Clinical and Healthy Control Groups on Social Reward Anticipation Response Accuracy. More Negative Scores Indicate Hypoanticipation (Lower Response Accuracy) in the Clinical Group in Comparison to Healthy Controls



3.5.1. Schizophrenia Spectrum Conditions

Schizophrenia is a psychotic disorder characterised by positive (hallucinations, delusions) and negative (low motivation, depression) symptoms. The negative element of schizophrenia symptomatology often manifests in atypical social behaviour, including a lack of engagement with social norms and reduced motivation to be part of the social environment (Barch et al., 2008). Three studies on social reward anticipation in schizophrenia spectrum conditions were eligible for inclusion in this review (Hanewald et al., 2017; X. Li et al., 2016; Xie et al., 2014). All three were also included in the behavioural meta-analyses and supported the notion of reduced social reward anticipation (RT domain) in schizophrenia spectrum conditions. Hanewald et al. (2017) found a main effect of group with slower RTs in the schizophrenia clinical group in comparison to healthy controls across reward types. However, they did not find a significant difference between the clinical group and healthy controls on RT during social reward anticipation, nor did they find significant differences in behavioural anticipation towards social and non-social rewards in either group.

Hanewald et al. (2017) fully characterised the psychotropic medication use of their sample, with approximately seventy percent of the sample using one or more atypical antipsychotics at the time of participation (see Appendix 4, page 276). They suggested that use of atypical antipsychotics may have minimised the detectable differences in social reward anticipation between clinical and control groups.

Xie et al. (2014) found that their clinical group (individuals from the general population with high levels of self-reported social anhedonia, an important dimension of prodromal schizophrenia; Kwapil, 1998) had significantly slower RTs during social reward anticipation than the comparison group. Furthermore, they countered the Hanewald et al. (2017) correlational finding and reported positive associations between schizophrenia symptomatology and anticipatory RTs. They also compared anticipation between reward types and, whilst the control group demonstrated significantly greater anticipation of social rewards versus neutral, the clinical group did not demonstrate this difference. Li et al. (2016) ran their task with social rewards only (non-social rewards were not included) and mirrored the Xie et al. (2014) finding of social reward hypoanticipation in individuals high in schizophrenia spectrum traits. Li et al. (2016) and Xie et al. (2014) conducted their research with normative samples and thus no psychotropic medication use information was provided.

None of the studies reviewed found significant differences in response accuracy between the clinical and control groups for social rewards.

3.5.1.1. Meta-Analysis of Schizophrenia Spectrum Behavioural Data

Pooling schizophrenia spectrum condition data revealed a significant RT difference in social reward anticipation between the clinical group and healthy controls, with a medium-large effect size (Hedge's g = 0.72, df = 2, p = <.001, CI = [0.46, 0.99], I^2 = 0%, p = .820). This suggests that individuals with schizophrenia spectrum conditions demonstrate reduced behavioural processing (hypoanticipation) of social rewards. However, this was not significantly reflected in the response accuracy comparison (Hedge's g = -0.02, df = 2, p = .890, CI = [-0.28, 0.24], I^2 = 0%, p = .890).

3.5.2. Affective Disorders

3.5.2.1. Major Depressive Disorder

Major depressive disorder (MDD) is marked by feelings of low mood, poor self-esteem, thoughts of self-harm, and low motivation. Three studies (Ait Oumeziane et al., 2019; Han et al., 2019; He et al., 2019) investigating social reward anticipation in depression were eligible for review. Comparing a subclinical depression group (defined using the Self-Rating Depression Scale; Zung et al., 1965) and healthy control groups on an fMRI social reward anticipation task, He et al. (2019) found no significant differences between groups on behavioural measures of social reward anticipation. Similarly, relative to healthy controls, He et al. (2019) found no significant evidence of neural social reward hypoanticipation in the clinical group. Ait-Oumeziane et al. (2019) examined the influence of self-reported depression symptoms on anticipatory event-related potentials during social and monetary incentive delay tasks. They found that self-reported depression symptomology was associated with reduced stimulus-preceding negativity across both social and non-social reward types. Using subjective measures of social reward processing, Han et al. (2019) compared a clinical MDD group with a group of healthy controls. The MDD group reported experiencing significantly less pleasure when anticipating interpersonal interactions in comparison to healthy controls. Han et al. (2019) also included an ASD group (see below, section 3.5.5., page 58) and found no significant group differences in self-reported social reward anticipation between ASD and MDD individuals. Both He et al. (2019) and Ait-Oumeziane et al. (2019) included psychotropic medication use within their exclusion criteria and thus all participants were medication-free. Han et al. (2019) did not report medication use.

None of the studies reviewed were eligible for inclusion in the meta-analysis: He et al. (2019) did not report behavioural data, Ait-Oumeziane et al. (2019) treated depression as a dimensional construct rather than comparing between groups, and Han et al. (2019) used self-report methods only.

3.5.2.2. Social Anxiety Disorder

Social anxiety disorder (SAD) is characterised by a fear of different types of social situations. Those feelings of fear regarding social interaction, or social performance, can lead to reduced social motivation (Alden & Taylor, 2004) and difficulties with social cohesion and affiliation (Mathew et al., 2001). Richey et al. (2014), Richey et al. (2017), and Cremers et al. (2015) investigated social reward anticipation in social anxiety disorder. Comparing a clinical group with healthy individuals on an incentive delay paradigm, Richey et al. (2014) found no significant group differences in behavioural anticipation across social and non-social reward types. Similarly, Richey et al. (2017) did not report any significant differences in social reward anticipation between groups but did find that social anxiety disorder individuals react significantly slower than healthy controls when anticipating non-social rewards. Cremers et al. (2015) evidenced significantly faster RTs towards social rewards than neutral stimuli in clinical and healthy control groups, but like Richey et al. (2014) and Richey et al. (2017), did not find significant differences between groups for behavioural social reward anticipation.

At neural levels, however, both Richey et al. (2014) and Richey et al. (2017) evidenced significant neural social reward hypoanticipation, with social anxiety disorder individuals demonstrating reduced nucleus accumbens activity during anticipation in comparison to healthy controls. Furthermore, this effect was present for social rewards but not for non-social rewards. Richey et al. (2017) also showed that this social reward anticipation in the nucleus accumbens negatively correlated with symptomatology, suggesting that the hypoanticipation of social rewards intensifies as symptoms become more severe. In contrast, Cremers et al. (2015) found no significant neuroimaging evidence of social reward hypoanticipation in social anxiety disorder.

Richey et al. (2017) included psychotropic medication use within their exclusion criteria. Both Cremers et al. (2015) and Richey et al. (2014) included participants who were using psychotropic medication at the time of participating. Only Cremers et al. (2015) accounted for medication effects during analysis.

3.5.2.2.1. Meta-Analysis of Social Anxiety Disorder Behavioural Data

Pooling the reaction time data from Richey et al. (2017) and Cremers et al. (2015) found no significant evidence of social reward hypoanticipation in individuals with social anxiety disorder in comparison to healthy controls (Hedge's g = 0.20, df = 1, p = .650, CI = [-0.67, 1.07]), perhaps due to heterogeneity within the data (I^2 = 74%, p = .050).

3.5.2.3. Alexithymia

Alexithymia is a psychopathological personality dimension associated with dysfunction in emotional and reward processes (Fantini-Hauwel et al., 2015; Morie et al., 2016). Two studies (Foulkes et al., 2015; Goerlich et al., 2017) investigated social reward anticipation in alexithymia in medication-free samples. Foulkes et al. (2015) included subjective assessments of social reward processing, whilst Goerlich et al. (2017) used an incentive delay paradigm. Foulkes et al. (2015) found that alexithymia scores significantly predicted self-reported reduced processing of social rewards involving Admiration, Prosocial Interactions and Sociability. In contrast, Goerlich et al. (2017) found no behavioural evidence of social reward hypoanticipation in alexithymia, with no significant correlations between alexithymia and behavioural measures of social reward anticipation.

Goerlich et al. (2017) also included a neuroimaging component and, when conducting a region-of-interest analysis controlling for self-reported alexithymia scores, found that the difficulty identifying feelings facet of alexithymia was associated with greater subgenual and pregenual anterior cingulate cortex activity and increased ventromedial prefrontal cortex activation. The authors posit that this increased activation could reflect over-regulation of limbic activity during social reward anticipation which might lead to reduced emotional experience of social reward scenarios. Alternatively, they suggest that it may reflect greater levels of required effort during social reward anticipation.

Neither study was eligible for inclusion in the meta-analysis because both used a correlation design with alexithymia assessed as a dimensional trait.

3.5.2.4. Bipolar Disorder

Bipolar disorder is a mental illness associated with extreme and cyclical changes in mood that affect cognition, work life, and interpersonal relationships. Two studies (Dutra et al., 2015, 2017) were eligible for inclusion in this review. Incentive delay paradigms were used in both studies. Using neuroimaging, both studies showed that bipolar disorder is associated with hyperanticipation of social rewards, demonstrated by, in comparison to healthy individuals, increased striatal activation during social reward anticipation (Dutra et al., 2015). The bipolar disorder group also exhibited reduced orbitofrontal cortex activation during reward anticipation in comparison to healthy controls (Dutra et al., 2015), and greater ventral striatum-orbitofrontal cortex connectivity during reward receipt. The effects observed in social rewards were also observed in non-social rewards. Both studies included participants within the clinical group that were taking psychotropic medication at the time of participation (see Appendix 4, page 276) and all described effects remained when antipsychotic

medication use was included as a covariate. Neither study was eligible for inclusion in the meta-analysis as behavioural data were not reported.

3.5.2.5. Post-Traumatic Stress Disorder

Post-traumatic stress disorder (PTSD) is a debilitating psychiatric mood disorder that emerges following a traumatic event. Like some other affective disorders, individuals with PTSD often present with elevated levels of anhedonia (Nawijn et al., 2015) and those feelings of anhedonia can have a marked negative impact on treatment engagement and chronicity of illness (Hassija et al., 2012). Only one study (Nawijn et al., 2017) on PTSD was eligible for review. Rather than social reward anticipation in PTSD specifically, their primary research question was more about the effect of oxytocin administration on social reward processing in PTSD and so the data provided for placebo-administration are more limited. The data provided did not reveal any significant difference between PTSD individuals and healthy controls on response accuracy during an incentive delay paradigm with social and non-social rewards. Daily psychotropic medication use was included as an exclusion criterion in Nawijn et al. (2017) so all participants were medication-free at the time of participation.

3.5.2.5.1. Meta-Analysis of Post-Traumatic Stress Disorder Behavioural Data

Nawijn et al. (2017) were included in the meta-analysis as they ran an incentive delay paradigm but reported response accuracy data only. As the only study investigating social reward anticipation in PTSD, their data could only be included in the overall meta-analysis rather than analyses per diagnostic group.

3.5.3. Psychopathy

Psychopathy is a personality dimension encompassing a constellation of traits, including impulsivity, lack of empathy, pathological lying, manipulativeness, superficial charm and grandiosity (Hare, 2003). Individuals elevated in the interpersonal dimension of psychopathy are likely to be high in self-esteem (e.g., Cale & Lilienfeld, 2006) and thus may seek environments where there is the opportunity to be socially rewarded through praise, attention, and recognition (White, 2014). Conversely, a low sense of social love, cohesion, and communion, coupled with a strong tendency towards lack of care or cruelty towards others, is a prominent feature of psychopathy across the life-course (Viding & McCrory, 2019).

Foulkes, McCrory, et al. (2014) ran two studies with two separate normative participant samples that were included in one manuscript. In their first study, Foulkes, McCrory et al. (2014) correlated self-reported psychopathic traits with subjective social reward processing

and found significant positive correlations between psychopathic traits [total score and dimensions (Interpersonal, Affective, Lifestyle, Antisocial)] and subjective processing of Negative Social Potency. They also reported positive correlations between the Interpersonal dimension of psychopathy and subjective processing of social rewards involving Admiration. In contrast, they found that all aspects of psychopathy negatively correlated with subjective processing of Prosocial Interactions (Foulkes, McCrory, et al., 2014). In their second study, they again investigated the correlations between psychopathic traits and self-reported processing of social rewards and mimicked the findings of their first study. Furthermore, they added an experimental component (incentive delay task) into the second study and assessed correlations between psychopathic traits and behavioural anticipation social and non-social rewards. However, they found no significant relationships between psychopathic traits and task performance for either social or non-social rewards, although found behavioural evidence for increased preference towards social rewards relative to non-social rewards linked to the Interpersonal dimension. As Foulkes, McCrory, et al. (2014) employed a correlation design, rather than comparing clinical and control groups, their incentive delay task data were not eligible for inclusion in the meta-analysis.

3.5.4. Borderline Personality Disorder

Borderline personality disorder (BPD) is a personality disorder characterised by a tendency towards forming intense and volatile interpersonal relationships that fluctuate between idealisation and devaluation (Furnham et al., 2014). Doell et al. (2020) was the only study on social reward anticipation in BPD available for review. They reported no significant differences in anticipatory reaction times between BPD and healthy control groups for either reward type. However, Doell et al. (2020) did find evidence of social reward hyperanticipation in BPD at a neural level. In comparison to healthy controls, the BPD group exhibited greater superior temporal sulcus activation during social reward anticipation. Moreover, this increased activation was observed for social rewards but not non-social rewards, indicating that social rewards may be particularly salient for BPD individuals in comparison to healthy individuals. Doell et al. (2020) fully characterised participant medication use and found no significant association between medication use and reward anticipation.

3.5.4.1. Meta-Analysis of Borderline Personality Disorder Behavioural Data

Doell et al. (2020) provided reaction time data and so the data are included in the overall meta-analysis.

3.5.5. Autism Spectrum Disorder

Autism spectrum disorder (ASD) is a neurodevelopmental condition associated with difficulties in perspective-taking and interpersonal communication (Frith, 2003). Social motivation theory (Chevallier et al., 2012) asserts that individuals with ASD may not experience as many feelings of reward during typically socially rewarding scenarios, meaning that they are less likely to engage with the social environment in typical ways (Clements et al., 2018). Fifteen studies were included (Barman et al., 2014; Cox et al., 2015; Delmonte et al., 2012; Demurie et al., 2011, 2016; Dichter, Richey, et al., 2012; Foulkes et al., 2015; Han et al., 2019; Kohls et al., 2011, 2013; Pankert et al., 2014; Richey et al., 2014; Ruta et al., 2017; Scott-Van Zeeland et al., 2010; Stavropoulos & Carver, 2018). Of these, 7 were eligible for inclusion in the meta-analyses.

Two studies employed subjective measures of social reward processing. Foulkes et al. (2015) showed that autism quotient (Baron-Cohen et al., 2001) scores significantly predicted reduced subjective processing of social rewards involving opportunities for Admiration, Prosocial Interactions, Sexual Relationships, and Sociability. Scores also positively predicted increased subjective processing of opportunities for Negative Social Potency and Passivity. Similarly, Han et al. (2019) found that ASD individuals report significantly lower levels of anticipated pleasure from social interaction in comparison to healthy controls. This was also reflected dimensionally, with Han et al. (2019) reporting significant negative correlations between social responsiveness scale scores and anticipatory pleasure and temporal pleasure scales.

The reviewed studies presented a range of behavioural and neuroimaging evidence for reduced social reward processing (hypoanticipation) in ASD in comparison to healthy individuals. Moreover, multiple studies reported that individuals with ASD demonstrate reduced behavioural anticipation of social rewards in comparison to non-social rewards (Barman et al., 2015; Kohls et al., 2012; Ruta et al., 2017), reflected in slower RTs (Demurie et al., 2011; Dichter et al., 2012) and poorer response accuracy (Demurie et al., 2011). However, this difference in responses to social and non-social rewards was not found in other studies (Delmonte et al., 2012; Pankert et al., 2014 Scott-Van Zeeland et al., 2010).

From a neural perspective, the reviewed studies found consistent evidence of social reward hypoanticipation in ASD, reflected in reduced reward-circuit activity. In comparison to typically developing individuals, ASD groups demonstrated less ventral striatum activity during social reward anticipation (Barman et al., 2015) and whilst aiming to obtain social rewards (Scott-Van Zeeland et al., 2010). They also exhibited significantly less amygdala and anterior cingulate cortex activity than the comparison group (Kohls et al., 2013), and

showed less nucleus accumbens and ventromedial prefrontal cortex activity than controls during social reward anticipation (Richey et al., 2014).

Using EEG, more pronounced ASD traits (including reciprocal social interactions subscale of ADOS-G; Lord et al., 2000) were associated with attenuated P3 amplitude (at Pz electrode; temporal window 200-450ms post-stimulus onset) during social reward anticipation (Cox et al., 2015; Kohls et al., 2011). ASD individuals also showed less left-dominant alpha band suppression (8-12Hz) in temporal electrode locations than typically developing individuals during social reward anticipation (Stavropoulos & Carver, 2018). These EEG measures complement the neuroimaging evidence above: P3 amplitude is considered an electrophysiological marker of dopaminergic activity (Benarroch, 2009) and left-dominant alpha band suppression is said to correspond with the activity of temporal brain areas. Therefore, together with the neuroimaging evidence above, this EEG research suggests that individuals with ASD may hypoanticipate, and be less motivated to obtain (Glazer et al., 2018), social rewards than typically developing individuals. In addition to this neural hypoanticipation of social rewards, the reviewed studies provided some evidence for blunted reward-circuit activity during non-social reward anticipation (e.g., Dichter, Richey, et al., 2012).

Eight of the reviewed studies were conducted in medication-free samples where psychotropic medication use was included in the exclusion criteria (Cox et al., 2015; Delmonte et al., 2012; Kohls et al., 2013), discontinued twenty-four hours prior to participating (Demurie et al., 2011; Demurie et al., 2016; Pankert et al., 2014), or the research was conducted in normative samples only (Barman et al., 2015; Foulkes et al., 2015). Five studies (Dichter et al., 2012; Kohls et al., 2011; Richey et al., 2014; Scott-Van Zealand et al., 2010; Stavropoulos & Carver, 2018) included individuals within their sample who were taking psychotropic medication at the time of participation. Of these, only Scott-Van Zeeland et al. (2010) accounted for medication use and reported (descriptively rather than statistically) no association between medication status and ventral striatum activity in ASD participants during reward anticipation. Neither Han et al. (2019) nor Ruta et al. (2017) provided information on medication use within their samples. Full information on psychotropic medication use within the ASD studies is provided in Appendix 4, page 276.

3.5.5.1. Meta-Analysis of Autism Spectrum Disorder Behavioural Data

ASD participants showed significantly slower RTs when anticipating social rewards than typically developing individuals, with a small-medium effect size (Hedge's g = 0.38, df = 5, p = .006, CI = [0.11, 0.65], I^2 = 10%, p = .350). They also showed significantly lower response

accuracy, with a medium effect size (Hedge's g = -0.45, df =4, p = .002, CI = [-0.73, -0.17], I^2 = 0%, p = .430).

3.5.6. Attention-Deficit/Hyperactivity Disorder

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder featuring cognitive and motivational difficulties (Sonuga-Barke, 2002) that can make it harder for individuals with ADHD to form meaningful, long-term, interpersonal relationships (Young, 2000). Four studies (Demurie et al., 2011, 2016; Kohls et al., 2014; Kohls, Herpertz-Dahlmann, et al., 2009) investigating social reward anticipation in ADHD were reviewed. Three of them (Demurie et al., 2011; Kohls et al., 2014; Kohls, Herpertz-Dahlmann, et al., 2009) were also eligible for inclusion in the meta-analyses. Behavioural results from these studies were mixed. Demurie et al. (2011) used an incentive delay paradigm and reported that ADHD individuals anticipate social rewards less than non-social rewards. This was indicated by significantly slower RTs during social reward anticipation in comparison to non-social rewards, independent of reward magnitude. The control group of typically developing individuals did not show this same difference in reward anticipation. However, none of the reviewed studies reported specific significant differences between clinical and control groups in measures of behavioural anticipation of social rewards.

Kohls et al. (2014) included a neuroimaging component and found that the ADHD group demonstrated equal levels of ventral striatum activity for both reward types, but that the typically developing group demonstrated significantly more striatal activation towards the opportunity for non-social than social rewards. No significant correlations between dimensional ADHD symptomatology and neural activation during reward anticipation were reported. Demurie et al. (2016) found no significant differences in behavioural metrics of social or non-social reward anticipation between groups.

All studies examining social reward anticipation in ADHD asked participants to discontinue psychotropic medication use twenty-four hours (Demurie et al., 2011; Demurie et al., 2016) or forty-eight hours (Kohls et al., 2014; Kohls, Herpertz-Dahlmann, et al., 2009) prior to participating.

3.5.6.1. Meta-Analysis of ADHD Behavioural Data

When pooled, ADHD participants demonstrated significantly slower reaction time during social reward anticipation than typically developing individuals, with a medium overall effect size (Hedge's g = 0.56, df = 2, p = .001, CI = [0.22, 0.90], I^2 = 0%, p = .740). This reaction time difference was not meaningfully reflected in the response accuracy data, perhaps due to large heterogeneity within the data (I^2 = 77%, p = .010)

3.5.7. Eating and Feeding Disorders

Restricting type eating disorders, such as anorexia nervosa (restricting type), are defined by self-starvation and severe body-image dysmorphia (Oldershaw et al., 2011). In addition, restricting eating disorders are often associated with interpersonal difficulties (Anderluh et al., 2009) and comorbidity with social anxiety is also common (Godart et al., 2006). Whilst a distinct subtype of eating disorder, individuals with binging/purging eating disorders exhibit symptoms similar to the restrictive types, including difficulties with true body-image, obsession with the thin-ideal, and poor self-esteem. Fussner et al. (2018) studied social reward processing in eating disorders via self-report measures within a normative sample. They found that restricting and binging/purging types of eating disorders were associated with increased processing of social rewards, and so indicate that hyperanticipation of social rewards may be a characteristic of eating disorders of different types. This study used self-report measures only and therefore was not eligible for inclusion in the meta-analysis.

3.5.8. Pathological Gambling

Pathological gambling disorder describes a level of gambling behaviour that interferes with the individuals' occupational, emotional, or social wellbeing. Sescousse et al. (2013) was the only study eligible for review that tested social reward anticipation in pathological gambling. Using an incentive delay paradigm, they found that individuals with a diagnosis of pathological gambling anticipate non-social (e.g., monetary) rewards significantly more than social rewards, as reflected in faster RTs towards opportunities for non-social reward. The gamblers also evidenced significantly less ventral striatum activity during social reward anticipation compared to non-social rewards, and Sescousse et al. (2013) suggest that this reflects hypoanticipation of social rewards rather than hyperanticipation of non-social rewards. However, Sescousse et al. (2013) did not find any significant differences in task performance between groups for either social or non-social rewards. All participants in Sescousse et al. (2013) were medication-free at the time of testing. This study did not meet the inclusion criteria for meta-analysis as behavioural data were not reported.

3.5.9. Paraphilia and Sex Addiction

Paraphilia and sex addiction are defined as sexual preoccupations, thoughts, or acts that are disordered in nature to the degree that they negatively impact the life of the individual or other people (Bostwick & Bucci, 2008). Social reward anticipation in men with problematic pornography use was investigated by Gola et al. (2017) via an incentive delay paradigm. This was the only study eligible for review within this diagnostic category. Gola et al. (2017) showed that those with problematic pornography use demonstrated significantly faster anticipatory RTs for social rewards than non-social rewards. However, they reported no main

group effects when comparing behavioural task performance between the clinical group and a group of healthy controls. There was, however, a significant difference between the groups at the neural level; manifested in significantly more ventral striatum activity in the clinical group than the control group during social reward anticipation. This significant difference in striatal activity was present for social rewards only, and the ventral striatum activity during social reward anticipation also positively correlated with a self-report dimensional measure of sexual compulsion. All participants were medication-free at the point of participation. Gola et al. (2017) did include analysis of behavioural task data but did not report raw scores in text and so the data were not eligible for inclusion in the meta-analysis.

3.5.10. Behavioural Variant Frontotemporal Dementia

Behavioural variant frontotemporal dementia (bvftD) is a behavioural disorder associated with a decline in social and interpersonal conduct, as well as limited self-insight and emotional experience. Perry et al. (2015) studied social reward anticipation in bvftD and was the only study eligible for review in this diagnostic category. They found marked differences between non-social and social reward anticipation in bvftD, with anticipatory RTs being much slower for social rewards, but did not find such a large difference within healthy controls. Perry et al. (2015), however, did not report any significant differences between bvftD and healthy individuals on measures of behavioural social reward anticipation. Perry et al. (2015) did not report sample psychotropic medication use. Perry et al. (2015) did not include behavioural data scores and so were not eligible for inclusion in the meta-analysis.

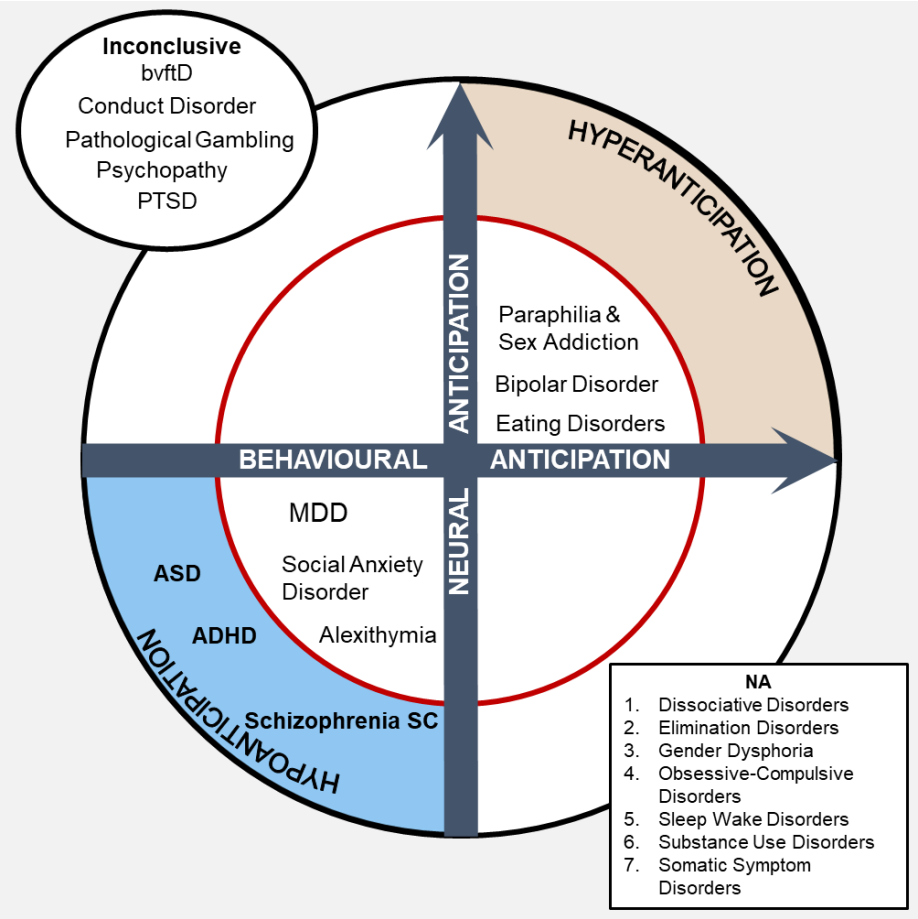
3.5.11. Atypical Social Reward Anticipation as a Transdiagnostic Characteristic

Overall, the narrative synthesis of studies included in this review highlights that most psychopathologies are associated with reduced processing, specifically hypoanticipation, of social rewards. As suggested earlier and illustrated in Figure 3.4., psychopathologies linked to social anhedonia or reduced interpersonal behaviour (e.g., ASD, schizophrenia spectrum conditions) were associated with hypoanticipation of social rewards at behavioural and neural levels. The evidence for an anticipation deficit for social rewards in comparison to non-social rewards was less compelling. Limited psychopathologies were associated with hyperanticipation of social rewards, with only bipolar disorder and sex addiction groups showing increased anticipation of social rewards in comparison to healthy controls. A lot of experimental evidence on social reward anticipation in other psychopathologies was either absent or inconclusive, and patterns of social reward anticipation in ADHD, pathological gambling, psychopathy, and bvftD remain mixed. The inclusion of self-report data helped temper some of these mixed findings.

3.5.11.1. Overall Meta-Analysis of Behavioural Data in Psychopathology

With the limited number of studies eligible for meta-analysis, some evidence of atypical social reward anticipation as a transdiagnostic characteristic was found. When pooling data from participants with schizophrenia spectrum conditions, social anxiety, BPD, ASD, and ADHD, the overall clinical group demonstrated significantly slower anticipatory RTs to social rewards than healthy controls, with a medium effect size (Hedge's g = 0.47, df = 14, p = <0.01, CI = [0.31, 0.64], I^2 = 19%, p = 0.25). However, this hypoanticipation was not reflected significantly in the response accuracy data (Hedge's g = -0.19, df = 11, p = 0.08, CI = [-0.39, 0.02], I^2 = 40%, p = 0.08).

Figure 3.4. Figure Illustrating Findings from This Review on Axes of Behavioural and Neural Anticipation



3.6. Discussion

This review of 42 studies evaluated subjective, behavioural, and neuroimaging evidence of atypical social reward anticipation in psychopathology. It yielded several observations that deserve comment.

Firstly, the meta-analytic findings showed that schizophrenia spectrum conditions, ASD, and ADHD are associated with significant hypoanticipation of social rewards, reflected in clinical groups demonstrating significantly slower anticipatory RTs towards social rewards in comparison to healthy individuals (Figure 3.2.). Furthermore, the overall meta-analysis indicates that this slower anticipatory RT may be a transdiagnostic characteristic, as the pooled RT towards social rewards was significantly slower in the pooled clinical group than the control group; although, this pooled effect included data from Cox et al. (2015) and Richey et al. (2017) who reported faster reaction times in the clinical group in comparison to healthy controls. Unlike RT, there was no significant meta-analytic evidence of impaired response accuracy during social reward anticipation in psychopathology. Taken together, these findings suggest that some clinical groups demonstrate reduced anticipation of social rewards in comparison to typical individuals, and that this reduced anticipation is most sensitively measured through RT rather than response accuracy.

Secondly, the narrative synthesis of subjective, neuroimaging, and meta-analytically ineligible behavioural data supported the meta-analytic findings in showing similar patterns of significant social reward hypoanticipation in ADHD, ASD and schizophrenia-spectrum conditions and extended them to include reduced social reward anticipation in MDD and social anxiety disorder. Self-report data on social reward processing in alexithymia were also reviewed and increased feelings of alexithymia were significantly linked to self-reported reduced processing of social rewards. Neuroimaging findings were largely in keeping with the behavioural findings, with multiple studies finding evidence of reduced reward-circuit activation during social reward anticipation (in ASD particularly).

Thirdly, the reviewed studies also revealed that some psychopathologies, namely, bipolar disorder, eating disorders, BPD, psychopathy, and paraphilia and sex addiction, may be associated with social reward hyperanticipation at behavioural and/or neural levels. Within this, the type of social reward available may be particularly important for psychopathic individuals, who appear to enjoy opportunities for Negative Social Potency and Admiration, and for individuals with problematic sexual behaviour, who may hyperanticipate social rewards of a sexual nature. Fourthly, there is very limited data on this topic in people with multiple other psychopathologies, including bvftD, conduct disorder, pathological gambling and PTSD, and no data in substance misuse disorders. There is a clear need for further research in this area.

Overall, this meta-analysis and systematic review highlights that hypoanticipation (evidenced by slower RTs) is common across schizophrenia, ASD, and ADHD diagnoses and could be associated with dimensional feelings of alexithymia or anhedonic symptomatology.

Therefore, based on the evidence reviewed, part of the reason these psychopathologies are associated with lower social motivation or social withdrawal could be because the individual is not anticipating social rewards to the same extent as healthy individuals. It is also possible that hyperanticipation of social rewards leads to atypical social behaviour, but further research is needed to substantiate these potential links.

3.7. Critical Evaluation of Methodology and Directions for Future Research

3.7.1. Social Reward Stimuli

Most studies reviewed here included emotional faces as social rewards. However, as noted in the previous chapter (Chapter 2, section 2.3.3., page 37), the psychopathologies reviewed are associated with a range of emotion recognition difficulties (e.g., Guyer et al., 2007; Hoertnagl & Hofer, 2014) which could have had an impact on the degree to which the individual was motivated to obtain (and thus anticipated) the social reward. In this way, social reward hypoanticipation is likely to be correlated with impairments in emotion recognition (Chevallier et al., 2012), and so future research should include a test of emotion recognition when also using emotional stimuli as social rewards. Given the issues related to facial emotion recognition, and the lack of specificity of emotional faces to social reward subtypes (see Chapter 2, section 2.3.3., page 37), the methodology of research investigating social reward anticipation in psychopathology should be refined. It could move away from presenting participants with happy faces as a social reward, and instead try to capture the social reward subtypes in other ways (e.g., use of animations or virtual reality; Fulford et al., 2018; Kim et al., 2010).

Similarly, whilst most studies used emotional/smiling faces as social rewards, Gola et al. (2017) and Sescousse et al. (2013) included erotic stimuli as social rewards. Given that Sexual Relationships are included as a social reward subtype in the Foulkes, Viding, et al. (2014) definition, the inclusion of these studies within this review is justified, while acknowledging that their results may be less comparable to the other studies included in this review. Having said that, the inclusion of erotic stimuli as a subtype of social reward does highlight the potential for the inclusion of similarly socially oriented stimuli within reward anticipation paradigms. Furthermore, including more of the Foulkes, Viding, et al. (2014) social reward subtypes within reward anticipation paradigms may then discover more nuanced links between symptomatology and processing of certain subtypes of social reward.

3.7.2. Influence of Psychotropic Medication on Reward System Function

Twenty-seven of the reviewed studies conducted their research within psychotropic medication-free populations, either because medication use was included in the exclusion

criteria, or because participants were asked to discontinue medication use twenty-four or forty-eight hours prior to participating, or their research was conducted in populations that were medication-free (e.g., normative samples). Three studies (Han et al., 2019; Perry et al., 2015; Ruta et al., 2017) did not report the medication status of their participants. The remaining studies included participants with a range of medication-use, including psychostimulant and antipsychotic (typical and atypical) medications. Long-term use of these medications has been shown to up-or-down regulate mesocortical reward system activity (e.g., Rubia et al., 2009; Schlagenhauf et al., 2008), which could have influenced the participants' anticipation of social and non-social rewards. Acute withdrawal effects (for example, dopamine super-sensitivity after sudden antipsychotic withdrawal; Llorca, Vaiva & Lancon, 2001) could also have affected participants' anticipation of rewards in studies that required their participants to suddenly discontinue medication for twenty-four or forty-eight hours. For this reason, making solid conclusions about group differences in social reward anticipation without accounting for medication effects is difficult. Thus, future research should control for the effects of medication within their analyses of social reward anticipation, study clinical participants on and off medication, or recruit participants from medication-free samples only (Richey et al., 2014).

3.7.3. Gender Effects

There is some evidence that healthy males and females anticipate social and non-social rewards differently at behavioural and neural levels (e.g., Spreckelmeyer et al., 2009). The gender distribution of participants, and any significant differences in number of males versus females, was reported in most studies. However, only five (Barman et al., 2015; Foulkes et al., 2015; Ruta et al., 2017; Foulkes et al., 2015; Nawijn et al., 2017) accounted for the effects of gender within their analyses. Accounting for gender within analyses, and thereby studying the interaction effects between psychopathology, gender, and social reward anticipation, could be important for future research. For example, the symptomatology of males and females with different clinical diagnoses is often slightly different (e.g., Leung & Chue, 2000), with males experiencing more prominent social anhedonia or social irritability (e.g., Chapman et al., 1976*;* Khesht-Masjedi et al., 2017; Goldstein & Link, 1988; Ring et al., 1991). This review has highlighted that more prominent anhedonic traits may be linked to more pronounced deficits in social reward anticipation and so, as males experience more of these types of symptoms, the influence of gender on social reward processing in psychopathology should be considered.

3.7.4. The Effect of Cognitive Deficits

It is likely that general dysfunction in cognitive ability will affect metrics of reward processing, as the paradigms used to assess reward anticipation rely on the participants' ability to respond to a target in order to obtain a reward. Therefore, their behavioural and neural anticipation following the administration of the reward cue may not only be an indication of the degree to which they are anticipating the reward, but could also be related to their ability to sustain attention, process the links between the reward cue and reward outcome, or other executive functions. Therefore, seventeen of the reviewed studies (Delmonte et al., 2012; Demurie et al., 2011; Dichter et al., 2012; Dutra et al., 2015; Dutra et al., 2017; Han et al., 2019; Kohls et al., 2009; Kohls et al., 2011; Kohls et al., 2013; Kohls et al., 2014; Lie et al., 2016; Pankert et al., 2014; Perry et al., 2015; Richey et al., 2014; Richey et al., 2017; Stavropoulos & Carver, 2018; Xie et al., 2014) accounted for deficits in cognition in psychopathology in some way – either by controlling for full scale IQ scores within their analysis or including only IQ-matched clinical and control groups. Thus, the atypical anticipation of social rewards in psychopathology seems to be separable and distinct from more general difficulties with cognition. This highlights that future work should continue to incorporate measures of cognitive functioning within their analysis of reward anticipation in psychopathology.

3.7.5. Implications for Sample Sizes of Future Research

Based on the effect size of the overall meta-analysis (Hedge's *g* 0.47), a sample size of 158 (79 per group) is required to achieve 90% power and a sample size of 114 (57 per group) to achieve 80% power (as informed by power analysis via G* Power) to detect significant behavioural differences between atypical and typical groups in social reward anticipation. This indicates that many of the studies reviewed here may be underpowered, perhaps explaining why some did not find significant behavioural differences between groups. Future studies should bare this sample size recommendation in mind if aiming to investigate differences in behavioural anticipation of social rewards between groups.

3.7.6. Implications for Clinical Practice

This review found evidence for atypical social reward anticipation as a transdiagnostic characteristic of psychopathology. Following these results, and if these effects are borne out in future studies, atypical social reward anticipation may have implications for how individuals with mental health difficulties are incentivised and engaged into psychosocial interventions. Affected individuals are often offered group-based cognitive behavioural therapy or group psychoeducation as part of their treatment (Bechdolf et al., 2010). Whilst group therapeutic approaches often increase an individuals' quality of life or their capacity to

manage their own difficulties (Bechdolf et al., 2010), the reward research included here highlights that clinical groups who demonstrate social reward hypoanticipation (e.g., ASD, schizophrenia spectrum conditions) may anticipate less pleasure towards, and thus benefit less from, group-work or practicing interpersonal skills. Conversely, clinical groups that demonstrate social reward hyperanticipation (particularly towards opportunities for Admiration or Negative Social Potency) may be more difficult to manage within group-therapy activities, reflected in the tendency towards bullying and taking control that is often seen in group work with highly psychopathic individuals (Harris & Rice, 2006; McGauley et al., 2008). Whilst tentative, these suggestions indicate that group psychotherapies may need to adapt to account for these atypicalities in social reward anticipation. Furthermore, this review has emphasised the importance of viewing social reward as a multidimensional construct, and so certain psychopathologies may respond to certain subtypes of social reward more than others. Future therapies could then look to take these different social reward subtypes into account and develop more bespoke group psychotherapeutic approaches.

3.8. Limitations

Whilst this review has been a comprehensive synthesis of social reward anticipation in clinical psychopathology, there are a few important points that have not been covered here. First, restrictions were made regarding the type of paradigms that were eligible for inclusion in this review (justification given in Methods, section 3.4.1., page 46). However, this meant that some data in the reviewed articles were not evaluated. For example, Kohls et al. (2011; 2013; 2014) used an incentivised go/no-go task but only ‘go trials’ could be used to extract RT and response accuracy data (similar to other incentive delay paradigms). Although, information about response inhibition in relation to social reward anticipation could also give insight into reward processing in psychopathology.

Second, whilst meta-analytic and narrative evidence for specific hypoanticipation of social rewards across psychopathologies has been presented, it is possible that general psychomotor slowing associated with clinical illness (e.g., Morrens et al., 2007) contributes to the behavioural results reviewed here and should be accounted for in future research investigating social reward anticipation. Third, one of the studies reviewed (Pankert et al., 2014) manipulated the modalities of social reward available to include visual and auditory stimuli. The inclusion criteria for this review allowed for all sensory modalities of social reward. However, given that the number of studies with non-visual social rewards was so small, this review focused on visual stimuli only. However, auditory social rewards could also be important and so should be incorporated into future research. Similarly, others (Delmonte

et al., 2012; Demurie et al., 2011; Demurie et al., 2016; Dutra et al., 2015; Dutra et al., 2017; Gola et al., 2017; Hanewald et al., 2017 Sescousse et al., 2013) manipulated the magnitude of social rewards available, and Pankert et al. (2014) used familiar (mother) and unfamiliar (stranger) social rewards but investigating these in detail was beyond the scope of this review due to the small number of studies available.

Moreover, this review deliberately focused on psychopathology, but it is possible that reward anticipation is affected in other illnesses that do not have a recognised psychopathological component (e.g., Parkinson's Disease; Czernecki et al., 2002). Future meta-analyses of social reward anticipation in psychopathology could also formally assess the effect of the moderator variables identified above (e.g., gender, cognition) through statistical moderator analysis, which was beyond the scope of this meta-analysis due to the limited number of studies available for review. Finally, the small amount of data available for review on this topic limits confidence in some of its findings until they are confirmed and supported by future research.

3.9. Chapter Summary

The systematic and meta-analytic review presented in this chapter investigated atypical social reward processing, specifically social reward anticipation, across different clinical psychopathologies. Its findings revealed i) meta-analytic and descriptive evidence of reduced social reward processing (hypoanticipation, reflected in slower anticipatory RTs towards social rewards) in schizophrenia spectrum conditions, ASD, and ADHD, when comparing clinical and healthy groups, ii) correlational evidence for reduced subjective social reward processing associated with feelings of anhedonia or alexithymia, iii) potential evidence of social reward hyperanticipation in bipolar disorder, eating disorders, psychopathy, and sexual addiction disorders. The narrative synthesis of results also revealed that ASD, social anxiety disorder, and pathological gambling disorder may be associated with a more marked reduction in neural reward-circuit activity during social reward anticipation in comparison to non-social rewards.

3.10. Implications for Studies Presented in Chapters 4-7

This chapter has discussed several methodological implications for the empirical investigations presented across the remainder of this thesis (Chapters 4-7). First, the coming studies address critique regarding social reward stimuli by using the MSIDT and SRS-IDT, which were designed to provide a more ecologically valid representation of social reward subtype processing (see Chapter 2, section 2.4., page 37). Second, Chapters 4, 5 and 7 account for the potential effects of cognitive deficits and medication-use by including these in the participant exclusion criteria. Third, to examine gender effects on social reward

processing, Chapter 4 includes participant gender as a between-subjects variable within MSIDT analysis. Finally, the coming chapters include dimensional assessments of psychopathology, which the current chapter has identified as a need for social reward research, with the aim of examining whether the between-group findings observed in this chapter extend dimensionally. This begins with the next chapter (Chapter 4) which examines associations between dimensional psychopathology and self-report (SRQ) and behavioural (MSIDT) measures of social reward processing within a normative sample.

4. Social and Monetary Reward Processing in Dimensional Psychopathology

4.1. Chapter Aims and Overview

The previous chapter found that atypical social reward processing is a transdiagnostic characteristic of psychopathology in clinical groups versus healthy controls. This chapter aims to extend these findings by investigating possible associations between psychopathology and social reward processing, as predicted by the findings of the review reported in Chapter 3, using a dimensional approach. To do so, the empirical investigation reported in this chapter examines associations between dimensional measures of psychopathology and subjective and behavioural measures of social reward processing, namely the Social Reward Questionnaire (SRQ; Foulkes, Viding, et al., 2014) and the modified Monetary and Social Incentive Delay Task (MSIDT). Following the results of the review presented in the previous chapter, this study includes a comprehensive range of dimensional psychopathology measures, focusing specifically on schizophrenia spectrum traits, affective symptoms, psychopathic personality traits, borderline personality disorder traits, and autism spectrum disorder traits. These dimensional psychopathologies are the focus of this chapter following the description of atypical interpersonal behaviour in psychopathology provided in Chapter 1, section 1.5.4., page 29, and the findings that emerged from the systematic review and meta-analysis detailed in the previous chapter. The chapter includes a brief overview of social reward processing in the psychopathologies of interest, before presenting associations between dimensional psychopathology and subjective and experimental measures of social reward processing.

4.2. Introduction

Social interactions and interpersonal behaviours have the potential to be rewarding (Krach et al., 2010). As described in Chapter 1 section 1.3., page 17, Foulkes, Viding, et al. (2014) sought to categorise the reward value of different forms of social interaction and defined six subtypes of social reward: Admiration (receiving flattery and positive attention), Negative Social Potency (enjoyment of witnessing or causing cruelty to others), Passivity (letting others have control of a social interaction), Prosocial Interactions (mutual kind relationships), Sexual Relationships (frequent sexual experiences) and Sociability (being part of social situations).

As highlighted in the previous chapter, the influence of psychopathology on monetary reward processing is well-understood, with psychopathologies with a prominent anhedonic component demonstrating reduced processing (e.g., Der-Avakian & Markou, 2012) and those with a pronounced impulsivity component demonstrating heightened processing (e.g., Franken & Muris, 2006). However, how psychopathology influences social reward

processing is less clear. As shown in the previous chapter (review, Aldridge-Waddon et al., 2020), a small number of studies have shown that certain clinical groups demonstrate atypical processing of social rewards but, to develop those findings, it is important to examine whether this categorical (as per DSM or ICD systems) group difference (clinical vs control group) in social reward processing extends dimensionally across general-population mental health and personality traits.

4.2.1. Schizophrenia Spectrum Conditions

Schizophrenia spectrum traits, often referred to as schizotypal traits (Cohen et al., 2010), include positive (unusual experiences or beliefs), negative (lower motivation, feelings of low mood), and disorganised (odd or eccentric behaviours) behaviour dimensions. The negative dimension is most often associated with atypical social behaviour, such as a lack of engagement with social norms and lower motivation to be part of the social environment (Shim et al., 2008). Fulford et al. (2018) posit that these atypical social behaviours are associated with atypical social reward processing. Indeed, the meta-analysis in the previous chapter found that clinical populations with schizophrenia spectrum diagnoses demonstrate reduced behavioural processing (hypoanticipation) of social rewards in comparison to healthy controls with a medium effect size, and that this is most related to the negative aspect of clinical schizophrenia symptomatology. Examining this dimensionally within the general population, research (e.g., Xie et al., 2014) has shown that individuals with more prominent schizophrenia spectrum traits demonstrate reduced subjective and behavioural social reward processing. Therefore, it is important to supplement this existing work by further investigating subjective and behavioural processing of social rewards linked to dimensional schizophrenia spectrum traits.

As outlined in Chapter 1 (see section 1.5., page 24), there is increasing evidence to suggest that schizophrenia-like experiences are expressed along a continuum, with clinical schizophrenia lying at the most extreme end of the continuum and sub-clinical expressions (such as magical ideation, e.g., beliefs horoscopes or conspiracy theories) lying at the other end of the continuum (Kwapil & Barrantes-Vidal, 2015). Indeed, Nelson et al. (2013) propose a fully dimensional relationship between schizotypy and clinical schizophrenia, whereby researchers can assess schizophrenia spectrum traits in the general population and then infer that they represent similar (albeit less severe) constructs to those observed in clinical schizophrenia (Lezenweger, 2018). This continuum perspective on the schizophrenia spectrum means that it is justifiable for the present study to examine dimensional associations between schizophrenia spectrum traits and social reward processing, with the

aim of seeing how well the clinical results observed in the previous chapter extend down the schizophrenia spectrum towards sub-clinical expressions of schizophrenia phenomenology.

4.2.2. Affective Symptoms

At clinical levels, depression is marked by feelings of low mood, poor self-esteem, thoughts of self-harm, and low motivation. Besteher et al. (2020) add that depression can also be experienced dimensionally within the general population, with the melancholic aspects of depression, such as non-interactivity or social anhedonia (Gooding et al., 2015), lying at the more severe end of the depression continuum. Feelings of depression can have a strong negative effect on social behaviour, including interpersonal inhibition and shyness (Hames et al., 2013). As indicated in the previous chapter, this could be related to reduced social reward processing, as individuals with clinical depression demonstrate less wanting of social rewards (Brinkmann et al., 2014) and those who experience feelings of depression at a non-clinical level demonstrate reduced neurobiological social reward processing (Pechtel et al., 2013). Therefore, if social reward processing reduces alongside increases in feelings of depression, it will be important to contribute further evidence of how this corresponds to subjective and behavioural processing of social rewards in dimensional depression.

Dimensional features of feelings of anxiety include panic attacks, avoidance behaviour and anticipatory anxiety (Shear et al., 2007) and, as described in the previous chapter, feelings of anxiety (general or social) can lead to reduced motivation (Alden & Taylor, 2004) and reduced social cohesion and affiliation (Mathew et al., 2001). Social anxiety is a specific form of anxiety defined by a fear of different types of social situations, including anxiety about upcoming social interactions, social performance, or anxiety about being looked at or judged by others (Richey et al., 2017). From a reward perspective on social anxiety, Maresh et al. (2014) propose that individuals with clinical social anxiety process monetary rewards similarly to healthy individuals but argue that the reward system may be specifically affected during social scenarios (Richey et al., 2014). The meta-analysis in the previous chapter revealed no significant differences between clinical (social anxiety) and control groups on behavioural social reward anticipation but did highlight that, in comparison to the control group, individuals with clinical social anxiety demonstrate neural hypoanticipation of social rewards (Richey et al., 2014). By examining the influence of dimensional feelings of anxiety (both general and social anxiety) on subjective and behavioural social reward processing, this study can, therefore, refine current understanding of the links between feelings of general and social anxiety and subjective/behavioural processing of both social and monetary rewards.

It is important to note that, unlike the schizophrenia spectrum, psychopathy, or borderline personality disorder, affective symptoms reflect a state (i.e., current mood) rather than trait (i.e., consistent across contexts over time) but can still be expressed and measured dimensionally (Ahmed et al., 2011). For example, the Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) was designed for use in non-clinical populations and has since been validated cross-culturally as a dimensional assessment of affective symptoms (e.g., Crawford et al., 2009; Norton, 2007). It is, therefore, appropriate for the present study to assess affective symptoms dimensionally and then explore their associations with subjective and behavioural measures of social reward processing.

4.2.3. Psychopathic Traits

Psychopathy is an aspect of personality that includes a cluster of traits such as a lack of empathy, superficial charm, sensation-seeking, and antisociality (Hare, 2003). Psychopathy is conceptualised both taxonomically (using cut-offs on measures of clinical psychopathy such as the Psychopathy Checklist – Revised; Hare, 2003) and dimensionally (via continuous measures of psychopathic traits; Edens et al., 2006). When assessing psychopathy dimensionally, studies (reviews., Sellbom & Drislane, 2008; Wright, 2009) sample participants from the general population and then infer that the features of clinical psychopathy (extreme impulsivity and irresponsibility, for example) vary in degree and kind from normality, rather than representing isolated constructs that can only be assessed in clinical/forensic populations. Thus, assessing psychopathy dimensionally in normative populations is a popular approach within psychopathy and personality research (e.g., Sellbom et al., 2018) that provides insight into how psychopathic traits might be linked to a range of psychosocial outcomes, in this case social reward processing (e.g., Foulkes, McCrory et al., 2014).

Both taxonomic and dimensional approaches have shown that psychopathy is associated with increased processing of monetary rewards. For example, in their review the neural bases of monetary reward responding in psychopathy, Murray et al. (2018) showed that psychopathy is associated with increased ventral striatum and prefrontal cortex activity during monetary reward anticipation; and they suggest that increased neural activity during monetary reward processing is most related to the impulsive, lifestyle, and antisocial aspects of psychopathy (Carré et al., 2013). However, whether this increased processing of monetary rewards in psychopathy translates to social rewards is unclear. As described previously, the dimensional features of psychopathy (superficial charm, grandiosity, manipulativeness, callousness) indicate that individuals with more prominent psychopathic traits might extract heightened feelings of social reward from social interactions that include

opportunities for admiration or cruelty to others (Waller & Wagner, 2019; White, 2014). Similarly, it could be that the sensation-seeking aspect of the Lifestyle dimension, which is associated with increased monetary reward processing, is associated with increased processing of social rewards also. However, despite these theoretical associations, to-date only Foulkes, McCrory, et al. (2014) have investigated links between social reward processing and psychopathic traits. As reviewed in the previous chapter, they found associations between dimensional psychopathy and atypical subjective social reward processing, as well as behavioural evidence of increased preference for social rewards linked specifically to the Interpersonal dimension. Thus, the current study aims to develop the findings of Foulkes, McCrory, et al. (2014) and further investigate relationships between dimensional psychopathy and subjective and behavioural measures of social reward processing.

4.2.4. Borderline Personality Disorder Traits

Borderline personality disorder (BPD) traits are associated with a tendency towards self-damaging behaviours and difficulties with response regulation (Stepp & Pilkonis, 2008) that can negatively affect the quality and nature of interpersonal relationships (Furnham et al., 2014). It may be that these behaviours stem from the interaction between the impulsivity dimension of BPD and heightened biobehavioural reward anticipation, as illustrated with work with monetary rewards in BPD previously (e.g., Lawrence et al., 2010; Paris, 2018). As described in the previous chapter, in their investigation of social reward processing in BPD individuals versus controls, Doell et al. (2020) found that the BPD group demonstrated increased activity within reward-related brain areas during social reward anticipation and showed atypical neural responses within frontolimbic regions during social reward consumption. Doell et al. (2020) posit that this atypical social reward processing manifests in the atypical social behaviours that characterise clinical BPD, including a tendency to form intense and volatile interpersonal relationships (Furnham et al., 2014).

As detailed in Chapter 1, section 1.5., page 24, the shift from categorical to dimensional approaches has had a crucial (beneficial) impact on how BPD is conceptualised and assessed (Hopwood et al., 2018). This increased dimensional understanding (Paris, 2018) has increased the use of continuous scales based on severity (e.g., PID-5) in BPD assessment (Hopwood et al., 2018), rather than binary judgements of presence or absence. From a research perspective, studies increasingly incorporate dimensional self-report measures of BPD traits developed in the general population, such as the Borderline Personality Questionnaire (Poreh et al., 2006), which position BPD traits on a continuum of normative personality functioning through to extreme, perhaps maladaptive, functioning.

Therefore, the present study follows this dimensional perspective and explores associations between self-reported dimensional BPD traits and social reward processing. Currently, Doell et al. (2020) is the only study to investigate social reward processing in BPD – which employed a categorical approach (see Chapter 3, section 3.5.4., page 57) - and so this study extends their research and examines dimensional relationships between BPD traits and subjective and behavioural measures of social reward processing.

4.2.5. Autism Spectrum Disorder

Autism spectrum disorder (ASD) traits are characterised by difficulties with social cognition and perspective-taking. By virtue of its conceptualisation as a spectrum condition, there is recognition that ASD varies dimensionally, with normative expressions of ASD traits observed across sub-clinical domains in the general population (Abu-Akel et al., 2019). The present study therefore focuses on sub-clinical expressions of ASD traits and examines self-reported ASD traits within a general population sample.

The interpersonal difficulties associated with more pronounced ASD traits can lead to atypical social behaviour, which social motivation theory (Chevallier et al., 2012) posits may be linked to reduced feelings of reward prior to, and during, social interaction. Chevalier et al. (2012) argue that this reduced social reward processing influences the trajectory of ASD trait development by reducing social motivation and learning, which negatively impacts the development of social brain circuitry. To this end, Sepeta et al. (2012) found that children with more pronounced ASD traits demonstrated less enhanced pupillary responses towards social faces (happy facial expressions). Similarly, Gossen et al. (2014) showed that male adults with lower levels of social proficiency [those scoring low on the Empathy Quotient (Baron-Cohen & Wheelwright, 2004) with a similar social skills profile to those with a formal ASD diagnosis] demonstrated less activity in reward-related brain areas when processing social rewards. The review in the previous chapter found narrative and meta-analytic evidence of reduced social reward processing (hypoanticipation) in clinical ASD groups in comparison to controls, and thus this study investigates how the results of between-group studies translate dimensionally in the general population at subjective and behavioural levels.

4.2.6. Transdiagnostic Approach

In their review of clinical social anhedonia, Barkus and Badcock (2019) advocate transdiagnostic approaches when investigating interpersonal behaviour in psychopathology and emphasise that a more nuanced understanding of the links between symptomatology and social reward processing is needed. This call for transdiagnostic approaches is echoed

in Stanton et al. (2020), who recently highlighted that research should employ a comprehensive battery of dimensional measures of psychopathology, which are then jointly examined in relation to the outcome of interest. For reward processing, this transdiagnostic dimensional approach enables the precise examination of relationships between shared dimensional traits and subjective, behavioural, and neuroimaging measures of social reward processing (Aldridge-Waddon et al., 2020). This study, therefore, includes a transdiagnostic component and examines relationships between transdiagnostic features of dimensional psychopathology and social reward processing.

4.3. Rationale and Aims

This study investigated the influence of dimensional psychopathology on subjective and behavioural measures of social reward processing. It aimed to provide dimensional self-report and behavioural data to compliment the findings of the systematic review and meta-analyses described in Chapter 3. As such, this study aimed to show that individuals with higher levels of schizophrenia spectrum traits, affective symptoms, or ASD traits demonstrate reduced processing of social rewards, indexed using subjective and behavioural measures. It also aimed to clarify whether individuals with more prominent psychopathic or BPD traits demonstrate increased processing of social rewards. Finally, this study aimed to provide further behavioural evidence that psychopathologies with an elevated impulsivity component are associated with increased processing monetary rewards. It assessed subjective processing of social rewards through the SRQ (Foulkes, Viding, et al., 2014), and tested behavioural processing experimentally using the modified MSIDT described in Chapter 2, section 2.4.1., page 38.

Specifically, this study tested the following hypotheses:

1. Schizophrenia spectrum traits, affective symptoms (specifically depression and social anxiety), and ASD traits will be associated with reduced subjective processing of social rewards involving Prosocial Interactions or Sociability.
2. Schizophrenia spectrum and ASD traits will correlate with reduced behavioural processing (hypoanticipation) of social rewards, reflected in slower reaction times (RTs) or response accuracy towards social rewards.
3. Psychopathic traits will positively correlate with subjective processing of social rewards involving Admiration and Negative Social Potency. They will also be associated with reduced subjective processing of Prosocial Interactions.

4. Psychopathic traits related to interpersonal behaviour (i.e., Interpersonal dimension) will be associated with increased behavioural processing (hyperanticipation) of social rewards.
5. The impulsivity aspect of schizophrenia spectrum, psychopathic, and BPD traits will be associated with increased behavioural processing (hyperanticipation) of monetary rewards.

In addition to these hypothesised associations, this research study also included an exploratory transdiagnostic approach which aimed to identify transdiagnostic dimensions of psychopathology (using exploratory factor analysis; EFA) and test their associations with social reward processing. This was with the aim of corroborating the transdiagnostic evidence of atypical social reward processing presented in the previous chapter (see Chapter 3, section 3.5.11., page 62). Given that this was an exploratory analysis, no hypotheses were made regarding which transdiagnostic dimensions would emerge from the EFA, nor how these dimensions would be associated with subjective and behavioural measures of social reward processing.

4.4. Materials and Methods

4.4.1. Ethics Statement

All procedures were approved by the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS), Brunel University London (ID: 16789). All participants provided informed consent prior to participating in the study. All participants were compensated for their time and could choose between university course credits (4) or an amazon voucher (£10).

4.4.2. Participants and Procedure

One hundred and fifty-four participants (36 male-identifying, 114 female-identifying, 4 gender non-binary) were recruited into this study via volunteer sampling. The mean age of the sample was 21.76 (SD = 6.08, range = 18-55). Sixty-one percent of the sample reported English as their first language, and 71.9% of the sample reported studying at undergraduate or postgraduate levels of education. Exclusion criteria included: (1) evidence of current or previous mental illness diagnoses, (2) evidence of current or previous serious head injury or neurological injury, (3) current and/or recent illicit substance dependence, and (4) current use of psychotropic medications that may affect neurocognitive functioning. All exclusion criteria were assessed via self-report during participant screening.

All participants completed all measures in one research session, which took place at a university psychology laboratory or online (n = 81 participated in laboratory, n = 73 participated online). After familiarising themselves with the aims and purpose of the research, participants provided informed consent and then completed the MSIDT followed by the self-report measures of psychopathology and the SRQ.

4.4.3. Self-Report Measures of Psychopathology

This research included dimensional measures of psychopathology designed to capture schizophrenia spectrum traits, affective symptoms (including feelings of depression, general anxiety, stress, and social anxiety), psychopathic traits, BPD traits, and ASD traits. All measures are intended for use in the general population and do not constitute a formal clinical assessment. Each of the measures is structured so that higher scores indicate more pronounced traits. The participants completed the self-report measures via the online platform, Qualtrics.

Schizophrenia spectrum traits were assessed using the brief revised version of the Schizotypal Personality Questionnaire (SPQ-BR; Cohen et al., 2010). It has 32 items which are rated on a five-point Likert scale (0 = Strongly disagree, 4 = Strongly agree). It has three subscales, capturing the dimensions of schizotypy as described (originally) in DSM III: Cognitive-Perceptual, Interpersonal, and Disorganised. The measure has reasonable reliability (Davidson et al., 2016) and demonstrates good criterion validity when predicting personal or family psychiatric history (Davidson et al., 2016).

Affective symptoms were assessed dimensionally using the Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) and the Social Phobia Inventory (SPIN; Connor et al., 2000). DASS-21 includes 21 items, split evenly across Depression, Anxiety, and Stress dimensions. It presents participants with a series of statements describing their mood over the last week and asks them to rate the degree to which the statements apply to them on a four-point Likert scale (0 = “Did not apply to me at all, 3 = “Applied to me very much or most of the time”). DASS-21 is described as an accurate and valid measure of feelings of depression, anxiety, and stress (Crawford & Henry, 2003) that has a more refined factor structure (Clara et al., 2001) than the extended 42-item Depression, Anxiety and Stress Scale (Lovibond & Lovibond, 1995).

Feelings of social anxiety were assessed via the 17-item Social Phobia Inventory (SPIN; Connor et al., 2000). The items include statements about how often the participant has been bothered by feelings of social anxiety over the last week. The participant gives their responses to the items on a five-point Likert scale (0 = Not at all, 4 = Extremely) and responses are totalled to give a total score for social anxiety. The measure has good test-

retest reliability (Connor et al., 2000) and has acceptable convergent and discriminant validity when compared to similar measures (Antony et al., 2006).

Psychopathic traits were assessed using the Self-Report Psychopathy Scale 4 Short Form (SRP-4-SF; Paulhus et al., 2016). It includes 29 items and collects participant responses on a five-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). The scale generates a total score for overall level of psychopathic traits and includes scores for each of the four dimensions of psychopathy reported by Hare (2003): Interpersonal, Affective, Lifestyle and Antisocial. The SRP-4-SF is described as an accurate measure of dimensional psychopathic traits (Paulhus et al., 2016) that is strongly correlated with both clinical measures of psychopathy (e.g., PCL-R; Tew et al., 2015) and other measures of psychopathic traits that are designed for use in the normative population (e.g., Lynam et al., 2011).

BPD traits were measured using the Borderline Personality Questionnaire (BPQ; Poreh et al., 2006). The measure contains 80 items which are rated by the participant as True (1) or False (0). The BPQ develops other measures of BPD symptomatology by including nine BPD dimensions (Impulsivity, Affective Instability, Abandonment, Relationships, Self-Image, Suicide/Self-Mutilation, Emptiness, Intense Anger, and Quasi-Psychotic States), rather than the traditional four (Affective Instability, Identity Problems, Negative Relationships and Self-Harm; Distel et al., 2010), and it has a good level of convergent validity with other measures of BPD traits such as the Minnesota Multiphasic Personality Inventory – 2 (Furnham et al., 2014).

ASD traits were assessed using the Autism Quotient (AQ; Baron-Cohen et al., 2001). The Autism Quotient comprises 50 items and asks the participant to indicate how much they agree with each item on a four-point Likert scale. The measure is scored using 1 or 0 per item, with a 1 given any time a non-neurotypical response is endorsed. The AQ generates a total score and scores for the ASD dimensions individually (Social skills, Details/Patterns, Communication/Mindreading; Hurst et al., 2007; Russell-Smith et al., 2011). The measure has acceptable reliability (Baron-Cohen et al., 2001) and is one of the more popular and useful measures of ASD traits in the general population (Austin, 2005; Hurst et al., 2007).

4.4.4. Subjective Social Reward Processing

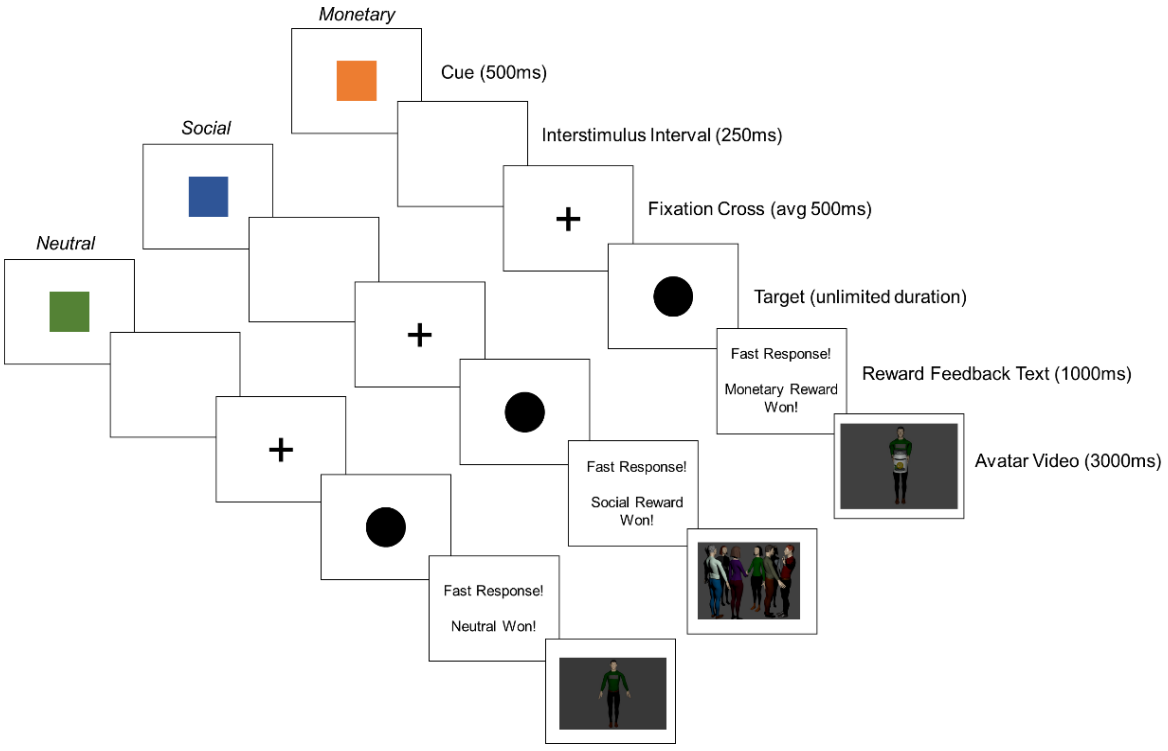
Subjective social reward processing was assessed via the SRQ (Foulkes, Viding, et al., 2014). The measure has 23 items which span the six different subtypes of social reward described in Chapter 1: Admiration, Negative Social Potency, Passivity, Prosocial Interactions, Sexual Relationships, and Sociability. Responses are collected via a six-point Likert scale (Strongly disagree = 1, Strongly agree = 7). Detailed information on the SRQ is provided in Chapter 2, section 2.2.1., page 32.

4.4.5. Behavioural Processing of Monetary and Social Rewards

The MSIDT was used as a behavioural measure of social reward processing. The development of the task and its parameters is described in detail in Chapter 2, section 2.4.1., page 38. It is designed to assess behavioural anticipation of monetary rewards, social rewards, and neutral stimuli (12 trials per stimuli type). This research employed a modified version of the traditional incentive delay paradigm in which participants could win monetary or social rewards for an avatar which were presented via animated video (Figure 4.1). Participants selected which avatar they wanted to represent themselves as prior to the start of the first trial, and they were encouraged to relate to the avatar as much as possible.

Monetary rewards showed the avatar receiving a coin into a money jar which was accompanied by the sound of a cash register. Social rewards showed the avatar engaging in four different subtypes of social reward (Admiration, Negative Social Potency, Passivity and Sociability), each accompanied by a matching sound (e.g., Admiration = Video of avatar receiving applause from a crowd, accompanied by sound of clapping and cheering). Neutral stimuli showed the avatar stood stationary in the centre of the screen and were accompanied by a neutral tone. All rewards were administered via video and no actual reward was associated with task performance.

Figure 4.1. Monetary and Social Incentive Delay Task



Each trial began with the presentation of a cue which indicated the type of reward that was available. This was followed by a target, which the participant had to respond to within the predefined RT threshold to obtain the reward. Like the original Knutson et al. (2000) incentive delay task, task performance was calibrated with the participants' individual RT by setting the RT threshold during the practice trials (threshold defined as mean RT across practice trials). As described in Chapter 2, this follows other studies (e.g., Wang et al., 2017) that have set a bespoke RT threshold rather than setting it trial-by-trial or at a precise value (e.g., 500ms; Demurie et al., 2011). The participant obtained the reward if they responded to the target faster than their individual RT threshold. Pixelated videos accompanied by the sound of radio static were shown following any misses, and the participant was prompted to respond faster to obtain the available rewards.

As illustrated in Figure 4.1, each trial had a six-part sequence with a 500ms interval between trials: (1) cue (500ms), (2) interstimulus interval (250ms), (3) fixation cross (jittered duration, average 500ms), (4) target (unlimited duration), (5) reward feedback text (1000ms), and (6) reward feedback video (3000ms). The reward types were intermixed and there were twelve trials per reward type.

4.4.5.1. Indexing Task Performance on the modified MSIDT

Processing of the reward types in the MSIDT was indexed through RT and response accuracy (%), with faster RTs and greater response accuracy indicating increased reward processing (Knutson et al., 2000). In addition to raw measures of RT and response accuracy, reward difference scores were calculated to compare processing of the reward types relative to one other. These reward difference scores were calculated by subtracting the task performance metrics from one another. The calculations were arranged so that positive values indicated increased processing of social rewards relative to monetary rewards, monetary rewards relative to neutral, and social rewards relative to neutral.

4.4.6. Data Screening

All data screening was performed using SPSS Version 26. Data were first checked for missing values, presence of outliers, and normality of distribution. Aside from SPIN, which was only completed by a subset of participants (n = 80), all participants completed all self-report measures of psychopathology (n = 154). However, one participant's SPQ-BR data had to be removed due to missing values, reducing the sample size for this specific measure to n = 153. Similarly, SRQ subscale scores could not be calculated for the full sample due to missing values (Admiration: n = 152, Negative Social Potency: n = 152; Passivity: n = 152; Prosocial Interactions: n = 152; Sexual Relationships: n = 149; Sociability: n = 151). Fourteen participants provided incomplete MSIDT data and thus were not included in the

task data analyses. Furthermore, after assessing the presence of outliers through boxplots, participants who recorded a mean RT ≥1000ms for any of the reward types had to be excluded from the MSIDT analyses. This affected five participants, leaving a final sample of n = 135 for task data analyses. A series of Shapiro-Wilk tests were run to assess the distribution of the data (non-normally distributed variables: SPQ Cognitive-Perceptual, DASS-21 Depression, DASS-21 Anxiety, SPIN total, SRP-4-SF Interpersonal, SRP-4-SF Affective, SRP-4-SF Antisocial, All BPQ Subscales, AQ Social Skills, AQ Details/Patterns, AQ Communication/Mindreading, All SRQ subscales, All MSIDT Variables).

4.4.7. Data Analyses

There were several stages to the analyses, which were performed using SPSS Version 26 with statistical significance set at $p = .05$ unless specified otherwise. First, the sample was fully characterised on data from the self-report measures of psychopathology, the subjective measure of social reward processing (SRQ), and the behavioural measure of reward processing (MSIDT). Second, correlational analyses (Pearson's *r* for normally distributed variables, and Spearman rank order correlations for non-normally distributed variables) were computed to test intra-correlations between the self-report measures of psychopathology. Third, main effects of reward type on MSIDT task performance (n = 135) were tested via a series of repeated measures ANOVAs, using RT and response accuracy per reward type (monetary, social, neutral) as the dependent variable. Gender was first entered as a between-subjects variable (male-identifying or female-identifying) in this comparison and then was removed if no significant main or interaction effects were found. The Greenhouse-Geisser correction was applied in all instances of the sphericity assumption being violated (results include corrected *p* value when correction applied). Statistically significant main and interaction effects were examined post-hoc using the Bonferroni correction. Effect sizes were calculated as partial eta squared (η^2_p) and interpreted as small ($\eta^2_p = .01$), medium ($\eta^2_p = .06$), and large ($\eta^2_p = .140$) (Cohen, 1992).

To investigate the first and third hypotheses, relationships between self-report measures of psychopathology and subjective processing of social rewards (as measured by SRQ) were tested via zero-order correlational analyses. To investigate the second, fourth and fifth hypotheses, associations between self-reported psychopathology and behavioural processing of rewards (MSIDT metrics) were tested using zero-order correlational analyses. These zero-order correlations were computed both with and without Hochberg correction (Hochberg, 1988). Hochberg correction is a popular step-up adjustment method in which *p* vales are assigned ranks from largest-smallest and then multiplied by the number of remaining ranks (n-1 with each computation e.g., $p = .023 * 10$, $p = .019 * 9$ etc.). Correcting

the *p* value via the Hochberg correction accounts for multiple comparisons (in this case multiple correlations) whilst retaining meaningful significant results (Menyhart et al., 2021; Chen et al., 2017). The correction was calculated by ranking the *p* values of correlations between dimensions of psychopathology and outcome separately, for example ranking all *p* values of correlations between psychopathology subscale scores and response accuracy towards social rewards on the MSIDT. Both uncorrected and corrected *p* values are reported in-text where relevant, with corrected values entered as "survived/did not survive correction, *p*^ =". As much of the work and hypotheses tested here are novel, the interpretation of results given in the discussion section (section 4.6., page 104) includes the uncorrected results. This is to provide a broader picture of possible associations between dimensional psychopathology and subjective and behavioural social reward processing, rather focusing on corrected results only. Having said that, the large number of correlations being run should be borne in mind during interpretation, and the methods employed here should be replicated in larger samples before accepting the uncorrected or corrected results conclusively.

4.4.7.1. Identifying Transdiagnostic Dimensions

An exploratory factor analyses (EFA) was used to collate the subscales of the self-report measures of dimensional psychopathology and identify their shared diagnostic dimensions. A series of EFA models were computed, refining the model each time based on initial eigenvalues and scree plots. The first model included 22 subscales from eight of the questionnaires used in this study. SPIN scores were not included as the measure was only completed by a subset of participants. Psychopathology measure subscales that were completed by all participants (n = 153) were included in the model. Recommendations given in Osborne et al. (2011), Mundfrom et al. (2005), and Gorsuch (1983) suggest that sample size should be at least five times greater than the number of observed variables. Thus, as the model included 22 observed variables with 153 participants, conducting EFA with this dataset was deemed appropriate, with the important caveat that the model structure should be replicated in larger samples before being accepted conclusively.

The subscale scores were loaded as a principal axis factoring model with promax rotation to allow for correlations between subscale scores and to account for the non-normal distribution of some variables (Osborne et al., 2011). The model was systematically revised and refined over the course of five runs, and each time the quality of the model was improved by the removal of highly cross-loading subscales (loadings within .20 of one another; Field, 2013), removing subscales with a primary loading of less than .30, and removing factors with less than three adequately loading subscales (Worthington & Whittaker, 2006). The final EFA model is presented in the results section.

Confirmatory Factor Analysis (CFA) was computed using SPSS Amos Version 26. CFA was run to confirm the validity and structure of the transdiagnostic EFA model described above. Following guidelines given in West et al. (2012), Kline (2010) and Hooper et al. (2008), model fit was established using the following tests of relative model fit: Root Mean Square Error of Approximation (RMSEA; good fit value ≤.08), the Comparative Fit Index (CFI; good fit value ≥.90), and the Tucker–Lewis index (TLI; good fit value ≥.95). As with the EFA, the CFA was modelled using data from the participants with complete questionnaire data (n = 153) and modification indices were included to account for highly correlated variables.

4.5. Results

4.5.1. Characterisation of Psychopathology

Mean and range scores for the full sample on each of the self-report measures of psychopathology are presented in Table 4.1.

Table 4.1. Scores on Self-Report Measures of Psychopathology for Full Sample

	Mean (SD)	Observed Range (Possible Range)	N
Schizophrenia Spectrum Traits			
SPQ-BR Cognitive-Perceptual	19.14 (10.32)	0-48 (0-56)	153
SPQ-BR Interpersonal	19.47 (8.48)	0-39 (0-40)	153
SPQ-BR Disorganised	16.08 (7.02)	0-32 (0-32)	153
Mood Disorder Symptoms			
DASS-21 Depression	6.54 (5.40)	0-21 (0-21)	154
DASS-21 Anxiety	5.66 (4.94)	0-21 (0-21)	154
DASS-21 Stress	7.06 (4.66)	0-20 (0-21)	154
SPIN Total	23.74 (13.64)	2-52 (0-68)	80
Psychopathic Traits			
SRP-4-SF Interpersonal	13.38 (5.34)	7-29 (7-35)	154
SRP-4-SF Affective	13.60 (4.61)	7-30 (7-35)	154
SRP-4-SF Lifestyle	15.32 (5.19)	7-29 (7-35)	154

SRP-4-SF Antisocial	10.21 (3.18)	7-22 (7-35)	154
SRP-4-SF Total	53.08 (15.47)	30-97 (29-145)	154
BPD Traits			
BPQ Impulsivity	1.82 (1.72)	0-8 (0-9)	154
BPQ Affective Instability	5.05 (3.10)	0-10 (0-10)	154
BPQ Abandonment	2.58 (2.25)	0-9 (0-10)	154
BPQ Relationships	3.09 (2.19)	0-8 (0-8)	154
BPQ Self-Image	3.33 (2.98)	0-9 (0-9)	154
BPQ Suicide/Self-Mutilation	1.37 (1.83)	0-7 (0-7)	154
BPQ Emptiness	3.89 (3.11)	0-10 (0-10)	154
BPQ Intense Anger	3.06 (2.91)	0-9 (0-10)	154
BPQ Quasi-Psychotic States	1.40 (1.51)	0-6 (0-7)	154
ASD Traits			
AQ Social Skills	4.74 (3.37)	0-13 (0-13)	154
AQ Details/Patterns	3.50 (1.96)	0-7 (0-7)	154
AQ Communication/Mindreading	2.34 (1.94)	0-8 (0-8)	154
AQ Total	19.24 (6.62)	0-35 (0-50)	154

The intra-correlations between self-report measures of psychopathology are presented in Table 4.2. Results suggested that many of the dimensions were at least moderately positively correlated with one another (r_s or r > .30; Field, 2010). Strong positive correlations (r_s or r > .60; Field, 2010) across diagnostic categories included SPQ-BR Interpersonal and SPIN, r_s = .77, p = <.001, SPQ-BR Interpersonal and BPQ Emptiness, r_s = .70, p = <.001, SPQ-BR Interpersonal and BPQ Self-Image, r_s = .63, p = <.001, and SPQ-BR Interpersonal and AQ Social Skills, r_s = .64, p = <.001. Strong correlations were also observed between BPQ Emptiness and both DASS-21 Depression, r_s = .63, p = <.001, and SPIN, r_s = .63, p = <.001, scores. SPIN and AQ Social Skills scores were also highlighted correlated, r_s = .60, p = <.001. These correlations indicate that these dimensions may share some phenotypic

similarities, such as social anhedonia or social anxiety (Lis & Bohus, 2013; Spek & Wouters, 2010). Of course, strong positive correlations were also observed within diagnostic categories (for example, strong positive correlations between DASS-21 dimensions).

4.5.2. Task Performance

As summarised in Chapter 1, previous research (e.g., Spreckelmeyer et al., 2009) has reported gender differences in the processing of social rewards. Therefore, to account for these differences and investigate interaction effects between gender and task performance, task performance analyses were first computed with gender entered as a between-subjects variable (male n = 33, female n = 98). No significant interaction effect between gender and anticipatory RT was found F (1.75, 226.19) = 1.29, p = .277, η_p^2 = .01. This was also the case for response accuracy, F (2, 258) = 2.93, p = .055, η_p^2 = .02. Gender was thus not included as a between-subjects variable within subsequent analyses.

4.5.2.1. Main Effects

The mean task performance data are presented in Figures 4.2 and 4.3 below. A significant main effect of reward type on anticipatory RT was found, F (1.76, 236.09) = 8.34, p = .001, η_p^2 = .06. Post hoc pairwise comparisons with Bonferroni correction applied showed this effect to be driven by significantly faster RTs towards monetary rewards (M = 266.74 ± 98.88) than neutral stimuli (M = 299.80 ± 117.79). However, no significant difference in RT towards social rewards versus neutral stimuli was found. A significant main effect of reward type on response accuracy was also found F (2, 268) = 27.75, p = <.001, η_p^2 = .17. Post-hoc tests with Bonferroni correction applied found significantly greater response accuracy towards monetary rewards (M = 71.42 ± 22.15) than neutral stimuli (M = 61.23 ± 25.28), and social rewards (M = 70.80 ± 20.77) than neutral stimuli (M = 61.23 ± 25.28). Together, the RT and response accuracy suggest that the task functioned as expected (with greater behavioural anticipation of rewards than neutral stimuli) and that participants demonstrated similar levels of behavioural anticipation for both monetary and social rewards.

Figure 4.2. Mean Anticipatory Reaction Time per Reward Type with 95% CI Error Bars (ms)

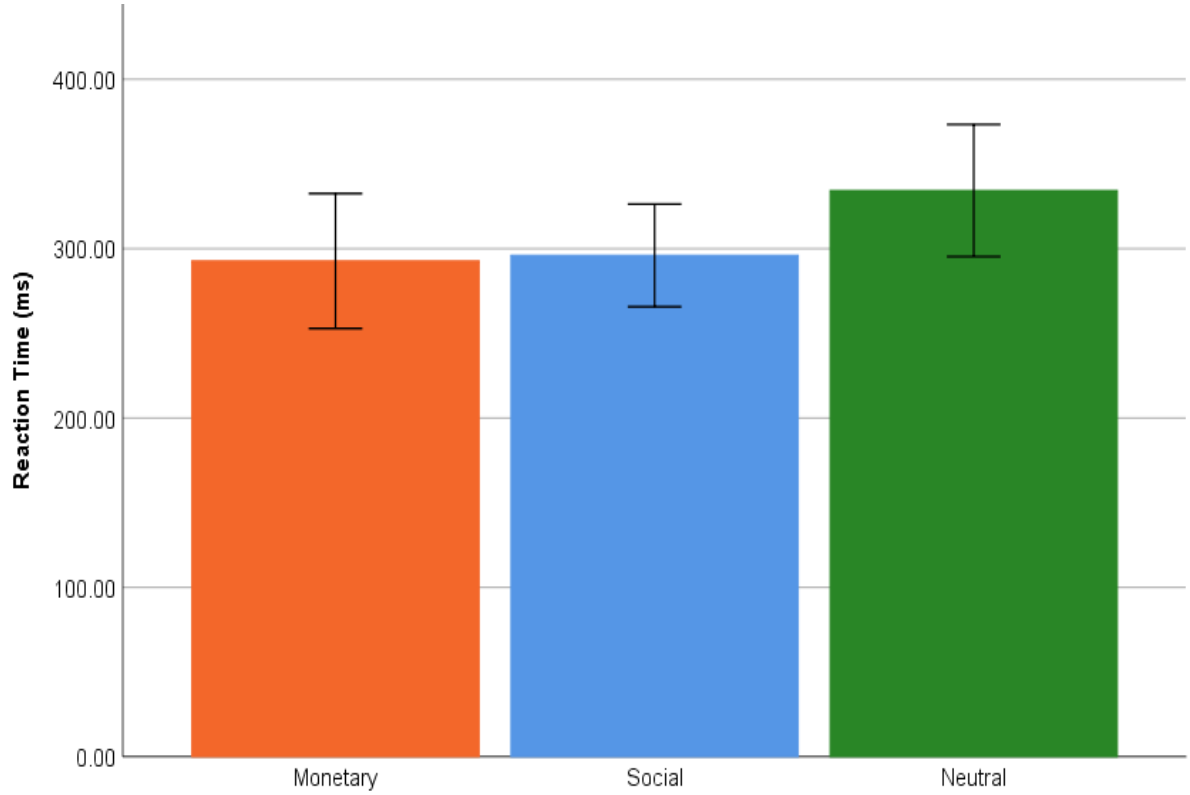


Figure 4.3. Mean Anticipatory Response Accuracy per Reward Type with 95% CI Error Bars (%)

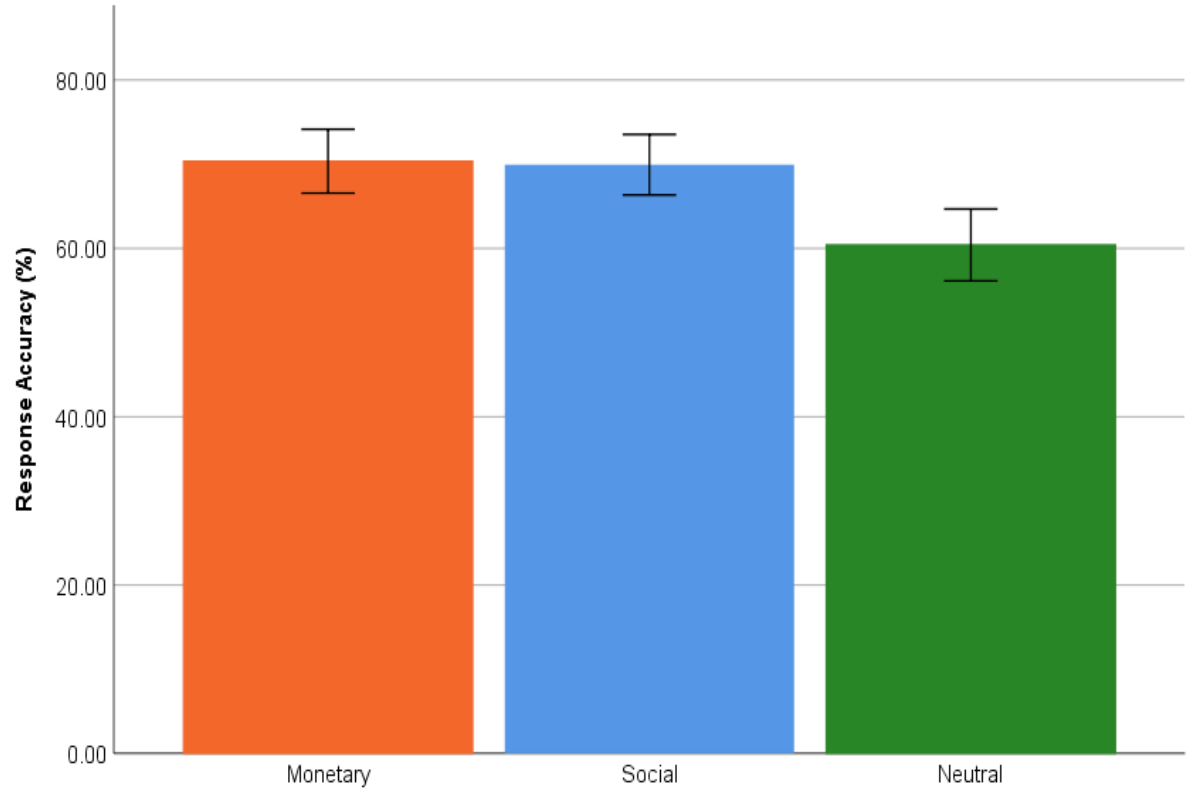


Table 4.2. Intra-Correlations Between Dimensional Measures of Psychopathology

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. SPQ Cognitive-Perceptual	-	.51**	.52**	.42**	.58**	.51**	.54**	.42**	.37**	.26**	.26**	.39**	.28**	.55**	.54**	.53**	.40**	.33**	.43**	.43**	.58**	.17*	.34**	.09	.36**
2. SPQ Interpersonal	.51**	-	*.48***	.58**	.45**	*.53***	.77**	.20*	.26**	*.13*	.04	*.25***	.20*	.51**	.57**	.46**	.63**	.33**	.70**	.37**	.23**	.64**	.09	.20*	*.58***
3. SPQ Disorganised	.52**	*.48***	-	.39**	.39**	*.45***	.25*	.44**	.33**	*.47***	.17*	*.45***	.50**	.37**	.39**	.29**	.30**	.20*	.44**	.37**	.29**	.18*	.07	.22**	*.29***
4. DASS-21 Depression	.42**	.58**	.39**	-	.60**	.65**	.52**	.29**	.26**	.20*	.09	.27**	.31**	.56**	.52**	.40**	.59**	.39**	.63**	.42**	.25**	.34**	.06	.23**	.42**
5. DASS-21 Anxiety	.58**	.45**	.39**	.60**	-	.75**	.52**	.30**	.27**	.16	.26**	.28**	.28**	.48**	.47**	.47**	.32**	.35**	.40**	.40**	.38**	.25**	.18*	.17*	.35**
6. DASS-21 Stress	.51**	*.53***	*.45***	.65**	.75**	-	.47**	.35**	.24**	*.22***	.24**	*.32***	.27**	.56**	.46**	.40**	.36**	.42**	.44**	.47**	.25**	.27**	.10	.09	*.34***
7. SPIN Total	.54**	.77**	.25*	.52**	.52**	.47**	-	.15	.18	.02	.08	.14	.01	.54**	.55**	.44**	.57**	.31**	.63**	.39**	.23*	.60**	.02	.15	.55**
8. SRP-4-SF Interpersonal	.42**	.20*	.44**	.29**	.30**	.35**	.15	-	.71**	.66**	.49**	.89**	.41**	.30**	.31**	.21**	.16*	.28**	.21**	.29**	.36**	.07	.21**	.20*	.20*
9. SRP-4-SF Affective	.37**	.26**	.33**	.26**	.27**	.24**	.18	.71**	-	.66**	.43**	.86**	.39**	.27**	.30**	.25**	.11	.12	.16*	.26**	.30**	.10	.10	.14	.19*
10. SRP-4-SF Lifestyle	.26**	*.13*	*.47***	.20*	.16	*.22***	.02	.66**	.66**	-	.47**	*.85***	.56**	.14	.27**	.17*	.11	.18*	.15	.25**	.25**	-.11	.09	.12	*-.01*
11. SRP-4-SF Antisocial	.26**	.04	.17*	.09	.26**	.24**	.08	.49**	.43**	.47**	-	.64**	.32**	.11	.15	.11	-.02	.24**	-.04	.10	.18*	-.07	.18*	.15	.06
12. SRP-4-SF Total	.39**	*.25***	*.45***	.27**	.28**	*.32***	.14	.89**	.86**	*.85***	.64**	-	.52**	.26**	.33**	.23**	.12	.25**	.17*	.29**	.33**	.00	.17*	.18*	*.15*
13. BPQ Impulsivity	.28**	.20*	.50**	.31**	.28**	.27**	.01	.41**	.39**	.56**	.32**	.52**	-	.31**	.41**	.22**	.24**	.32**	.31**	.32**	.21**	.01	.08	.24**	.13

14. BPQ Affective Instability	.55**	.51**	.37**	.56**	.48**	.56**	.54**	.30**	.27**	.14	.11	.26**	.31**	-	.57**	.51**	.50**	.45**	.66**	.64**	.44**	.31**	.19*	.07	.40**
15. BPQ Abandonment	.54**	.57**	.39**	.52**	.47**	.46**	.55**	.31**	.30**	.27**	.15	.33**	.41**	.57**	-	.64**	.52**	.42**	.59**	.46**	.35**	.35**	.24**	.32**	.55**
16. BPQ Relationships	.53**	.46**	.29**	.40**	.47**	.40**	.44**	.21**	.25**	.17*	.11	.23**	.22**	.51**	.64**	-	.37**	.27**	.45**	.41**	.35**	.32**	.24**	.30**	.49**
17. BPQ Self-Image	.40**	.63**	.30**	.59**	.32**	.36**	.57**	.16*	.11	.11	-.02	.12	.24**	.50**	.52**	.37**	-	.36**	.72**	.34**	.27**	.49**	.13	.21*	.53**
18. BPQ Suicide/Self-Mutilation	.33**	.33**	.20*	.39**	.35**	.42**	.31**	.28**	.12	.18*	.24**	.25**	.32**	.45**	.42**	.27**	.36**	-	.34**	.29**	.26**	.14	.09	.10	.22**
19. BPQ Emptiness	.43**	.70**	.44**	.63**	.40**	.44**	.63**	.21**	.16*	.15	-.04	.17*	.31**	.66**	.59**	.45**	.72**	.34**	-	.42**	.31**	.48**	.11	.24**	.54**
20. BPQ Intense Anger	.43**	.37**	.37**	.42**	.40**	.47**	.39**	.29**	.26**	.25**	.10	.29**	.32**	.64**	.46**	.41**	.34**	.29**	.42**	-	.41**	.23**	.21*	.08	.34**
21. BPQ Quasi-Psychotic States	.58**	.23**	.29**	.25**	.38**	.25**	.23*	.36**	.30**	.25**	.18*	.33**	.21**	.44**	.35**	.35**	.27**	.26**	.31**	.41**	-	.04	.35**	.07	.21*
22. AQ Social Skills	.17*	.64**	.18*	.34**	.25**	.27**	.60**	.07	.10	-.11	-.07	.00	.01	.31**	.35**	.32**	.49**	.14	.48**	.23**	.04	-	.01	.27**	.74**
23. AQ Details/Patterns	.34**	.09	.07	.06	.18*	.10	.02	.21**	.10	.09	.18*	.17*	.08	.19*	.24**	.24**	.13	.09	.11	.21*	.35**	.01	-	.07	.40**
24. AQ Communication Mindreading	.09	.20*	.22**	.23**	.17*	.09	.15	.20*	.14	.12	.15	.18*	.24**	.07	.32**	.30**	.21*	.10	.24**	.08	.07	.27**	.07	-	.56**
25. AQ Total	.36**	*.58***	*.29***	.42**	.35**	*.34***	.55**	.20*	.19*	*-.01*	.06	*.15*	.13	.40**	.55**	.49**	.53**	.22**	.54**	.34**	.21*	.74**	.40**	.56**	-

* = significant at p = .05; ** = significant at p =.01; r_s unless italicised

4.5.3. Determining Transdiagnostic Dimensions

The initial eigenvalues and scree plot from the EFA were generated using all subscale scores. The systematic item reduction process (see Methods, 4.4.7.1., page 84) resulted in a four-factor model of transdiagnostic dimensional psychopathology including 17 subscales with a total variance explained value of 68.03% (see Table 4.3. for the pattern loading matrix).

According to the recommendations given in Williams et al. (2010), the model was suitable for analysis via EFA, as the Bartlett's test of sphericity was statistically significant, $X^2(136) = 1481.03$, $p = <.001$, and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .85. As noted earlier, the model was generated using principal axis factoring with promax rotation and kaiser normalisation to parse the factors whilst accounting for possible correlations between them. RMSEA and CFI tests of relative model fit indicated that the model was appropriate for use: $X^2(103) = 173.11$, $p = < .001$, RMSEA = .067, CFI = .950, TLI = .934.

The four-factor model of transdiagnostic dimensions included the following factors:

1. Interpersonal Anhedonia (4 subscales; Highest loading subscale = .84, BPQ Emptiness; Total % variance = 38.59).
2. Externalising-Antagonising (6 subscales; Highest loading subscale = .99, SRP Lifestyle; Total % variance = 15.11).
3. Mood (4 subscales; Highest loading subscale = .91, DASS-21 Stress; Total % variance = 8.15).
4. Thought Disorder (3 subscales; Highest loading subscale = .71, BPQ Quasi-Psychotic States; Total % variance = 6.19).

Table 4.3. Four-Factor Transdiagnostic Model Pattern Matrix

Subscale	Interpersonal Anhedonia	Externalising-Antagonising	Mood	Thought Disorder	*C*.
BPQ Emptiness	.84				.76
SPQ-BR Interpersonal	.82				.73
BPQ Self-Image	.79				.64
AQ Social Skills	.78				.47
SRP-4-SF Lifestyle		.99			.77
SRP-4-SF Affective		.77			.59

SRP-4-SF Interpersonal		.71			.69
BPQ Impulsivity		.67			.44
SRP-4-SF Antisocial		.52			.40
SPQ-BR Disorganised		.40			.42
DASS-21 Stress			.91		.74
DASS-21 Anxiety			.91		.77
DASS-21 Depression			.63		.71
BPQ Suicide/Self-Mutilation			.47		.32
BPQ Quasi-Psychotic States				.71	.55
SPQ-BR Cognitive-Perceptual				.66	.74
AQ Details/Patterns				.60	.25
Cumulative Variance Explained (%)	38.59	53.70	61.84	68.03	

C = Communality.

4.5.4. Psychopathology and Subjective Processing of Social Rewards

The zero-order spearman's rho rank correlations between scores on the self-report measures of psychopathology and responses on the SRQ are presented in Table 4.4.

4.5.4.1. Schizophrenia Spectrum Traits

The correlations between schizophrenia spectrum traits and SRQ scores provided evidence in support of hypothesis one. The negative symptom dimension of the schizophrenia spectrum (as assessed by SRQ-BR Interpersonal) negatively correlated with scores on the Sociability subscale of the SRQ, $r_s(149) = -.39$, $p = <.001$ [survived correction, $p^{\wedge} <.001$], as did the Cognitive-Perceptual dimension, $r_s(149) = -.17$, $p = .037$ [did not survive correction, $p^{\wedge} = .444$], perhaps suggesting reduced subjective processing of social rewards involving Sociability linked to these dimensions of the schizophrenia spectrum. However, the hypothesised associations between schizophrenia spectrum traits and reduced subjective processing of Prosocial Interactions were not found.

In addition to the hypothesised associations, positive correlations were observed between SPQ-BR Cognitive-Perceptual and Disorganised subscales and subjective processing of Negative Social Potency, $r_s(150) = .30$, $p = <.001$ [survived correction, $p^{\wedge} = .002$], and $r_s(150) = .36$, $p = <.001$ [survived correction, $p^{\wedge} <.001$], respectively; perhaps indicating that these

dimensions are associated increased feelings of reward when enacting or observing cruelty to others. Similarly, the Disorganised subscale of the SPQ-BR correlated with increased subjective processing of social rewards involving Sexual Relationships, $r_s(147) = .28$, $p = .001$ [survived correction, $p^{\wedge} = .001$]. These findings indicate that reduced subjective processing of social rewards in the schizophrenia spectrum may be dependent on the type of social reward available, with reduced subjective processing of social rewards involving Sociability but increased subjective processing of other types of social reward (i.e., Negative Social Potency, Sexual Relationships).

4.5.4.2. Affective Symptoms

In keeping with the first hypothesis, correlational analyses found associations between affective symptomatology and reduced subjective processing of Prosocial Interactions [DASS-21 Depression: $r_s(150) = -.24$, $p = .003$ [survived correction, $p^{\wedge} = .017$]; DASS-21 Anxiety: $r_s(150) = -.17$, $p = .033$ [did not survive correction, $p^{\wedge} = .365$]; DASS-21 Stress: $r_s(150) = -.18$, $p = .026$ [did not survive correction, $p^{\wedge} = .258$]]. Likewise, in keeping with hypothesis one, significant relationships between affective symptoms and reduced subjective processing of social rewards involving Sociability were also found [DASS-21 Depression: $r_s(149) = -.20$, $p = .013$ [did not survive correction, $p^{\wedge} = .089$]; DASS-21 Anxiety: $r_s(149) = -.18$, $p = .031$ [did not survive correction, $p^{\wedge} = .308$]; SPIN Total: $r_s(75) = -.52$, $p = <.001$ [survived correction, $p^{\wedge} < .001$]].

4.5.4.3. Psychopathic Traits

The results of the correlation analysis in part supported the third hypothesis regarding the relationship between psychopathic traits and subjective processing of social rewards. No significant positive relationships were found between psychopathic traits and self-reported enjoyment of Admiration. In contrast, the affective dimension of psychopathy (as measured by SRP-4-SF Affective) was found to negatively correlate with Admiration scores, $r_s(150) = -.18$, $p = .031$ [did not survive correction, $p^{\wedge} = .061$]. However, the rest of the third hypothesis was supported, in that all psychopathy SRP-4-SF dimensions (and SRP-4-SF total score) correlated with increased subjective processing of social rewards involving Negative Social Potency [Interpersonal: $r_s(150) = .60$, $p = <.001$; Affective: $r_s(150) = .45$, $p = <.001$; Lifestyle: $r_s(150) = .53$, $p = <.001$; Antisocial: $r_s(150) = .49$, $p = <.001$; SRP-4-SF total: $r_s(150) = .63$, $p = <.001$ [all survived correction, $p^{\wedge} < .001$]]. As hypothesised, negative associations between psychopathy dimensions and subjective processing of social rewards involving Prosocial Interactions were also found [SRP-4-SF Interpersonal: $r_s(150) = -.25$, $p = .002$ [survived correction, $p^{\wedge} = .008$]; SRP-4-SF Affective: $r_s(150) = -.29$, $p = <.001$ [survived correction, $p^{\wedge} = .001$]; SRP-4-SF Lifestyle: $r_s(150) = -.27$, $p = .001$ [survived correction, $p^{\wedge} = .004$]; SRP-4-

SF Antisocial: $r_s(150) = -.22$, $p = .006$ [survived correction, $p^\wedge = .044$]; SRP-4-SF total: $r_s(150) = -.30$, $p = <.001$ [survived correction, $p^\wedge < .001$]]. Interestingly, in addition to these hypothesised associations, a positive correlation between the Lifestyle dimension and subjective processing of Sociability was observed, $r_s(149) = .17$, $p = .034$ [did not survive correction, $p^\wedge = .371$], perhaps suggesting that the gregarious interpersonal behaviour that sometimes characterises the Lifestyle dimension may be linked to increased feelings of social reward.

4.5.4.4. Borderline Personality Disorder Traits

No hypotheses were made regarding the links between BPD traits and self-reported experience of social rewards. However, the analysis revealed three associations between BPQ dimensions and reduced subjective processing of social rewards involving Sociability [Affective Instability: $r_s(149) = -.22$, $p = .006$ [survived correction, $p^\wedge = .029$]; Self-Image: $r_s(149) = -.20$, $p = .016$ [did not survive correction, $p^\wedge = .127$]; Emptiness: $r_s(149) = -.22$, $p = .008$ [survived correction, $p^\wedge = .049$]]. BPQ Impulsivity and BPQ Intense Anger also negatively correlated with subjective processing of Prosocial Interactions [$r_s(150) = -.21$, $p = .008$, and $r_s(150) = -.20$, $p = .014$, respectively [neither survived correction, $p^\wedge > .05$]]. Five BPQ dimensions positively correlated with subjective processing of Negative Social Potency, suggesting elements of BPD symptomatology may be associated with increased enjoyment of witnessing or causing cruelty to others [Impulsivity: $r_s(150) = .40$, $p = <.001$ [survived correction, $p^\wedge < .001$]; Abandonment: $r_s(150) = .24$, $p = .003$ [survived correction, $p^\wedge = .028$]; Suicide/Self-Mutilation: $r_s(150) = .18$, $p = .030$ [did not survive correction, $p^\wedge = .443$]; Intense Anger: $r_s(150) = .28$, $p = <.001$ [survived correction, $p^\wedge = .005$]; Quasi-Psychotic States: $r_s(150) = .24$, $p = .004$ [survived correction, $p^\wedge = .043$]].

4.5.4.5. Autism Spectrum Disorder Traits

The correlations between ASD traits and SRQ scores were in support of the prediction that ASD traits would be associated with reduced subjective processing of social rewards. Results showed that higher scores on AQ Social Skills dimension were associated with reduced subjective processing of Prosocial Interactions, $r_s(150) = -.27$, $p = .001$ [survived correction, $p^\wedge = .003$], Sociability, $r_s(149) = -.52$, $p = <.001$ [survived correction, $p^\wedge < .001$], and social rewards involving Admiration, $r_s(150) = -.26$, $p = .001$ [survived correction, $p^\wedge = .001$]. Reduced subjective processing of social rewards linked to dimensional ASD was also reflected in a negative correlation between AQ total scores and SRQ Sociability scores, $r_s(150) = -.34$, $p = <.001$ [survived correction, $p^\wedge < .001$]. In addition to the hypothesised associations, two AQ dimensions (in addition to AQ total scores) related to increased subjective processing of social rewards involving Negative Social Potency [Details/Patterns:

$r_s(150) = .22$, $p = .005$ [did not survive correction, $p^\wedge = .071$]; Communication/Mindreading: $r_s(150) = .28$, $p = <.001$ [survived correction, $p^\wedge = .004$]; AQ total: $r_s(150) = .22$, $p = .008$ [did not survive correction, $p^\wedge = .107$]] and increased subjective processing of Passivity linked to the Social Skills dimension was also observed, $r_s(150) = .18$, $p = .024$ [survived correction, $p^\wedge = .024$].

4.5.4.6. Transdiagnostic Dimensions

Several statistically significant correlations between the transdiagnostic dimensions and subjective social reward processing were found. The Interpersonal Anhedonia dimension was associated with reduced subjective processing of social rewards involving Sociability, $r_s(149) = -.33$, $p = <.001$ [survived correction, $p^\wedge < .001$]. As might be expected, the Externalising-Antagonising dimension was associated with reduced subjective processing of social rewards involving Prosocial Interactions, $r_s(150) = -.30$, $p = <.001$ [survived correction, $p^\wedge < .001$], but increased processing of social rewards involving Negative Social Potency, $r_s(150) = .63$, $p = <.001$ [survived correction, $p^\wedge < .001$], and Sexual Relationships, $r_s(147) = .32$, $p = <.001$ [survived correction, $p^\wedge < .001$]. The Mood dimension was associated with reduced subjective processing of Prosocial Interactions and Sociability, $r_s(150) = -.20$, $p = .015$ [survived correction, $p^\wedge = .031$], and, $r_s(149) = -.17$, $p = .041$ [did not survive correction, $p^\wedge = .083$], respectively. In addition to reduced subjective processing of these social reward subtypes, the Mood dimension was simultaneously associated with increased subjective processing of rewards involving Negative Social Potency, $r_s(150) = .20$, $p = .012$ [survived correction, $p^\wedge = .035$], and Passivity, $r_s(150) = .17$, $p = .037$ [survived correction, $p^\wedge = .037$]. Finally, the Thought Disorder dimension was related to increased subjective processing of social rewards involving Negative Social Potency, $r_s(150) = .38$, $p = <.001$ [survived correction, $p^\wedge < .001$].

Table 4.4. Correlations Between Psychopathology Dimensions and SRQ Scores

	Admiration	Negative Social Potency	Passivity	Prosocial Interactions	Sexual Relationships	Sociability
Schizophrenia Spectrum Traits						
SPQ-BR Cognitive-Perceptual	.04	.30**^	.07	-.05	.07	-.17*
SPQ-BR Interpersonal	-.14	.15	.07	-.10	-.08	-.39**^

SPQ-BR Disorganised	.09	.36**^	.06	-.12	.28**^	.01
Mood Disorder Symptoms						
DASS-21 Depression	-.13	.15	.10	-.24**^	-.05	-.20*
DASS-21 Anxiety	-.05	.13	.15	-.17*	.00	-.18*
DASS-21 Stress	.03	.13	.16	-.18*	.04	-.10
SPIN Total	.02	.13	.12	-.18	-.13	-.52**^
Psychopathic Traits						
SRP-4-SF Interpersonal	.03	.60**^	.17*	-.25**^	.28**^	.05
SRP-4-SF Affective	-.18*	.45**^	.08	-.29**^	.20*	-.10
SRP-4-SF Lifestyle	-.02	.53**^	-.02	-.27**^	.34**^	.17*
SRP-4-SF Antisocial	-.03	.49**^	.09	-.22**^	.10	.04
SRP-4-SF Total	-.07	.63**^	.10	-.30**^	.29**^	.05
BPD Traits						
BPQ Impulsivity	.07	.40**^	.12	-.21**	.36**^	.18*
BPQ Affective Instability	.08	.15	.11	-.04	.00	-.22**^
BPQ Abandonment	-.07	.24**^	.05	-.10	.03	-.15
BPQ Relationships	.01	.07	-.04	.00	.00	-.08
BPQ Self-Image	-.06	.11	.14	-.13	-.06	-.20*
BPQ Suicide/Self-Mutilation	-.04	.18*	.05	-.13	.02	-.17*
BPQ Emptiness	.01	.15	.04	-.07	-.04	-.22**^

BPQ Intense Anger	-.02	.28**^	.00	-.20*	.00	-.11
BPQ Quasi-Psychotic States	.08	.24**^	.03	-.02	-.05	-.10
ASD Traits						
AQ Social Skills	-.26**^	.04	.18*^	-.27**^	-.20*	-.52**^
AQ Details/Patterns	.11	.22**	.04	.14	.15	.03
AQ Communication /Mindreading	-.14	.28**^	.07	-.16	-.12	-.03
AQ Total	-.13	.22**	.13	-.13	-.10	-.34**^
Transdiagnostic Dimensions						
Interpersonal Anhedonia	-.09	.15	.09	-.14	-.06	-.33**^
Externalising-Antagonising	-.02	.63**^	.08	-.30**^	.32**^	.07
Mood	-.01	.20*^	.17*^	-.20*^	.03	-.17*
Thought Disorder	.06	.38**^	.10	-.04	.06	-.13

* = significant at p = .05; ** = significant at p = .01; ^ = survived Hochberg correction; all values r_s

4.5.5. Psychopathology and Behavioural Processing of Rewards

To investigate hypotheses two, four and five, relationships between psychopathology dimensions and MSIDT task performance were assessed via zero-order correlational analyses (see Table 4.5. for all r_s values).

4.5.5.1. Schizophrenia Spectrum Traits

Only one significant association between schizophrenia spectrum traits and behavioural reward processing was found, with SPQ-BR Disorganised scores negatively correlating with response accuracy towards neutral stimuli, $r_s(132) = -.17$, $p = .045$ [did not survive correction, $p^{\wedge} = .090$]. No other significant associations between schizophrenia spectrum dimensions and MSIDT task performance were found and, as such, the results were not in keeping with hypothesis two.

4.5.5.2. Affective Symptoms

SPIN total scores were associated with significantly slower anticipatory RTs towards monetary rewards, $r_s(78) = .23$, $p = .042$ [survived correction, $p^{\wedge} = .042$]. No other significant relationships between affective symptom dimensions and MSIDT task performance were found.

4.5.5.3. Psychopathic Traits

In contrast to hypotheses four and five, no significant associations between psychopathy dimensions and MSIDT task performance were found. The SRP-4-SF Interpersonal facet was not significantly associated with anticipatory RTs, nor response accuracy, towards social rewards. Similarly, no associations between psychopathy and increased processing of monetary rewards were observed

4.5.5.4. Borderline Personality Disorder Traits

BPQ Intense Anger scores significantly correlated with reduced anticipatory response accuracy towards social rewards relative to monetary rewards, $r_s(133) = -.18$, $p = .032$ [did not survive correction, $p^{\wedge} = .065$], perhaps indicating reduced behavioural social reward processing associated with this BPD dimension. In contrast, BPQ Impulsivity and BPQ Suicide/Self-Mutilation were linked to increased social reward processing, with significantly greater anticipatory accuracy towards social rewards relative to neutral stimuli, $r_s(133) = .17$, $p = .048$ [did not survive correction, $p^{\wedge} = .096$], and $r_s(133) = .17$, $p = .043$ [survived correction, $p^{\wedge} = .043$], respectively. BPQ Intense Anger also correlated with greater response accuracy towards monetary rewards relative to neutral stimuli, $r_s(133) = .20$, $p = .019$ [survived correction, $p^{\wedge} = .019$]. Finally, BPQ Impulsivity correlated with reduced response accuracy towards neutral stimuli, $r_s(133) = -.24$, $p = .006$ [survived correction, $p^{\wedge} = .006$]. Together, these findings illustrate diverging relationships between BPD traits and reward processing – indicating that some aspects may be associated with increased behavioural reward processing and others with reduced behavioural processing.

4.5.5.5. Autism Spectrum Disorder Traits

It was hypothesised that ASD traits would be associated with reduced behavioural processing of social rewards. This hypothesis was met, with the Communication/Mindreading dimension negatively correlating with anticipatory response accuracy towards social rewards, $r_s(133) = -.22$, $p = .010$ [survived correction, $p^{\wedge} = .010$]. This reduced behavioural processing of social rewards was also reflected in the reward difference data, with the Communication/Mindreading dimension linked to reduced response accuracy towards social rewards relative to monetary rewards, $r_s(133) = -.20$, $p = .018$

[survived correction, $p^{\wedge}$ = .018]. No other significant relationships between ASD traits and MSIDT task performance metrics were found.

4.5.5.6. Transdiagnostic Dimensions

In contrast to the subjective social reward processing data, where a range of significant relationships between transdiagnostic psychopathology and social reward processing were found, no significant associations between the four transdiagnostic dimensions and MSIDT task performance metrics were observed.

4.5.6. Subjective and Experimental Social Reward Processing

As a supplementary analysis, relationships between SRQ scores and MSIDT task performance metrics were investigated to clarify how well the measures map-onto one another. As the MSIDT included social reward stimuli denoting Admiration, Negative Social Potency, Passivity, and Sociability, the four corresponding SRQ subscales were correlated with MSIDT task metrics. No significant correlations between the SRQ subscales and task performance were found [RT: Admiration: $r_s(131) = -.06$, $p = .492$; Negative Social Potency: $r_s(131) = .02$, $p = .799$; Passivity: $r_s(131) = -.04$, $p = .627$; Sociability: $r_s(130) = -.16$, $p = .069$], [RA: Admiration: $r_s(131) = .02$, $p = .813$; Negative Social Potency: $r_s(131) = -.04$, $p = .684$; Passivity: $r_s(131) = -.04$, $p = .642$; Sociability: $r_s(131) = -.04$, $p = .636$]. This was also the case for the reward difference data (all $p > .05$).

Table 4.5. Correlations Between Dimensional Measures of Psychopathology and MSIDT Performance

	Monetary RT	Social RT	Neutral RT	Monetary RA	Social RA	Neutral RA	Monetary-Social RT[a]	Neutral-Monetary RT[b]	Neutral-Social RT[c]	Social-Monetary RA[d]	Monetary-Neutral RA[e]	Social-Neutral RA[f]
Schizophrenia Spectrum Traits												
SPQ-BR Cognitive-Perceptual	.11	.10	.10	.01	-.08	-.10	-.02	.04	.04	-.12	.08	-.01
SPQ-BR Interpersonal	.04	.06	.05	.01	-.06	-.02	-.01	.03	.06	-.08	.05	.00
SPQ-BR Disorganised	-.12	-.06	.00	-.09	-.11	-.17*	-.08	.15	.08	-.09	.15	.09
Mood Disorder Symptoms												
DASS-21 Depression	-.01	.10	.05	-.02	-.09	-.11	-.07	.06	.04	-.11	.16	.06
DASS-21 Anxiety	.05	.05	-.04	-.04	-.06	.01	.00	-.09	-.08	-.06	.05	-.01
DASS-21 Stress	.02	.00	-.03	-.07	-.13	-.10	.01	-.03	-.04	-.04	.10	.06

SPIN Total	.23*	.10	.15	.06	.13	.11	.07	-.09	.06	.01	-.03	.03
Psychopathic Traits												
SRP-4-SF Interpersonal	-.02	.00	.07	-.12	-.17	-.16	.01	.07	.06	-.04	.07	.06
SRP-4-SF Affective	.04	.00	-.08	-.16	-.10	-.08	.07	-.13	.10	.05	-.09	.00
SRP-4-SF Lifestyle	-.06	-.10	-.02	-.05	.01	-.10	.09	.00	.10	.05	.06	.12
SRP-4-SF Antisocial	.09	.09	.06	-.10	-.05	-.03	-.01	-.03	-.12	.00	-.05	-.01
SRP-4-SF Total	.01	-.02	.01	-.11	-.08	-.12	.06	-.01	.02	.02	.02	.08
BPD Traits												
BPQ Impulsivity	.01	-.10	.02	-.14	-.12	-.24**^	.15	-.01	.11	.04	.10	.17*
BPQ Affective Instability	.01	.04	.09	-.03	-.11	-.15	-.06	.11	.07	-.06	.15	.10
BPQ Abandonment	.04	.00	.05	.05	-.02	-.03	.07	-.01	.11	-.09	.10	.03

BPQ Relationships	-.06	.01	.06	.03	-.04	-.05	-.05	.09	.11	-.11	.13	.05
BPQ Self-Image	-.11	-.09	-.08	.03	-.05	-.07	.09	-.01	.17	-.04	.13	.09
BPQ Suicide/Self-Mutilation	.12	.02	.12	-.02	-.02	-.13	.14	.04	.11	.02	.14	.17*^
BPQ Emptiness	.01	.06	.05	.00	-.10	-.07	-.02	.03	.10	-.09	.09	.01
BPQ Intense Anger	.09	.07	.12	.06	-.11	-.08	.04	.06	.08	-.18*	.20*	.01
BPQ Quasi-Psychotic States	-.05	-.06	-.05	-.06	-.09	-.05	.01	.00	.07	-.03	.03	.02
ASD Traits												
AQ Social Skills	.02	.10	.03	.06	-.04	.06	-.03	-.02	.02	-.13	-.01	-.09
AQ Details/Patterns	-.01	-.04	-.04	-.08	-.05	-.09	.01	.04	.09	-.02	.00	.03
AQ Communication /Mindreading	.07	.09	-.01	-.06	-.22*^	-.13	-.11	.00	-.08	-.20*^	.09	-.06

AQ Total	.01	.08	.04	.02	-.10	-.05	-.02	.03	.05	-.17	.09	-.04
Transdiagnostic Dimensions												
Interpersonal Anhedonia	.00	.05	.03	.00	-.09	-.05	.00	.02	.09	-.10	.09	.00
Externalising-Antagonising	-.03	-.07	.02	-.10	-.08	-.17	.08	.03	.09	.01	.08	.13
Mood	.01	.03	.01	-.04	-.10	-.08	-.01	.00	.00	-.07	.12	.06
Thought Disorder	.08	.06	.07	-.06	-.12	-.07	.00	.04	.07	-.08	.07	.02

* = significant at p = .05; ** = significant at p = .01; RT = Reaction Time; RA = Response Accuracy; [a]calculated by subtracting mean RT in social trials from mean RT in monetary trials; [b]calculated by subtracting mean RT in monetary trials from mean RT in neutral trials; [c]calculated by subtracting mean RT in social trials from mean RT in neutral trials; [d]calculated by subtracting monetary response accuracy from social response accuracy; [e]calculated by subtracting neutral response accuracy from monetary response accuracy; [f]calculated by subtracting neutral response accuracy from social response accuracy; ^ = survived Hochberg correction; all values r_s

4.6. Discussion

This chapter aimed to examine the influence of dimensional psychopathology on social reward processing. Self-report measures of psychopathology (schizophrenia spectrum traits, affective symptoms, psychopathic personality traits, BPD traits, ASD traits) were correlated with subjective (SRQ; Foulkes, Viding, et al., 2014) and behavioural (modified MSIDT) measures of social reward processing. Hypotheses were formulated based on the findings of the systematic review and meta-analysis described in Chapter 3. In keeping with the findings of the systematic review and meta-analyses, results broadly revealed subjective and behavioural evidence of atypical social reward processing in psychopathology.

Dealing first with task effects, analyses revealed a main effect of reward type on RT and response accuracy, with significantly lower anticipatory response accuracy towards neutral stimuli than either social or monetary rewards, and RTs were significantly slower towards neutral stimuli than monetary rewards. Analyses also revealed that there were no significant differences in task performance between male-identifying and female-identifying participants. Together, these findings confirm that the task had the intended effect and elicited greater behavioural processing during reward rather than non-reward trials.

4.6.1. Schizophrenia Spectrum Traits

At the subjective level, schizophrenia spectrum traits were associated with atypical processing of social rewards. This was particularly visible in the Interpersonal and Cognitive-Perceptual domains of the SPQ-BR, with higher scores in both dimensions correlating with reduced subjective processing of social rewards involving Sociability. This self-report evidence of the relationship between schizophrenia spectrum traits and reduced subjective processing of Sociability is in keeping with the hypotheses and previous research (e.g., Li et al., 2016; Xie et al., 2014) in finding that more pronounced schizophrenia spectrum traits are associated with reduced enjoyment of social rewards.

This association between schizophrenia spectrum traits and reduced subjective processing of social rewards involving Sociability did not translate behaviourally, however. No significant links between schizophrenia spectrum traits and behavioural measures of social reward processing were found, suggesting, like other research (e.g., Hanewald et al., 2017) that the differences observed between clinical and control groups in behavioural social reward anticipation (see Chapter 3, section 3.5.1., page 52) may not extend dimensionally across the schizophrenia spectrum. Given that atypical social behaviour in non-clinical schizophrenia spectrum populations is conceptually most linked to the Interpersonal dimension (Cohen et al., 2015), it is perhaps surprising that no significant associations between this dimension and experimental indices of social reward processing were found.

This should be investigated further in research within other samples, perhaps including additional measures of negative schizophrenia spectrum symptomatology (e.g., O-Life Introvertive Anhedonia subscale; Mason & Claridge, 2006) to clarify the links between schizophrenia spectrum traits and behavioural processing of social rewards further.

Atypical subjective processing of social rewards linked to schizophrenia spectrum traits was also reflected in associations between SPQ-BR dimensions and Negative Social Potency scores. Analysis revealed associations between higher scores on the Cognitive-Perceptual and Disorganised dimensions and increased subjective processing of social rewards involving Negative Social Potency, suggesting that these dimensions of the schizophrenia spectrum may be associated with increased enjoyment of opportunities to witness or enact cruelty towards others. It may be that this heightened enjoyment of Negative Social Potency reflects increased proclivity for antisocial behaviour linked to schizophrenia spectrum traits. Indeed, several conceptualisations of schizophrenia spectrum traits (schizotypy, Mason et al., 1995; psychoticism, Eysenck, 1992) include antisocial behaviour and impulsivity as features of the schizophrenia spectrum, perhaps suggesting that individuals with more pronounced schizophrenia spectrum traits demonstrate increased propensity for these types of behaviours. This link between schizophrenia spectrum traits and antisocial behaviour may also reflect overlaps between self-reported schizophrenia spectrum traits and psychopathic traits (Anderson, 2020; Ragsdale et al., 2013), as several significant intra-correlations between schizophrenia spectrum traits and psychopathic traits were observed in this study (see Table 4.2.). As such, psychopathic traits could contribute to the expression of violent or antisocial behaviour in individuals with prominent schizophrenia traits (McGregor et al., 2012), including the self-reported enjoyment of participating in social interactions which involve witnessing or enacting cruelty towards others. Thus, as both schizophrenia spectrum and psychopathic traits are associated with increased subjective processing of social rewards involving Negative Social Potency, their shared and independent contributions to the enjoyment of ‘antisocial’ rewards should be investigated further in normative samples.

4.6.2. Affective Symptoms

In keeping with hypothesis one, Depression, Anxiety and Stress dimensions from DASS-21 were related to reduced subjective processing of social rewards involving Prosocial Interactions. Feelings of depression (as assessed by DASS-21) and social anxiety (as assessed by SPIN) were also associated with reduced subjective processing of social rewards involving Sociability. Like previous research (e.g., Han et al., 2019), the combination of subjective evidence presented here highlights that subjective social reward processing may be influenced by affective symptoms, specifically symptoms of depression (Forbes,

2010), stress (Stanton et al., 2019), and social anxiety (Richey et al., 2014). For example, the results suggest that affective symptoms may decrease the subjective reward value of Prosocial Interactions (such as being treated fairly; Gradin et al., 2015). Moreover, in demonstrating this dimensionally, these results extend the results of the previous chapter and show that subclinical affective symptoms dimensionally affect subjective social reward processing.

In addition to links between dimensional affective symptomatology and reduced subjective social reward processing, the MSIDT results also revealed negative associations between affective symptoms and monetary reward processing. Specifically, SPIN total score, used to measure social anxiety, was related to reduced behavioural processing of monetary rewards as indexed by anticipatory RTs. However, no other evidence of atypical behavioural reward processing (either social or monetary rewards) linked to affective symptoms was observed. The lack of significant association between affective symptomatology and behavioural processing of social rewards is consistent with other research investigating social reward processing in mood disorder populations both categorically and dimensionally (e.g., Cremers et al., 2015; He et al., 2019; Richey et al., 2014, 2017 – see Chapter 3, section 3.5.2., page 53) and may suggest that dimensional affective symptomology more affects subjective reward experience rather than behavioural metrics of reward anticipation (Bushman et al., 2012).

4.6.3. Psychopathic Traits

Psychopathic traits were associated with atypical social reward processing at the subjective level but not at the behavioural level. As hypothesised, psychopathic traits correlated with increased subjective processing of social rewards involving Negative Social Potency but, contrary to hypothesis three, no significant correlations between psychopathic traits and subjective processing of social rewards involving Admiration were found. As predicted, all dimensions of psychopathy were also significantly associated with reduced subjective processing of Prosocial Interactions. A significant positive correlation between the Lifestyle dimension and subjective processing of Sociability was also observed. The results of the MSIDT found no statistically significant relationships between psychopathy dimensions and behavioural processing of social or monetary rewards.

As described in the previous chapter, little research has investigated social reward processing in psychopathy and so these results contribute important knowledge on how psychopathic traits influence subjective processing of social rewards. The subjective findings are consistent with those described in Foulkes, McCrory, et al. (2014) but the behavioural results do not meet the expectations set in the previous chapter, nor in hypothesis four, as

no increased behavioural processing of social rewards linked to dimensional psychopathy was observed in this study. Unlike the results presented here, and as presented in the previous chapter, Foulkes, McCrory, et al. (2014) found evidence for increased behavioural processing of social rewards, relative to other reward types, linked to the Interpersonal dimension of psychopathy. However, based on the self-report results of this study, it could be that increased behavioural processing of social rewards in psychopathy is dependent on which subtype of social reward (for example Sociability or Negative Social Potency) is available. However, it was beyond the scope of this study to investigate this experimentally here. This is developed in the next chapter, with an experimental investigation of the behavioural processing of the different social reward subtypes in relation to psychopathology.

4.6.4. Borderline Personality Disorder

Correlating BPQ scores with SRQ responses showed that Impulsivity and Intense Anger dimensions negatively correlated with subjective processing of Prosocial Interactions. Affective Instability, Self-Image, and Emptiness dimensions negatively correlated with subjective processing of social rewards involving Sociability. In contrast to reduced subjective processing of Prosocial Interactions and Sociability, five BPQ dimensions (Impulsivity, Abandonment, Suicide/Self-Mutilation, Intense Anger, Quasi-Psychotic States) related to increased subjective processing of social rewards involving Negative Social Potency. Based on this self-report data, it appears that BPD dimensions differentially affect social reward processing – with specific dimensions linked to reduced subjective processing, and with others linked to increased subjective processing.

This differential pattern is also reflected in the MSIDT data. Intense Anger scores were associated with reduced behavioural social reward processing relative to monetary rewards, indicating reduced preference for social rewards in this dimension of BPD, but then this is contrasted by increased anticipatory response accuracy towards social rewards relative to neutral stimuli linked to the BPQ Impulsivity and Suicide/Self-Mutilation dimensions.

This study is the first to examine subjective processing of the different subtypes of social reward in dimensional BPD and so provides meaningful insight into how the atypical aspects of social behaviour in BPD (e.g., intense/volatile interpersonal relationships) could be differently related to atypical processing of social rewards (reduced subjective processing of Sociability and Prosocial Interactions but increased subjective processing of rewards involving Negative Social Potency). Like the increased processing of social rewards observed in Doell et al. (2020), the MSIDT performance data revealed increased behavioural social reward processing related to BPD Impulsivity and Suicide/Self-Mutilation dimensions.

Although, how these behavioural findings tally with reduced subjective processing of Sociability/Prosocial Interactions, increased processing of Negative Social Potency, and the atypical social behaviour that characterises BPD is difficult to infer without more closely examining the relationship between BPD traits and behavioural processing of the different social reward subtypes.

4.6.5. Autism Spectrum Disorder

The hypotheses that ASD traits would be associated with reduced subjective and behavioural processing of social rewards were supported. The Social Skills dimension was associated with reduced subjective processing of social rewards involving Admiration, Sociability, and Prosocial Interactions. The reduced processing of Sociability in dimensional ASD was also illustrated through its correlation with AQ total scores. The reduced processing of social rewards linked to ASD traits at the subjective level also translated to the behavioural level, with reduced social reward processing (indexed by social reward response accuracy and response accuracy difference) linked to the Communication/Mindreading dimension of ASD.

These findings are in keeping with the results of the meta-analysis and narrative synthesis of social reward processing in ASD presented in the previous chapter. The Social Skills dimension captures (reduced) enjoyment of social interactions, for example social gatherings or social chit-chat, and so the observed correlation between Social Skills and reduced subjective processing of social rewards involving Admiration, Prosocial Interactions, and Sociability is consistent with social motivation theory (Chevallier et al., 2012) and conceptualisations of atypical interpersonal behaviour in ASD (Bottini, 2018; Novacek et al., 2016). Regarding the MSIDT data, whilst the results follow the same overall trend as the self-report data (reduced subjective social reward processing in ASD), all significant task-dimension relationships involve the Communication/Mindreading dimension, and not the Social Skills dimension. This could, in part, be because the task itself relies on a degree of perspective-taking (the participant is instructed to adopt the position of the avatar as best possible) and thus restricted perspective-taking will affect engagement with the task – leading to reduced motivation to obtain the available rewards (manifesting as reduced behavioural social reward processing). Alternatively, rather than purely an issue of task engagement, this may suggest that difficulties with mentalising mediate social reward responses in ASD. Indeed, Krach et al. (2010) posit that social reward processes depend on mentalising, and thus difficulties with mentalising may manifest as reduced social reward processing. This is a tentative suggestion, however, and should be corroborated by future studies.

4.6.6. Transdiagnostic Dimensions

The exploratory transdiagnostic approach employed in this study aimed to extend the transdiagnostic evidence presented in the previous chapter and explore associations between transdiagnostic features of dimensional psychopathology and social reward processing. Analysing the self-report psychopathology measure subscales via EFA revealed four transdiagnostic dimensions: Interpersonal Anhedonia, Externalising-Antagonising, Mood, and Thought Disorder. The model explained 68.03% of the total variance and represented four distinct transdiagnostic factors within dimensional psychopathology. The four dimensions capture the internalising, disinhibited and antagonistic spectra of psychopathology described in Stanton et al. (2020) and inform existing work that has examined the shared features of psychopathology (e.g., Goekoop & Goekoop, 2014) in relation to social reward processing (Aldridge-Waddon et al., 2020).

The Interpersonal Anhedonia dimension comprised BPQ Emptiness, SPQ-BR Interpersonal, BPQ Self-Image and AQ Social Skills. In bringing these dimensions together under a broader Interpersonal Anhedonia factor, this study follows Barkus and Badcock (2019) in suggesting that social anhedonia is a transdiagnostic feature of psychopathology which affects social reward processing - specifically the subjective processing of social rewards involving Sociability, such as attending parties or gatherings. Similarly, the Mood dimension, comprising DASS-21 dimensions and BPQ Suicide/Self-Mutilation, was associated with reduced subjective processing of Sociability and Prosocial Interactions. In contrast to this reduced subjective processing of 'prosocial' rewards, three of the transdiagnostic dimensions (Externalising-Antagonising, Mood, and Thought Disorder) were associated with increased subjective processing of Negative Social Potency. This perhaps suggests a transdiagnostic proclivity for antisocial behaviour in psychopathology, manifesting as increased enjoyment of witnessing or enacting cruelty to others. No significant associations between the transdiagnostic dimensions and behavioural social reward processing were observed, however.

Together, the findings of this transdiagnostic approach highlight that, rather than examining psychopathologies separately, it is important to examine their shared underlying dimensions and how those specific dimensions (in this case Interpersonal Anhedonia, Externalising-Antagonising, Mood, and Thought Disorder) relate to social reward processing. In showing that subjective social reward processing is affected across diagnostic dimensions, this study highlights the joint influence that psychopathology spectra, as per the Hierarchical Taxonomy of Psychopathology (HiTOP; Kotov et al., 2017), may have on social reward

processing, and thus the subsequent atypical interpersonal behaviour that characterises a range of psychiatric diagnoses.

Whilst the inclusion of an exploratory transdiagnostic approach is a strength of this research, the small sample size included in the EFA limits the extent to which robust conclusions regarding model structure can be made. As mentioned earlier, the model met minimum EFA requirements (minimum 5:1 ratio of participants to variables and relative fit statistics; Osborne et al., 2011) but should (of course) be replicated in larger samples to see whether the same four-factor structure emerges. Beyond this, it could also be important to employ a transdiagnostic approach at an item level (i.e., conduct EFA using each individual item of the self-report measures used here) to see how the items group together. Doing so would provide a comprehensive insight into the nuanced relationships between specific features of transdiagnostic psychopathology and social reward processing. This was, however, outside the scope of this study as a much larger participant sample (n > 2100) would be required.

4.6.7. Strengths and Limitations

There are several strengths to this investigation that require mention. This study included subjective and behavioural measures of social reward processing, namely the SRQ and the modified MSIDT. Combining measures in this way allowed this study to comprehensively examine social reward processing across psychopathologies and, following the systematic review and meta-analysis in Chapter 3, provide further subjective and behavioural evidence of atypical social reward processing in psychopathology. Within this, through using subjective measures, this study importantly highlights that the hedonic value of social rewards in psychopathology may depend on the social reward subtype available. The study detailed in the next chapter aims to supplement these self-report findings with behavioural evidence of atypical processing of the different subtypes of social reward.

Furthermore, this research included a modified version of the MSIDT. The inclusion of avatars increased the ecologically validity and engagement value of the task, which is a recognised limitation of many existing social reward tasks (Fulford et al., 2018). Although novel, these modifications elicited similar mean task performance results to previous studies and so use here seems both justified and meaningful. As such, this study illustrates the potential for integrating more ecologically valid social reward stimuli within reward paradigms, that could then elicit more robust relationships between dimensional psychopathology and behavioural reward processing.

There are some limitations within this empirical investigation that should be acknowledged and addressed by future research. Although the dimensional measures of psychopathology included in this study were comprehensive, there may be some dimensions of

psychopathology that were not directly addressed here which influence social reward processing at subjective and/or behavioural levels. For example, the previous chapter highlighted that alexithymia (e.g., Foulkes et al., 2015) and bipolar symptomatology (Dutra et al., 2015) affect social reward processing, and thus future research could expand the battery of measures used here to assess psychopathologies such as these. It is also important to note that many of the correlations reported are small-medium in size and, although both uncorrected and corrected *p* values are reported, the legitimacy of the relationships reported here should be tested further through replication in larger samples before being accepted conclusively.

A further consideration is that the supplementary analysis of subjective and behavioural measures of social reward processing indicated that the two methods do not map-onto one another well (no significant correlations between measures were found). This may be because subjective and behavioural measures of social reward rely on different contextual, cognitive, and qualitative processes (Gold et al., 2008; Wang et al., 2017) and thus the measures should not necessarily be expected to map onto one another. Alternatively, as described earlier, the MSIDT included stimuli denoting four different subtypes of social reward that were then broadly grouped as “social rewards”; meaning it was difficult to precisely measure how the subjective and behavioural measures of social reward processing match. The study presented in the next chapter addresses this in more detail by assessing the subtypes of social reward experimentally. Finally, although the use of avatar videos is a strength of this research, no real monetary or social rewards were awarded which could have potentially restricted the actual reward value of the MSIDT.

4.7. Chapter Summary

This chapter investigated associations between dimensional psychopathology and subjective and behavioural measures of social reward processing. The results were largely consistent with previous research and strengthen the findings of the systematic review and meta-analysis presented in the previous chapter. The psychopathology-related adjustments in reward processing described here seem largely specific to social rewards (there were few significant associations between psychopathology and monetary reward processing) and so indicate that atypical social reward processing could contribute to some of the atypical interpersonal behaviours that characterise these psychopathologies. The next chapter will investigate the behavioural correlates of social reward processing in psychopathology in more detail, with the objective of exploring associations between dimensional psychopathology and the behavioural processing of different social reward subtypes.

5. Behavioural Processing of Social Reward Subtypes in Dimensional Psychopathology

5.1. Chapter Aims and Overview

The previous chapter provided evidence of atypical social reward processing in relation to dimensional psychopathology at both subjective and behavioural levels. It found significant dimensional associations between schizophrenia spectrum traits, affective symptoms, psychopathic traits, borderline personality disorder (BPD) traits, autism spectrum disorder (ASD) traits, and atypical social reward processing as indexed by the Social Reward Questionnaire (Foulkes, Viding, et al., 2014) and the modified Monetary and Social Incentive Delay Task (MSIDT). The empirical investigation reported in this chapter aims to supplement these findings by examining relationships between the same dimensions of psychopathology and behavioural processing of the subtypes of social reward using the novel Social Reward Subtype Incentive Delay Task (SRS-IDT) introduced in Chapter 2, section 2.4.2., page 40. The same dimensions of psychopathology are examined here with the aim of providing further evidence of atypical behavioural reward across the psychopathologies of interest. The chapter begins with a summary of previous research that has investigated links between psychopathology and the processing of the different social reward subtypes, before presenting empirical data on associations between psychopathological dimensions and behavioural processing of the different social reward subtypes.

5.2. Introduction

As emphasised throughout this thesis thus far, the pursuit and experience of social rewards is a central feature of human social behaviour (Krach et al., 2010). The social rewards attached to social interaction, such as praise or feelings of comfort, are important for the initiation and maintenance of social behaviour (Matyjek et al., 2020), and can also have a protective effect on physical and psychological wellbeing (Gable & Prok, 2012). As described previously, understanding the importance of social rewards in interpersonal behaviour has led some researchers (e.g., Chevallier et al., 2012) to infer that atypical social motivation or interaction, as seen in certain psychopathologies, may in part be due to alterations in social reward processing. The empirical investigations presented in Chapters 3 and 4 are consistent with this perspective on atypical interpersonal behaviour in psychopathology, finding categorical and dimensional evidence of atypical social reward processing across a range of psychopathologies. However, rather than addressing social reward purely as a singular construct, it is important to recognise that psychopathology may relate differently to each of the subtypes of social reward described by Foulkes, Viding, et al. (2014). For the purposes of this investigation and following the design of the Social Reward Subtype Incentive Delay Task (SRC-IDT, see Chapter 2, section 2.4.2., page 40), this

chapter will focus on four of the social reward subtypes: Admiration, Negative Social Potency, Passivity, and Sociability.

5.2.1. Admiration – Enjoyment of Receiving Flattery and Positive Attention

Clinical conceptualisations of schizophrenia spectrum traits and affective symptoms describe a reduced motivation to obtain approval and praise from others (Brinkmann et al., 2014; Gard et al., 2014). This reduced motivation to obtain others' approval is in part linked to reduced reward circuitry activity during peer approval (Makowski et al., 2016) but also reflects a reduced responsivity to praise (e.g., Pechtel et al., 2013; Premkumar et al., 2019). Similarly, the opportunity to receive praise or reputation is less incentivising for individuals with ASD (e.g., Izuma et al., 2011; Neuhaus et al., 2015) and behavioural reinforcers that are non-social are often more effective in eliciting behavioural change in ASD individuals than social reinforcers (for example verbal praise) (Kohls et al., 2012). Admiration, as defined by Foulkes, Viding, et al. (2014), captures a desire for praise and approval, and thus individuals higher in schizophrenia spectrum traits, affective symptomatology, and ASD traits might be expected to demonstrate reduced processing of social rewards involving Admiration. This, however, was not reflected in the subjective social reward processing data presented in the previous chapter.

Processing of social rewards involving Admiration appears to also be adjusted in BPD. BPD patients report less feelings of happiness and approval when viewing videos of actors expressing praise (Reichenberger et al., 2017) and others (e.g., Weinbrecht et al., 2020) have reported that a fear of positive evaluation, which includes praise and recognition, is a characteristic of BPD. However, whether this evidence of reduced subjective processing of Admiration in BPD patients translates dimensionally is unclear. The findings of the previous chapter would suggest not, as no correlations between BPD dimensions and reduced subjective processing of Admiration were found. In response, the study presented in this chapter will assess links between BPD dimensions and behavioural processing of social rewards involving Admiration.

In contrast to reduced processing of social rewards involving Admiration in the other psychopathological dimensions, the glib and narcissistic aspects of psychopathy indicate that individuals with more pronounced psychopathic traits might demonstrate increased processing of social rewards involving Admiration (White, 2014). Indeed, using the Social Reward Questionnaire, Foulkes, McCrory, et al. (2014) found that the Interpersonal dimension of psychopathy (which captures grandiose or narcissistic behaviour) positively correlated with subjective processing of social rewards involving Admiration. Similarly, dimensional psychopathy correlates with an increased self-reported desire for status and

recognition (Glenn et al., 2017). However, despite self-report evidence of associations between psychopathy and Admiration, how dimensional psychopathy relates to behavioural processing of social rewards involving Admiration is unknown at present.

5.2.2. Negative Social Potency – Enjoyment of Witnessing or Causing Cruelty to Others

The study presented in Chapter 4 found several associations between self-reported enjoyment of Negative Social Potency and dimensional psychopathology that require further investigation in this chapter through experimental methods. As expected, all dimensions of psychopathy correlated with increased subjective processing of Negative Social Potency, which is consistent with a series of research studies (e.g., Buckels et al., 2014; Craker & March, 2016; March, 2019) which have found increased reward processing of opportunities for harm or cruelty towards others in dimensional psychopathy. The previous chapter also found evidence of increased processing of Negative Social Potency in ASD, reporting significant positive correlations between the Details/Patterns dimension, Communication/Mindreading dimension, total ASD traits, and subjective processing of Negative Social Potency. Therefore, this chapter aims to investigate if this heightened subjective enjoyment of Negative Social Potency in dimensional psychopathy and ASD translates to increased processing of social rewards involving Negative Social Potency at the behavioural level.

The other associations found in the previous chapter are perhaps more surprising and require further investigation using experimental methods. Results showed that the Cognitive-Perceptual and Disorganised dimensions of the schizophrenia spectrum positively correlated with subjective processing of Negative Social Potency. This was also the case for the Impulsivity, Abandonment, Suicide/Self-Mutilation, Intense Anger and Quasi-Psychotic States dimensions of BPD. As described previously, antisocial behaviour is sometimes positioned as a feature of the schizophrenia spectrum (Mason et al., 1995) and there are overlaps between schizophrenia spectrum traits and psychopathy (Anderson, 2020). However, Negative Social Potency captures an enjoyment of antisocial behaviour and, whilst there are some links between schizophrenia, proclivity for violence, and co-morbid sadism (a clinical proxy of extreme Negative Social Potency; Foulkes, 2019) (Zghal et al., 2017), this usually occurs within a clinical-forensic context and thus is a surprising association that will be assessed experimentally here. Similarly, no research to-date has examined the reward value of Negative Social Potency in BPD (either dimensionally or categorically) and thus the present study adds value in testing whether these subjective associations are borne out behaviourally.

5.2.3. Passivity – Enjoyment of Letting Others Control of a Social Interaction

It is important to note that Passivity in a social reward context is different to the 'Passivity' that is sometimes identified in thought-disordered schizophrenia symptomatology, such as third-person auditory hallucinations (Brüne et al., 2008). As described in Chapter 1 (see section 1.3.3., page 21), the social reward subtype 'Passivity' is phenomenologically related to submissiveness and social loafing; concepts which have been assessed in psychopathology previously. Schizophrenia spectrum, depression, and BPD symptomatology are all associated with an increased tendency towards submissiveness (Barnow et al., 2009; Johansen et al., 2013; Malatynska & Knapp, 2005; Møller & Husby, 2000). The exact reward value of submissiveness in these psychopathologies is unknown, but Selten et al. (2005) propose that tendencies towards submissiveness in schizophrenia may be mediated by mesolimbic activity (which is implicated in reward processing – see Chapter 1). In dimensional ASD, Foulkes et al. (2015) showed that ASD traits correlate with increased subjective processing of rewards involving Passivity. This fits with clinical conceptualisations of ASD (Wing, 1992) which cite social passivity (observed as staying the background or letting others have control) as a feature of ASD. The previous chapter also found associations between increased subjective processing of Passivity and the Social Skills dimension of ASD.

Unlike the other psychopathologies described here, which demonstrate tendencies towards social submissiveness and thus may correlate with increased reward processing of Passivity, the dominating and manipulative aspects of psychopathy (Patrick et al., 2009) suggest that dimensional psychopathy is associated with reduced interpersonal passivity (Neal & Sellbom, 2012). However, no research other than Foulkes, McCrory et al. (2014) has investigated the reward value of Passivity in dimensional psychopathy. They found, perhaps surprisingly, that dimensional psychopathic traits correlated with increased subjective processing of social rewards involving Passivity. However, rather than interpreting this as increased enjoyment of the submissiveness aspect of Passivity, the authors propose that increased processing of Passivity in dimensional psychopathy may reflect increased enjoyment of social loafing (which is captured in the parasitic lifestyle aspect of psychopathy as described by Hare, 2003) rather than submissiveness. The previous chapter, however, found no significant associations between psychopathy and subjective processing of Passivity.

5.2.4. Sociability – Enjoying Being Part of Social Situations

Schizophrenia spectrum, affective, and ASD traits are all associated with reduced levels of social motivation, asociality, and a tendency towards introverted behaviour. As Sociability

captures enjoyment of social gatherings and social chit-chat, the interpersonal characteristics of these psychopathologies suggest that they may be associated with reduced processing of social rewards involving Sociability. Indeed, this was reflected in the findings of the previous chapter which showed that these psychopathological dimensions are associated with reduced subjective processing of Sociability. Thus, the present chapter aims to supplement those self-report findings with behavioural evidence of reduced Sociability processing linked to schizophrenia spectrum traits, affective symptoms, and ASD traits.

The relationship between Sociability and psychopathic and BPD traits is potentially more complex. Indeed, the sensation-seeking aspect of both psychopathy and BPD symptomatology (Peters et al., 2013; Weidacker et al., 2017) might relate to increased processing of social rewards involving Sociability (e.g., Foulkes, McCrory, et al., 2014), with the previous chapter showing that increased subjective processing of Sociability correlates with the Lifestyle dimension of psychopathy and the Impulsivity dimension of BPD. In contrast, other dimensions of psychopathy and BPD capture behaviours (e.g., contemptuousness, distrust in others; Drislane et al., 2019) that are perhaps less likely to be associated with increased processing of Sociability. Therefore, there is a need to clarify the specific relationships between individual dimensions of psychopathy and BPD and the processing of social rewards involving Sociability.

5.3. Rationale and Aims

As described by Matyjek et al. (2020), existing work on social reward processing in psychopathology frequently compares responses towards static social stimuli (for example happy faces) versus non-social stimuli (for example money), which may mask some of the nuanced relationships between psychopathology and the different subtypes of social reward. Having highlighted how dimensions of psychopathology may differentially relate to processing of the subtypes of social reward above, this study examined links between dimensional psychopathology and behavioural processing of the social reward subtypes using an experimental social reward task (SRS-IDT). It aimed to extend the results of the previous chapter and clarify how dimensional psychopathology influences behavioural processing of four different types of social reward.

To do so, this empirical investigation tested the following hypotheses:

1. Schizophrenia spectrum traits, affective symptoms, BPD traits, and ASD traits will be associated with reduced behavioural processing (hypoanticipation) of social rewards involving Admiration, reflected in slower reaction times (RTs) or lower response accuracy.

2. Psychopathic traits will be associated with increased behavioural processing (hyperanticipation) of social rewards involving Negative Social Potency, reflected in faster RTs or greater response accuracy.

3. Schizophrenia spectrum traits, affective symptoms, and ASD traits will be associated with increased behavioural processing (hyperanticipation) of social rewards involving Passivity, reflected in faster RTs or greater response accuracy.

4. Schizophrenia spectrum traits, affective symptoms, and ASD traits will be associated with reduced behavioural processing (hypoanticipation) of social rewards involving Sociability, reflected in slower RTs or lower response accuracy.

5.4. Materials and Methods

5.4.1. Ethics Statement

All procedures were approved by the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS), Brunel University London (ID: 25253). All participants provided informed consent prior to participating in the study. All participants were compensated for their time via university course credits (4).

5.4.2. Participants and Procedure

Fifty-eight (47 of whom were female) participants completed this study. The mean age of the sample was 19.69 (SD = 2.18, range = 18-34). Most of the sample (74.1%) reported English as their first language and all participants were undergraduate or postgraduate university students at the time of participation. All participants were recruited online via SONA. All participants included in this study also took part in the empirical investigation presented in Chapter 4. As in the previous chapter, exclusion criteria included: (1) evidence of current or previous mental illness diagnoses, (2) evidence of current or previous serious head injury or neurological injury, (3) current and/or recent illicit substance dependence, and (4) current use of psychotropic medications that may affect neurocognitive functioning.

5.4.3. Self-Report Measures of Psychopathology

This research employed measures of dimensional psychopathology that were also used in the previous chapter (see Chapter 4, section 4.4.3., page 79).

Schizophrenia spectrum traits were assessed using the brief revised version of the Schizotypal Personality Questionnaire (SPQ-BR; Cohen et al., 2010). The SPQ-BR presents participants with 32 items which they are asked to rate using a five-point Likert scale, from Strongly disagree (0) to Strongly agree (4). It captures three dimensions of the

schizophrenia spectrum: Cognitive-Perceptual, Interpersonal, and Disorganised. Higher scores on the SPQ-BR indicate more prominent schizophrenia spectrum traits.

Affective symptoms were assessed using the Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995). DASS-21 has 21 items, with seven items per dimension (i.e., 7 Depression, 7 Anxiety, 7 Stress). Participants are asked to rate how much over the last week each of the items have applied to them using a four-point Likert scale (0 = “Did not apply to me at all”, 3 = “Applied to me very much or most of the time”). Higher scores indicate more prominent affective symptoms.

Psychopathic traits were measured using the Self-Report Psychopathy Scale 4 Short Form (SRP-4-SF; Paulhus et al., 2016). It includes 29 items and collects participant responses on a five-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). The SRP-4-SF generates scores for each of the four dimensions of psychopathy (Interpersonal, Affective, Lifestyle, Antisocial), as well as a total score to provide an overall impression of psychopathic traits. Higher scores on this measure indicate more pronounced psychopathic traits.

BPD traits were measured using the Borderline Personality Questionnaire (BPQ; Poreh et al., 2006). It contains 80 items that are rated as True (1) or False (0). The BPQ assesses nine dimensions of BPD: Impulsivity, Affective Instability, Abandonment, Relationships, Self-Image, Suicide/Self-Mutilation, Emptiness, Intense Anger, and Quasi-Psychotic States. Higher scores indicate more elevated BPD traits.

ASD traits were assessed using the Autism Quotient (AQ; Baron-Cohen et al., 2001). This measure has 50 items and asks participants to indicate how much they agree with each item on a four-point Likert scale. The measure is scored using 1 or 0 per item, with a 1 given any time a non-neurotypical response is endorsed. The AQ measures three dimensions of ASD symptomatology (Social Skills, Details/Patterns, Communication/Mindreading; Hurst et al., 2007; Russell-Smith et al., 2011) and provides a total score for overall ASD traits. Higher scores indicate more elevated ASD traits.

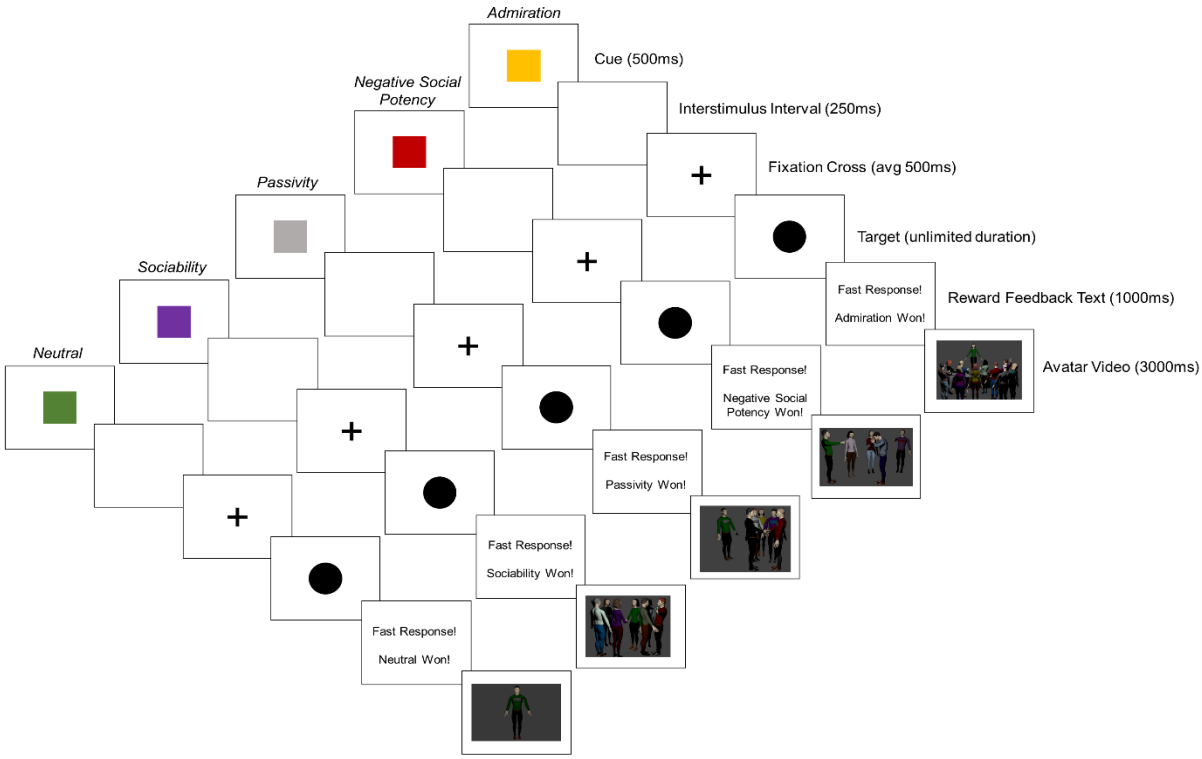
5.4.4. Behavioural Processing of Social Reward Subtypes

The SRS-IDT (see Figure 5.1.) was used to assess behavioural processing of four subtypes of social reward: Admiration, Negative Social Potency, Passivity and Sociability. Details of the development of the task are provided in Chapter 2, section 2.4.2., page 40. The SRS-IDT assesses behavioural anticipation of these four subtypes, with 12 trials per reward type, and 12 trials for neutral stimuli. As with the modified MSIDT, all rewards were presented via video and depicted avatars engaging in the four subtypes of social reward. Participants

selected which avatar they wanted to represent themselves as prior to the start of the first trial and were encouraged to relate to the avatar's experience as much as possible.

Social rewards involving Admiration depicted the avatar as the centre of attention whilst receiving applause and recognition from others. This was accompanied by the sound of cheering and clapping. Social rewards involving Negative Social Potency showed the avatar bullying others. This included them jeering and laughing whilst pointing at a crying avatar. Social rewards involving Passivity showed the avatar on the peripheries of social interaction, watching others take control and the initiative. This was accompanied by the sound of whispering, to give the impression the avatar was not involved in the group interaction. Social rewards involving Sociability showed the avatar engaging in large group social interactions, accompanied by the sound of chatter and social activity. Neutral stimuli showed the avatar standing stationary in the centre of the screen and were accompanied by a neutral tone.

Figure 5.1. Social Reward Subtype Incentive Delay Task



Each trial began with a cue indicating which subtype of social reward was available to win. To ease accessibility and decrease working memory demands, the social reward subtype linked to the cue (e.g., Admiration) was also written on the cue. As shown in Figure 5.1, each trial had a six-part sequence with a 500ms interval between trials: (1) cue (500ms), (2) interstimulus interval (250ms), (3) fixation cross (jittered duration, average 500ms), (4) target

(unlimited duration), (5) reward feedback text (1000ms), and (6) reward feedback video (3000ms). As per the modified MSIDT, winning rewards was dependent on the participant responding to their bespoke RT threshold which was set during the practice trials. Pixelated videos accompanied by the sound of radio static were shown following any misses, and the participant was prompted to respond faster to obtain the available rewards.

5.4.4.1. Indexing Task Performance on the SRS-IDT

Processing of the social reward subtypes in the SRS-IDT was indexed through RT (ms) and response accuracy (%), with faster RTs and greater response accuracy indicating increased reward processing (Knutson et al., 2000).

5.4.5. Data Screening and Analysis

All data screening and analysis was performed using SPSS Version 26 with statistical significance set at $p = .05$. Screening for the presence of outliers via boxplots identified 16 participants with mean SRS-IDT RTs larger than 1000ms who were, therefore, excluded from all subsequent analyses. This left a final participant sample size of n = 42 for all analyses. Shapiro-Wilk tests of data distribution revealed that very few self-report variables (all SPQ-BR scores, SRP-4-SF Affective, SRP-4-SF Lifestyle, AQ Details/Patterns, AQ total) were normally distributed and thus non-parametric statistical approaches were adopted throughout.

The analyses were computed in two stages. First, main effects of social reward subtype on task performance were assessed using repeated measures ANOVAs, with RT and response accuracy per reward subtype (Admiration, Negative Social Potency, Passivity, Sociability, Neutral) as the dependent variable. The Greenhouse-Geisser correction was applied if the sphericity assumption was violated (results include corrected *p* value if correction applied). Main effects were investigated post-hoc using the Bonferroni correction. Effect size was calculated using partial eta squared (η^2_p), with sizes interpreted as small ($\eta^2_p = .01$), medium ($\eta^2_p = .06$), and large ($\eta^2_p = .14$) (Cohen, 1992). All hypotheses were assessed through zero-order Spearman's rank order correlations, assessing relationships between scores on the dimensional measures of psychopathology and SRS-IDT task performance metrics. Like the previous chapter (see section 4.4.7., page 83), the Hochberg correction (Hochberg, 1988) was applied to account for the number of correlations run, and both corrected and uncorrected *p* values are reported. Again, the interpretation of results includes discussion of findings from both uncorrected and corrected analyses.

5.5. Results

5.5.1. Characterisation of Psychopathology

The mean and range scores for each of the dimensional measures of psychopathology are presented in Table 5.1. Only scores from participants with usable SRS-IDT data are included.

Table 5.1. Scores on Self-Report Measures of Psychopathology

	Mean (SD)	Observed Range (Possible Range)	N
Schizophrenia Spectrum Traits			
SPQ-BR Cognitive-Perceptual	18.55 (10.75)	0-48 (0-56)	42
SPQ-BR Interpersonal	20.10 (9.16)	0-39 (0-40)	42
SPQ-BR Disorganised	15.10 (6.60)	0-32 (0-32)	42
Mood Disorder Symptoms			
DASS-21 Depression	6.36 (6.07)	0-21 (0-21)	42
DASS-21 Anxiety	4.43 (5.46)	0-21 (0-21)	42
DASS-21 Stress	5.40 (5.07)	0-20 (0-21)	42
Psychopathic Traits			
SRP-4-SF Interpersonal	11.83 (5.08)	7-25 (7-35)	42
SRP-4-SF Affective	12.93 (3.96)	7-23 (7-35)	42
SRP-4-SF Lifestyle	13.74 (4.92)	7-28 (7-35)	42
SRP-4-SF Antisocial	9.69 (3.30)	7-22 (7-35)	42
SRP-4-SF Total	49.26 (15.14)	31-94 (29-145)	42
BPD Traits			
BPQ Impulsivity	1.50 (1.35)	0-4 (0-9)	42
BPQ Affective Instability	5.19 (3.11)	0-10 (0-10)	42

BPQ Abandonment	2.67 (2.34)	0-9 (0-10)	42
BPQ Relationships	2.83 (1.92)	0-7 (0-8)	42
BPQ Self-Image	3.64 (2.99)	0-9 (0-9)	42
BPQ Suicide/Self-Mutilation	1.21 (1.91)	0-7 (0-7)	42
BPQ Emptiness	4.52 (3.25)	0-10 (0-10)	42
BPQ Intense Anger	3.07 (3.03)	0-9 (0-10)	42
BPQ Quasi-Psychotic States	1.38 (1.60)	0-6 (0-7)	42
ASD Traits			
AQ Social Skills	4.86 (3.54)	0-12 (0-13)	42
AQ Details/Patterns	3.36 (1.91)	0-7 (0-7)	42
AQ Communication/Mindreading	2.00 (1.81)	0-7 (0-8)	42
AQ Total	19.33 (6.54)	4-33 (0-50)	42

5.5.2. Task Performance Main Effects

The mean task performance data from the SRS-IDT are presented in Figures 5.2 and 5.3.

A significant main effect of social reward subtype on anticipatory RT was found, F (4, 164) = 7.11, p = <.001, η_p^2 = .15. Post hoc pairwise comparisons with Bonferroni correction applied revealed several significant differences between social reward subtypes. Significantly faster RTs towards social rewards involving Admiration (M = 247.23 ± 121.08) in comparison to Negative Social Potency (M = 359.87 ± 168.59) and Passivity (M = 315.86 ± 162.78) were observed. Similarly, RTs towards social rewards involving Sociability (M = 267.40 ± 125.64) were significantly faster than those towards Negative Social Potency. This indicates that Admiration and Sociability may have been the most salient social reward subtypes and/or that Negative Social Potency may have been less salient than other social reward subtypes.

A significant main effect of social reward type was also found for anticipatory response accuracy, F (2.41, 98.70) = 8.07, p = <.001, η_p^2 = .16. As with RT, post-hoc analysis revealed anticipatory response accuracy towards Negative Social Potency (M = 54.56 ± 28.47) was significantly lower than all social reward subtypes other than Sociability.

Taken together, these results indicate that social rewards involving Negative Social Potency may be less incentivising than other social reward subtypes for most individuals, which is to be expected in a normal sample given that Negative Social Potency is defined as the enjoyment of witnessing or enacting cruelty to others.

Figure 5.2. Mean Anticipatory Reaction Time per Social Reward Subtype with 95% CI Error Bars (ms)

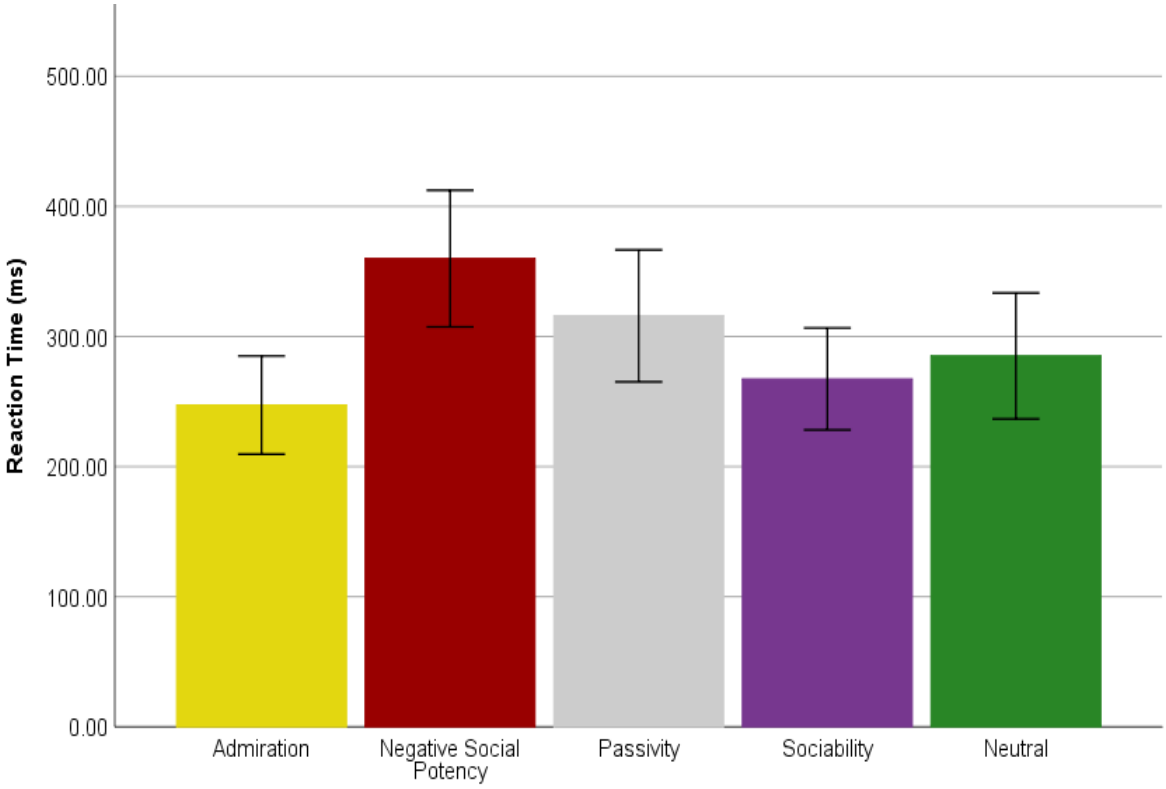
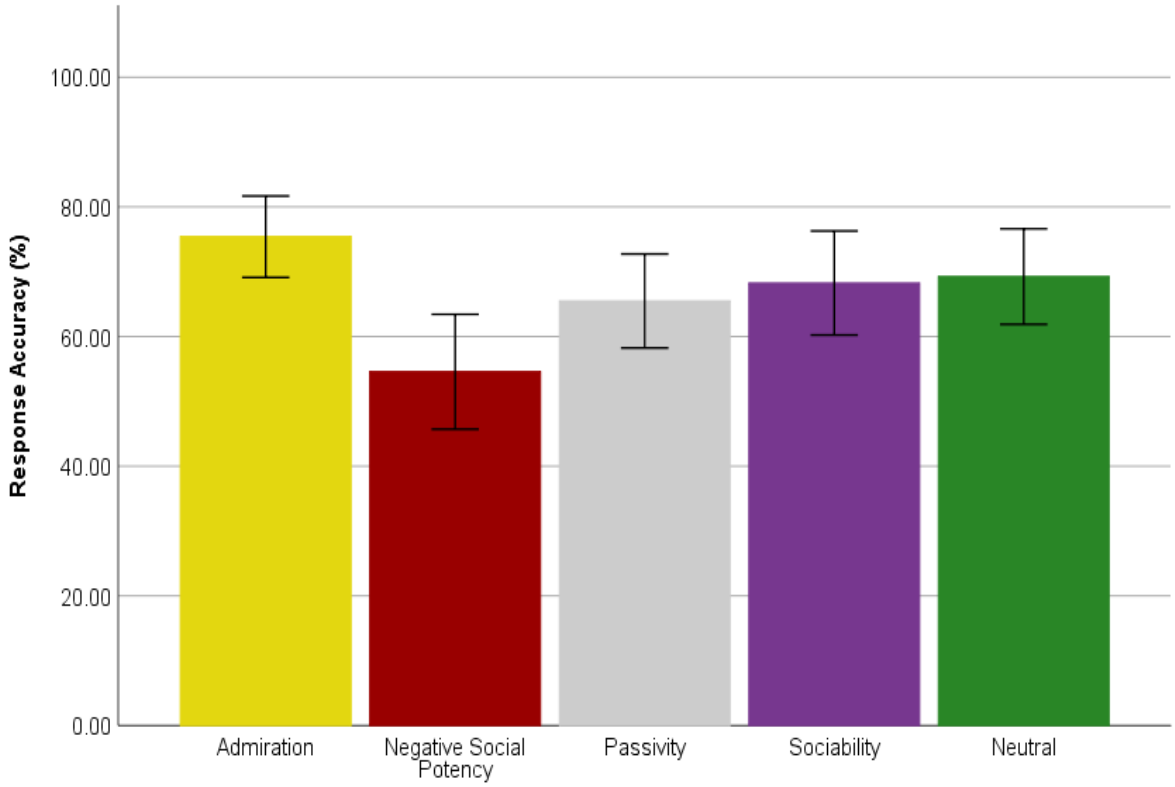


Figure 5.3. Mean Anticipatory Response Accuracy per Social Reward Subtype with 95% CI Error Bars (%)



5.5.3. Psychopathology and Behavioural Processing of Social Reward Subtypes

The zero-order Spearman's rho rank correlations between the dimensions of psychopathology and behavioural indices of social reward processing are presented in Table 5.2.

5.5.3.1. Admiration

The Cognitive-Perceptual dimension of the schizophrenia spectrum significantly correlated with reduced processing of social rewards involving Admiration, as indexed by slower anticipatory RTs towards social rewards involving Admiration, $r_s(40) = .36$, $p = .020$ [survived correction, $p^{\wedge} = .020$]. A similar relationship was observed in dimensional affective symptoms, with DASS-21 Stress, $r_s(40) = .34$, $p = .027$ [did not survive correction, $p^{\wedge} = .054$], also correlating with slower RTs towards social rewards involving Admiration. In addition to these hypothesised associations, a negative association between anticipatory response accuracy towards Admiration and the Antisocial dimension of the SRP-4-SF was observed, $r_s(40) = -.31$, $p = .045$ [survived correction, $p^{\wedge} = .045$]; indicating that this dimension of psychopathy is also associated with reduced processing of social rewards involving Admiration. No other significant associations between dimensions of psychopathology and social reward processing of Admiration were found.

5.5.3.2. Negative Social Potency

No significant associations were observed between RTs or response accuracy towards Negative Social Potency and dimensional psychopathy. The only psychopathological dimension that significantly related to Negative Social Potency was Disorganised dimension of the schizophrenia spectrum, which significantly correlated with slower anticipatory RTs towards Negative Social Potency, $r_s(40) = .34$, $p = .029$ [survived correction, $p^{\wedge} = .029$]. No other significant associations between psychopathology and Negative Social Potency were found – including those flagged earlier as requiring further investigation following the subjective social reward processing data presented in Chapter 4.

5.5.3.3. Passivity

As shown in Table 5.2, several significant associations between dimensional psychopathology and anticipatory response accuracy towards social rewards involving Passivity were observed. As hypothesised, schizophrenia spectrum traits (Cognitive-Perceptual dimension) and affective symptoms (Anxiety and Stress dimension) correlated with increased behavioural processing of social rewards involving Passivity, $r_s(40) = .32$, $p = .042$ [did not survive correction, $p^{\wedge} = .167$], $r_s(40) = .37$, $p = .017$ [survived correction, $p^{\wedge} = .034$], and $r_s(40) = .32$, $p = .040$ [did not survive correction, $p^{\wedge} = .121$], respectively. Increased behavioural processing of Passivity was also associated with the Abandonment dimension of BPD, $r_s(40) = .37$, $p = .016$ [survived correction, $p^{\wedge} = .016$]. No other significant associations were found.

5.5.3.4. Sociability

The Cognitive-Perceptual dimension of the schizophrenia spectrum correlated with reduced processing of Sociability, reflected in slower anticipatory RTs, $r_s(40) = .38$, $p = .013$ [survived correction, $p^{\wedge} = .013$]. In contrast, the Lifestyle dimension of psychopathy was associated with increased processing of Sociability, with Lifestyle traits correlating with faster RTs towards rewards involving Sociability, $r_s(40) = -.34$, $p = .029$ [did not survive correction, $p^{\wedge} = .058$]. For the response accuracy data, a positive correlation between anticipatory response accuracy towards Sociability and dimensional Anxiety was found, $r_s(40) = .33$, $p = .032$ [survived correction, $p^{\wedge} = .032$].

5.6. Discussion

This chapter aimed to extend the findings presented in Chapter 4 and provide further behavioural evidence of atypical social reward processing in psychopathology. To do so, this chapter investigated links between dimensional psychopathology and behavioural processing of the social reward subtypes identified by Foulkes, Viding et al. (2014). Scores

on self-report measures of schizophrenia spectrum traits, affective symptoms, psychopathic traits, BPD traits, and ASD traits were correlated with behavioural indices of social reward processing using the SRS-IDT. Results were largely in keeping with the hypotheses and provide further insight into how dimensional psychopathology affects specific aspects of social reward processing.

The SRS-IDT was employed as a behavioural measure of social reward processing. The task assesses behavioural anticipation of four subtypes of social reward (Admiration, Negative Social Potency, Passivity and Sociability) and indexes reward processing through anticipatory RTs and response accuracy towards a cued target. As such, the task compliments the Social Reward Questionnaire (Foulkes, Viding, et al., 2014) and provides an objective but nuanced measure of behavioural social reward processing. Main effects of social reward subtype were found for both RT and response accuracy, with post-hoc tests suggesting that social rewards involving Negative Social Potency may elicit less behavioural reward processing in healthy individuals in comparison to other subtypes.

Better understanding the links between dimensional psychopathology and processing of the subtypes of social reward has implications for work which aims to characterise social reward processing in psychopathology (e.g., Chevallier et al., 2012). As noted in the previous chapter, the findings reported here suggest that, rather than global alterations in social reward processing, social reward processing in psychopathology may be differently affected depending on the subtype of social reward available.

Table 5.2. Correlations between Dimensional Measures of Psychopathology and SRS-IDT Performance

	Admiration RT	Negative Social Potency RT	Passivity RT	Sociability RT	Neutral RT	Admiration RA	Negative Social Potency RA	Passivity RA	Sociability RA	Neutral RA
Schizophrenia Spectrum Traits										
SPQ-BR Cognitive-Perceptual	.36*^	.23	-.02	.38*^	.30	-.12	.26	.32*	.00	-.14
SPQ-BR Interpersonal	.04	.14	-.08	.05	.19	.04	.14	.28	.17	.06
SPQ-BR Disorganised	.26	.34*^	.03	.28	.29	.15	.07	.20	.28	.13
Affective Symptoms										
DASS-21 Depression	.05	.18	.09	.03	.18	.15	.05	.19	.26	.06
DASS-21 Anxiety	.18	.17	.12	.13	.09	.13	.28	.37*^	.33*^	.19
DASS-21 Stress	.34*	.30	.05	.21	.24	.06	.21	.32*	.24	.08
Psychopathic Traits										

SRP-4-SF Interpersonal	-.18	.03	-.13	-.01	-.09	-.12	-.07	.05	-.14	-.06
SRP-4-SF Affective	-.24	-.01	-.26	-.12	-.18	-.09	.07	.06	-.08	.03
SRP-4-SF Lifestyle	-.29	-.22	-.29	-.34*	-.29	-.23	-.06	-.07	-.14	-.08
SRP-4-SF Antisocial	.07	-.08	-.09	.25	.09	-.31*^	.18	.06	-.27	-.21
SRP-4-SF Total	-.22	-.07	-.26	-.13	-.16	-.22	-.01	.00	-.19	-.08
BPD Traits										
BPQ Impulsivity	-.11	-.07	-.22	-.26	-.14	-.06	.04	-.05	.04	-.09
BPQ Affective Instability	.03	.13	-.11	-.10	.04	.00	.10	.18	.06	-.09
BPQ Abandonment	.03	-.07	-.18	-.11	-.02	.00	.29	.37*^	.15	.09
BPQ Relationships	.03	.10	.01	-.15	.00	-.14	-.07	.01	.07	-.09
BPQ Self-Image	-.23	-.12	-.06	-.31*	-.13	.15	.11	.18	.23	.11
BPQ Suicide/Self-Mutilation	.13	.26	.12	.17	.19	.02	.16	.22	.04	.01
BPQ Emptiness	-.08	.12	-.04	-.15	.05	.04	-.02	.16	.21	.03

BPQ Intense Anger	-.02	-.08	-.06	-.15	-.07	-.07	-.01	-.05	-.08	-.21
BPQ Quasi-Psychotic States	.05	.09	.11	.04	.00	-.01	-.09	.02	.11	-.10
ASD Traits										
AQ Social Skills	.06	.06	.04	-.05	.18	.00	-.03	.11	.05	-.04
AQ Details/Patterns	-.14	.15	-.05	-.15	-.13	.03	.04	.05	.02	-.08
AQ Communication /Mindreading	.10	.13	.04	.11	.06	-.09	-.02	.16	.09	.10
AQ Total	.07	.26	.15	-.08	.16	-.02	-.01	.09	.13	-.07

* = significant at *p* = .05; RT = Reaction Time; RA = Response Accuracy; ^ = survived Hochberg correction

5.6.1. Schizophrenia Spectrum Conditions

The findings presented in Chapters 3 and 4 propose that social reward processing is affected in schizophrenia spectrum conditions. Chapter 3 found meta-analytic evidence of reduced behavioural processing of social rewards in clinical groups with schizophrenia, with Chapter 4 illustrating this dimensionally via correlations between schizophrenia spectrum traits and reduced subjective processing of social rewards. These findings are extended further by the results of this chapter, which highlight that Cognitive-Perceptual symptomatology may specifically affect the behavioural processing of social rewards involving Admiration and Sociability.

As mentioned in the previous chapter, it is perhaps surprising that the Cognitive-Perceptual dimension of the schizophrenia spectrum, rather than the Interpersonal dimension, was associated with reduced behavioural social reward processing – specifically social rewards involving Admiration and Sociability. It may be that reduced social reward processing linked to this dimension is driven by the subordinate features of Cognitive-Perceptual symptomatology, namely ideas of reference and a tendency towards suspiciousness. Ideas of reference share some phenotypic similarities with social anxiety (Morrison & Cohen, 2014), with individuals who self-report more ideas of reference expressing increased anxiety about other people judging them or being laughed at by others (Meyer & Lenzenweger, 2009). Therefore, it is perhaps logical that more prominent ideas of reference would lead to reduced processing of social rewards involving Admiration or Sociability; subtypes of social reward which inherently involve being paid attention to or increase ones' exposure to the judgements of others (Foulkes, Viding, et al., 2014). In addition to Admiration and Sociability, it was also hypothesised that schizophrenia spectrum traits would be associated with increased behavioural processing of rewards involving Passivity. This hypothesis was met, with the Cognitive-Perceptual dimension correlating with increased anticipatory response accuracy towards social rewards involving Passivity.

5.6.2. Affective Symptoms

The first, third and fourth hypotheses predicted that affective symptomatology would be associated with reduced behavioural processing of social rewards involving Admiration and Sociability, and increased processing of rewards involving Passivity. These hypotheses were formulated following previous research (e.g., Brinkmann et al., 2014) which has shown that affective symptomatology affects the subjective enjoyment and motivational value of these types of social interaction.

These hypotheses were only partially met. As predicted, reduced behavioural processing of social rewards involving Admiration was associated with the Stress dimension of DASS-21.

This is consistent with research which has shown that affective symptomatology affects the reward value of peer-acceptance (a related construct to Admiration) (Rappaport et al., 2019) and fits within the wider experiential-avoidance literature (e.g., Kashdan et al., 2014) which proposes that higher levels of stress decrease wanting of potentially revealing or vulnerable situations, such as being the centre of attention (Gerhart et al., 2014). Similarly, Anxiety and Stress dimensions both correlated with increased response accuracy towards social rewards involving Passivity. As with schizophrenia spectrum traits, this finding is in keeping with existing research which has shown that affective symptomatology increases propensity for socially passive behaviours (e.g., Bird et al., 2018).

In contrast to the hypothesised associations between behavioural social reward processing and dimensional affective symptoms, this study found evidence of increased behavioural processing of Sociability in dimensional anxiety. Given that the previous chapter found no significant associations between subjective processing of Sociability and anxiety, and that there are no clear links between dimensional anxiety and increased Sociability published elsewhere, this finding of increased behavioural processing of Sociability (indexed through anticipatory response) requires replication in larger samples before interpretation.

5.6.3. Psychopathic Traits

Increased enjoyment of social rewards involving Negative Social Potency is a prominent feature of psychopathy (Foulkes, McCrory et al., 2014). Individuals higher in psychopathic traits are more likely to enjoy witnessing or causing harm to others and experience increased feelings of reward during trolling or taunting behaviour (March, 2019). Therefore, it was hypothesised that dimensional psychopathic traits would be associated with increased behavioural processing of social rewards involving Negative Social Potency. However, no such associations were observed. Rather than suggesting that processing of Negative Social Potency is not enhanced in dimensional psychopathy, the lack of observed relationship likely indicates issues within the presentation of Negative Social Potency stimuli (see Strengths and Limitations, 5.6.6., below).

The previous chapter found evidence of increased subjective processing of Sociability related to the Lifestyle dimension of psychopathy. This self-report finding was corroborated by the behavioural data collected in this study; finding a significant association between Lifestyle dimension scores and increased behavioural processing of Sociability. The Lifestyle dimension of psychopathy captures sensation-seeking and irresponsible behaviours which, following the results of this and the previous chapter, may well manifest in increased enjoyment of parties and large social gatherings (Lilienfeld et al., 2019).

5.6.4. Borderline Personality Disorder Traits

Contrary to the first hypothesis, no significant relationships between BPD dimensions and reduced processing of Admiration were found. This was also the case for the subjective data in the previous chapter (see Table 4.4.), challenging research (e.g., Weinbrecht et al., 2020) which has proposed that BPD is associated with reduced wanting of Admiration. However, as noted earlier, it may be that Admiration-related adjustments in BPD are only observable at the clinical level and are not expressed dimensionally. This study found preliminary evidence of increased behavioural processing of Passivity linked to the Abandonment dimension of BPD. As with schizophrenia spectrum traits and affective symptoms, this indicates that individuals higher in the Abandonment dimension of BPD demonstrate increased processing of opportunities for Passivity. Although not hypothesised, this increased wanting of Passivity suggests that the interpersonal submissiveness that is associated with BPD (Barnow et al., 2009) may have a reward value. An unexpected significant association between BPD Self-Image scores and increased behavioural processing of social rewards involving Sociability was also found.

The lack of previous research investigating social reward processing in BPD makes it difficult to draw robust conclusions regarding these BPD findings. As per the previous two chapters, the data indicate that social reward processing may be adjusted in BPD – but the exact nature of these adjustments is difficult to infer based on the data presented here. Thus, future research should look to replicate these findings using both subjective and behavioural assessments of social reward processing in dimensional BPD, towards the end of clarifying how exactly social reward processing is dimensionally affected in BPD.

5.6.5. Autism Spectrum Disorder Traits

The social motivation hypothesis of autism (Chevallier et al., 2012) proposes that deficits in social reward processing contribute to atypical interpersonal behaviour in ASD. Following the results of the previous chapter, it was hypothesised that ASD traits would be associated with reduced behavioural processing of rewards involving Admiration and Sociability. However, these hypotheses were not met as no significant associations between Admiration, Sociability, and dimensional ASD were found. This was also the case for the hypothesis regarding Passivity, with no observed associations between ASD traits and increased processing of Passivity.

Much of the existing evidence for the behavioural bases of atypical social reward processing in ASD comes from research comparing behavioural processing of social rewards (often emotional faces) versus non-social rewards (often money or neutral stimuli) (Bottini, 2018). This study contributes knowledge, therefore, by showing that these global social reward

processing deficits may not extend to the behavioural processing of specific subtypes of social reward. Whilst some research has attempted to examine impairments in particular aspects of social interaction in ASD, for example reduced interest in obtaining social reputation (Izuma et al., 2011), this work tends to not be in the context of social reward processing per se but rather social functioning more generally, and thus the reward value of specific subtypes of social reward in dimensional ASD needs to be further investigated. The previous chapter and Foulkes et al. (2015) both provide preliminary evidence that dimensional ASD traits are associated with reduced subjective processing of social rewards involving Admiration and Sociability, but this was not reflected behaviourally in this investigation.

5.6.6. Strengths and Limitations

This research used the SRS-IDT. To-date, this is the first incentive delay paradigm to simultaneously assess behavioural processing of different subtypes of social reward and thus its inclusion is a strength of this research. Indeed, whilst other research has examined the reward value of social reward subtypes in separate tasks, combining them within an incentive delay format has helped to clarify how dimensional psychopathology specifically affects the anticipation of different social reward subtypes without increasing the cognitive demands of the task, as is often the case in other social interaction paradigms (Gu et al., 2019; Knutson & Greer, 2008).

The inclusion of avatar-based social rewards is also a strength of this research. As with the modified MSIDT used in the previous chapter, visualising the social reward subtypes through avatars increases the engagement value of the task (Freedman & Flanagan, 2017) and is line with reward research recommendations made by Fulford et al. (2018). However, as noted earlier, the design of the Negative Social Potency stimuli may have restricted the potential reward value of this subtype. Whilst stimuli were developed with the aim of depicting the avatar witnessing or causing harm to others (see Chapter 2, section 2.5., page 41), it was challenging to do so within the bounds of ethics requirements and whilst ensuring that Negative Social Potency rewards were of a similar intensity to the other social reward subtypes. Moreover, the Negative Social Potency subscale of the Social Reward Questionnaire (Foulkes, Viding, et al., 2014) includes items such as "*I enjoy being nice to someone only if I get something out of it*" and "*I enjoy tricking someone out of something*", concepts which are difficult to capture and visualise within a 3000ms avatar-based video. This suggests, to experimentally assess reward responses to Negative Social Potency, it may be necessary to follow recent definitions of sadistic behaviour (Foulkes, 2019) and

parse psychological forms of Negative Social Potency (for example trolling, bullying) from physical forms (for example causing or witnessing physical harm to others).

Furthermore, a second limitation within the SRS-IDT is that it did not include all subtypes of social reward defined by Foulkes, Viding, et al. (2014). Whilst the rationale for this is provided in Chapter 2 (see section 2.5., page 41), the exclusion of the Prosocial Interactions subtype of social reward does restrict the utility of the findings presented here. Indeed, the previous chapter indicated that several dimensions of psychopathology are related to reduced subjective processing of social rewards involving Prosocial Interactions. Following this self-report evidence, future research should develop the SRS-IDT to include the Prosocial Interaction subtype, thereby increasing the usefulness of the task. Finally, as most of the sample identified as female, the assessment of gender-related effects was not possible due to lack of statistical power. However, gender affects both social reward processing (Spreckelmeyer et al., 2009) and expression of psychopathology (Hartung & Lefler, 2019). Thus, a recommendation of this chapter is that future studies should recruit larger samples of male-identifying and female-identifying participants and compare social reward subtype processing between genders.

5.7. Chapter Summary

This chapter investigated associations between dimensional psychopathology and behavioural processing of subtypes of social reward. It found preliminary evidence of reduced behavioural processing of social rewards involving Admiration linked to the Cognitive-Perceptual dimension of the schizophrenia spectrum, Stress symptomatology, and the Antisocial dimension of psychopathy. Reduced behavioural processing of social rewards involving Sociability was associated with the Cognitive-Perceptual dimension, but increased processing was associated with SRP-4-SF Lifestyle, BPQ Self-Image, and DASS-21 Anxiety. Increased behavioural processing of Passivity was also seen across diagnostic dimensions, with schizophrenia spectrum, affective, and BPD dimensions correlating with increased response accuracy towards Passivity. Together, these findings give insight into the specific relationships between psychopathological dimensions and subtypes of social reward, with the caveat that the methods employed here should be replicated in other samples. The next chapter is informed by the methodology and findings of Chapters 4 and 5 and transfers this work in normative populations to a pilot clinical sample of forensic mental health service users.

6. Social Reward Processing in a Clinical Sample of Forensic Psychiatric Service Users: A Pilot Study

6.1. Chapter Aims and Overview

The findings presented in this thesis thus far have shown that atypical social reward processing is a transdiagnostic characteristic of clinical psychopathology (Chapter 3), and that dimensional psychopathology affects subjective and behavioural social reward processing (Chapters 4 and 5). The preliminary investigation detailed in this chapter aims to bring this work together, combine between-group and dimensional approaches, and investigate social reward processing in a pilot sample of forensic psychiatric service users. It begins with an introduction to forensic psychiatric service user symptomatology and interpersonal behaviour, before presenting results on subjective (Social Reward Questionnaire; Foulkes, Viding, et al., 2014) and behavioural (modified Monetary and Social Incentive Delay Task; MSIDT) measures of social reward processing.

6.2. Introduction

Most service users receiving care within forensic psychiatric settings have a complex history of mental illness and/or personality disorder diagnoses and present a level of risk to themselves or others which means they require care within a secure environment. In addition, most also have a history of criminal offending and antisocial behaviour that is thought to be associated with their mental health and personality. Despite the substantial resources (estimates of approximately £175,000 per patient per year; Hare Duke et al., 2018) that are dedicated to rehabilitating offenders with mental health and personality diagnoses, forensic psychiatric service users represent a relatively poorly understood patient population (Ashworth et al., 2021) and treatment progress is often small, with a considerable risk of relapse or reoffending upon discharge for a significant proportion (Völlm et al., 2018).

Characterisations of forensic psychiatric service user symptomatology (e.g., Palijan et al., 2009) suggest a high prevalence of schizophrenia spectrum and personality disorders, with 60% of service users having a primary diagnosis of schizophrenia spectrum conditions (Degl' Innocenti et al., 2014). Comorbidity is common, with 45% of service users within high secure psychiatric hospitals meeting diagnostic criteria for both schizophrenia and antisocial personality disorder (Blackburn et al., 2003). Affective symptoms (Piselli et al., 2015) and autism spectrum disorder (ASD) (Murphy, 2020) are also frequently identified as co-morbid conditions. As in psychopathology more generally, there is an increasing emphasis on using dimensional approaches to understand the complex symptom profiles of forensic psychiatric service users and the overlap between psychotic, antisocial, and affective symptomatology (Anderson et al., 2018).

The potential for forensic psychiatric service users to act violently towards themselves or others is what separates them from other mental health populations (Warburton, 2013). This increased proclivity towards violence or antisocial behaviour is often linked to feelings of paranoia or suspiciousness regarding the intentions of others (Palijan et al., 2009) but is also underscored by deficits in social cognition (Cullen et al., 2012), anger regulation (Greer et al., 2020), and an antagonistic/provocative/coercive interpersonal style (Vernham et al., 2016). Marked levels of psychopathy, characterised by a lack of empathy and persistent antisocial behaviour, are also highly prevalent within this population (Hildebrand, 2005) and thus likely contribute to forensic psychiatric service user antisocial behaviour.

This propensity for antisocial behaviour is often coupled with reduced prosocial motivation. Indeed, forensic psychiatric service users are often described as socially aloof and demonstrate a disregard for social norms (Williams & Chard, 2016). As highlighted in previous chapters, reduced social motivation and social withdrawal characterise a range of psychopathologies, and Van Dongen et al. (2015) posit that, in forensic psychiatric service users, reduced social motivation is jointly influenced by schizophrenia spectrum symptomatology and antisocial personality traits.

6.2.1. Atypical Social Reward Processing as Potential Explanatory Mechanism

This characterisation of forensic psychiatric service users as simultaneously antisocial and asocial (Pomp et al., 2010) has implications for reward-related conceptualisations of interpersonal behaviour in psychopathology. The findings presented in this thesis thus far have highlighted that psychopathology affects social reward processing, with reduced subjective and/or behavioural processing of social rewards involving Admiration, Prosocial Interactions, and Sociability linked to schizophrenia spectrum traits, affective symptoms, and ASD traits. Concurrently, schizophrenia spectrum, psychopathic, BPD, and ASD traits have been shown to be associated with increased subjective processing of social rewards involving Negative Social Potency – defined by Foulkes, Viding et al. (2014) as the enjoyment of enacting or witnessing cruelty to others.

It is, thus, possible that psychopathology-related atypical social reward processing may contribute to the antisocial and asocial behaviours of forensic psychiatric service users. However, no work to-date has examined social reward processing within a forensic psychiatric context. Following the findings presented in the previous chapters, adjustments in social reward processing are likely to be influenced by psychopathology dimensionally, and thus it is important to employ continuous measures of psychopathology and reward processing, in addition to comparing clinical populations to samples from the general population (as was done in Chapter 3). This could help to identify atypical social reward

processing as a mechanism which maintains forensic psychiatric service user antisocial and asocial behaviour, and thereby offer a potential avenue for therapeutic intervention.

6.3. Rationale and Aims

This study, therefore, aimed to present preliminary evidence of associations between psychopathology and social reward processing in a pilot sample of forensic psychiatric service users. As described above, forensic psychiatric service users demonstrate a range of atypical interpersonal behaviours which may, following the results of the previous two chapters (see Chapter 4 and Chapter 5), be linked to adjusted subjective and/or behavioural processing of social rewards.

This study compared social reward processing, as assessed by the Social Reward Questionnaire (SRQ) and the modified MSIDT in a small clinical sample - hereon referred to as the clinical group - and an age and gender matched control group. This was with the aim of further exploring the meta-analytic findings of Chapter 3 (see section 3.5., page 49) which identified atypical social reward processing as a characteristic of clinical mental health groups versus healthy controls. In addition to this between-groups comparison, this study investigated whether the dimensional relationships between psychopathology and social reward processing observed in Chapters 4 and 5 translate to a clinical sample scored on the same dimensions of psychopathology.

Thus, this pilot study had the following hypotheses:

1. Clinical group SRQ scores will be different to the control group, with the clinical group reporting reduced subjective processing of social rewards involving Admiration, Prosocial Interactions, and Sociability. Negative Social Potency scores will be higher in the clinical group than the control group, suggesting increased subjective processing of Negative Social Potency in the clinical group.
2. Within the clinical group, dimensional measures of schizophrenia spectrum traits, affective symptoms, psychopathic traits, and ASD traits, will correlate with reduced subjective processing of social rewards involving Prosocial Interactions. Schizophrenia spectrum traits and ASD traits will be associated with reduced subjective processing of Sociability. Psychopathic traits will also correlate with increased subjective processing of social rewards involving Negative Social Potency.
3. Analysis of behavioural processing of rewards will show an interaction between group (clinical or control) and reward type (monetary, social, neutral), with the

clinical group demonstrating reduced behavioural processing (hypoanticipation) of social rewards in comparison to the control group.

4. Dimensional psychopathology will be associated with reduced processing (hypoanticipation) of social rewards, with schizophrenia spectrum traits, affective symptoms, and ASD traits, correlating with slower anticipatory reaction times (RTs) and response accuracy towards social rewards.

6.4. Methods

6.4.1. Ethics Statement

Full ethical approval for this study was granted by the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS), Brunel University London (ID: 16789) and by the National Research Ethics Service through IRAS (REC ID: 19/LO/0605; IRAS ID: 260683). All participants provided written informed consent prior to participating and were compensated £30 as a thank you for their time.

6.4.2. Participants and Procedure

Fifteen male adults currently receiving treatment within a forensic psychiatric service participated. Participant demographic information is presented in Table 6.1. All participants within the clinical group were receiving psychiatric care within conditions of medium security at the time of their participation and thus were considered to pose a significant risk of violence towards themselves and/or others.

Participants in the clinical group were recruited from within the West London Forensic Service, West London NHS Trust. Potential participants were referred for recruitment into the study by their Responsible Clinician and then approached by a member of the research team. Participants were referred for recruitment into the study if: (1) they had the capacity to provide written informed consent regarding their participation, (2) were clinically stable enough to meaningfully participate in the research, (3) had normal or corrected-to-normal vision and hearing, and (4) did not pose an imminent risk of violence to the researchers. All participants were taking a range of psychotropic medications (including typical and atypical antipsychotic medications) at the time of participation.

All research sessions took place in a quiet interview space on-ward. The data presented here were gathered as part of a much larger study which took approximately 3.5 hours per participant. Participants completed all parts of the research independently with support from the researcher as required.

For the purposes of between-group comparisons, participant data from the study in Chapter 4 were extracted and used as an age and gender matched control group (n = 15, M_{age} = 32.33 ± 11.15; age not significantly different to clinical group: $t(28) = 1.03$, $p = .31$). The control group had no history of mental health difficulties, had normal or corrected-to-normal vision and hearing, and were not using illicit substances (as self-reported) at the time of participation.

Table 6.1. Clinical Group Demographic Information

Age (Mean, SD)	36.80 (12.59)
Ethnicity	Asian (n = 4) Black (n = 7) Other (n = 2) White (n = 2)
Diagnoses (Primary and Secondary)	Paranoid Schizophrenia (n = 9) Schizoaffective Disorder (n = 3) Bipolar Disorder (n = 2) Hebephrenic (Disorganised) Schizophrenia (n = 1) Borderline Personality Disorder (n = 1) Antisocial Personality Disorder (n = 1) Autism Spectrum Disorder (n = 1)
First Language	English (n = 13) Other (n = 2)

6.4.3. Measures of Psychopathology

6.4.3.1. Self-Report Measures

The Schizotypal Personal Questionnaire – Brief (SPQ-BR; Cohen et al., 2010) was employed as a dimensional measure of schizophrenia spectrum traits. The SPQ-BR has 32 items which are rated on a five-point Likert scale (0-4, 0 = Strongly disagree and 4 = Strongly agree). The SPQ-BR generates scores on three subscales, each representing a dimension of the schizophrenia spectrum: Cognitive-Perceptual, Interpersonal, and Disorganised. No total score is calculated. Higher scores on the SPQ-BR indicate more pronounced schizophrenia spectrum traits. The SPQ-BR was used to assess schizophrenia spectrum traits in the previous two chapters (see 4.4.3., page 79, and 5.4.3., page 117).

Feelings of depression were assessed via the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). PHQ-9 is a short 9 item scale which assesses the severity of depression symptoms, rated by the participant on a four-point scale (0 = Not at all, 3 = Nearly every day). It is a self-report measure of depression symptomatology that can be used both as a screening tool (with mild, moderate, moderately severe, and severe cut-off points) and dimensionally (Kroenke et al., 2001).

The Borderline Personality Disorder Questionnaire (BPQ; Poreh et al., 2006) was used to measure dimensional BPD traits. The BPQ has 80 items which are rated by the respondent as True (1) or False (0). It generates scores for nine dimensions of BPD: Impulsivity, Affective Instability, Abandonment, Relationships, Self-Image, Suicide/Self-Mutilation, Emptiness, Intense Anger, and Quasi-Psychotic States. No total score is calculated. Higher scores on the BPQ indicate more pronounced BPD traits. The BPQ was used to assess BPD traits in the previous two chapters (see 4.4.3. and 5.4.3.).

ASD traits were measured using the 10 item Autism Quotient (AQ-10; Allison et al., 2012). This is an abbreviated version of the full Autism Quotient used in Chapters 4 and 5. Each of the 10 items is rated by the participant using a four-point scale of Definitely agree to Definitely disagree. Each item is scored as '1' each time a non-neurotypical response is given. The AQ-10 is intended as a quick self-reported screening tool for ASD and generates a total score for an overall impression of ASD traits.

Corresponding control group self-report psychopathology data were also extracted where available. It is important to note that some of the self-report measures completed by the clinical group (PHQ-9, AQ-10) were not completed by the control group (control group completed DASS-21, AQ; see Chapter 4, section 4.4.3., page 79) and thus the two groups could not be compared on these measures.

6.4.3.2. Psychopathy Checklist – Revised

Clinical group participants were assessed for psychopathic traits using the Psychopathy Checklist - Revised (PCL-R; Hare, 2003) via file review. The PCL-R has 20 items, each of which are scored by the interviewer/researcher as absent (0), partially present (1), or present (2), totalling to a maximum score of 40. Research adopting taxonomic approaches to psychopathy (e.g., Cooke et al., 2005) typically employs a score of 25 as the cut-off for clinical psychopathy within European samples. The PCL-R can also be used dimensionally (Edens et al., 2006) and provides scores for each of the four dimensions of psychopathy as per the SRP-4-SF: Interpersonal, Affective, Lifestyle, and Antisocial. The PCL-R is usually completed via interview (with review of case files to provide supplementary information) but

is appropriate for use via file review only, provided an adequately detailed case history is available (Hare, 2003).

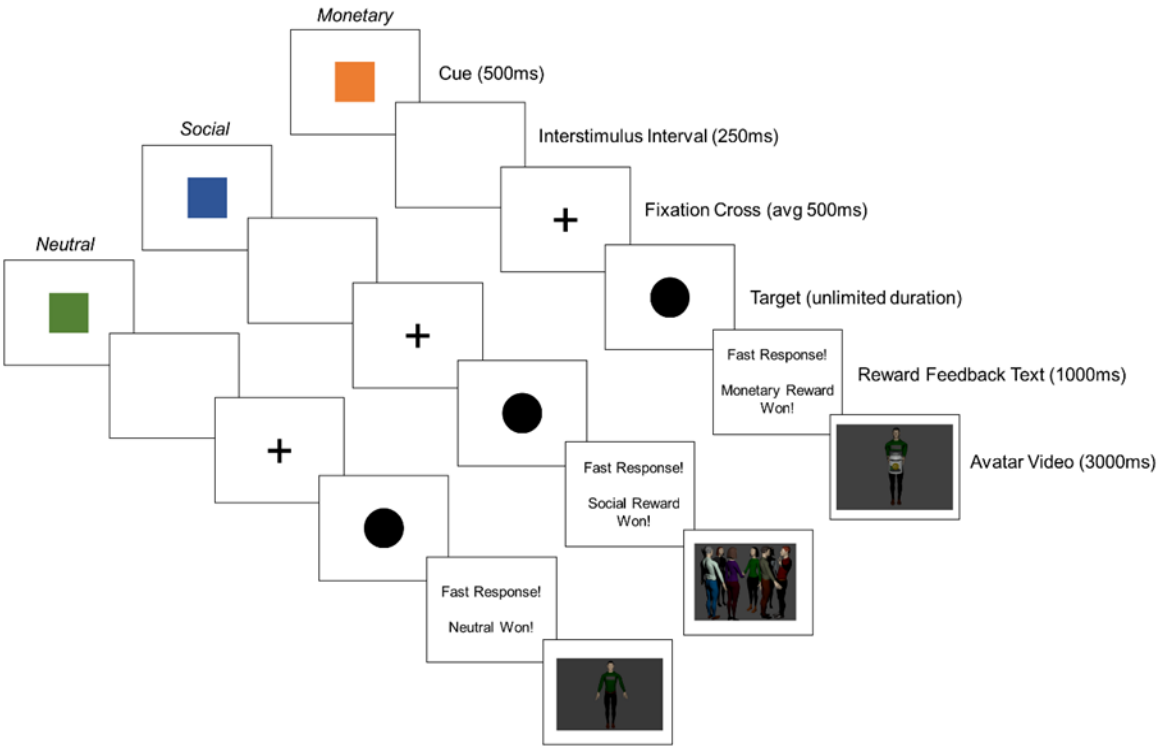
6.4.4. Subjective Social Reward Processing

As in previous chapters, subjective processing of social rewards was measured using the SRQ (Foulkes, Viding, et al., 2014). It assesses hedonic experience of the social reward subtypes described in Chapter 1 (see section 1.3., page 17): Admiration, Negative Social Potency, Passivity, Prosocial Interactions, Sexual Relationships and Sociability. It has 23 items, split into six subscales as per the social reward subtypes, which are rated using a seven-point Likert scale (1 = Strongly disagree, 7 = Strongly agree). Higher scores indicate increased subjective social reward processing.

6.4.5. Behavioural Processing of Monetary and Social Rewards

As in Chapter 4, behavioural processing of rewards was assessed in this study using the modified MSIDT (see Chapter 2, section 2.4.1., page 38, for full task information). The format of the task is presented in Figure 6.1 and is the same as in Chapter 4. It measures behavioural anticipation of monetary, social, and neutral reward stimuli, with 12 trials per stimulus type.

Figure 6.1. Monetary and Social Incentive Delay Task



As shown in Figure 6.1., each trial had a six-part sequence with a 500ms interval between trials. Each trial began with the presentation of a cue (500ms) which indicated the type of reward available (monetary, social, neutral). After a short interstimulus interval (250ms) and jittered fixation cross (average 500ms duration), a target appeared which the participant had to respond to as quickly as possible. As described in previous chapters, participants had to respond to the target within their predefined RT threshold (set during practice trials) to win the available reward.

All rewards were presented via animated avatar video (3000ms). Participants were able to select an avatar prior to starting the task and were encouraged to adopt the avatar's position as much as possible. Monetary rewards showed the avatar receiving a large gold coin into a jar, accompanied by the sound of a cash register. Social rewards showed the avatar participating in social interactions denoting four subtypes of social reward (Admiration, Negative Social Potency, Passivity and Sociability), each accompanied by a corresponding sound (e.g., Admiration = Avatar receiving applause from a crowd, accompanied by sound of clapping and cheering). Neutral stimuli showed the avatar stood stationary in the centre of the screen, accompanied by a neutral tone. All rewards were shown via video and no actual monetary or social reward was attached to task performance.

6.4.5.1. Indexing Task Performance on the modified MSIDT

Behavioural processing of monetary, social, and neutral rewards was indexed through anticipatory RT (ms) and response accuracy (%) towards the target, with faster RTs and greater response accuracy indicating increased reward processing (Knutson et al., 2000). As in Chapter 4, in addition to raw measures of RT and response accuracy, reward difference scores were calculated to compare behavioural processing across reward types. These reward difference scores were calculated by subtracting the task performance metrics from one another and were arranged so that positive values indicated increased behavioural processing of social rewards relative to monetary rewards, monetary rewards relative to neutral, and social rewards relative to neutral.

6.4.6. Data Screening

All data screening was performed using SPSS Version 26. Data were first checked for missing values, presence of outliers, and normality of distribution. Of the self-report measures of psychopathology, two clinical group participants did not complete the SPQ-BR (n = 13), all completed the BPQ (n = 15), and four did not complete the PHQ-9 (n = 11). One participant did not have sufficiently detailed information in their case record history to allow the PCL-R to be completed via file review (n = 14). Two clinical group participants did not complete the SRQ and thus could not be included in subsequent subjective social reward

processing analyses (n = 13). All participants in the control group provided complete self-report data (n = 15 for all analyses). All participants provided complete MSIDT data. However, as per the other studies using the MSIDT in this thesis, data from one participant within the clinical group who recorded mean RTs ≥1000ms across reward types was excluded from the MSIDT analyses, reducing the clinical group sample size for task performance analyses to n = 14. Normality of data distribution was determined using Shapiro-Wilk tests and identified the following variables as non-normally distributed: BPQ Impulsivity, BPQ Self-Image, BPQ Suicide/Self-Mutilation, BPQ Intense Anger, PHQ-9. All other self-report and task performance variables were found to be normally distributed.

6.4.7. Data Analysis

All analyses were conducted using SPSS Version 26. Unlike previous chapters, where conventional methods of determining statistical significance were followed, the decision was made in this chapter to report statistical trends ($p < .10$) alongside estimates of effect size (Cohen's *d,* small = .20, medium = .50, large = .80; reported where appropriate). This decision was made following suggestions given in Schumm et al. (2013) and Cohen (1992) which propose that adopting a less conservative alpha threshold is appropriate when conducting exploratory work in small 5samples with low statistical power. It was also felt that, because of this intention to explore trend-level findings, the Hochberg (1988) correction did not need to be applied as per previous chapters. This decision to not apply correction was towards the aim of maximising the exploratory contribution of this study given the small sample and low statistical power (Schumm et al., 2013). As this is the first study to-date to explore social reward processing in a pilot forensic psychiatric sample, it was thus felt that adopting the $p < .10$ threshold for statistical trends was appropriate.

Differences in self-reported psychopathology between clinical and control groups were first examined via independent samples t tests (or non-parametric equivalent, Mann Whitney U test). Second, in line with hypothesis one, SRQ scores were compared between groups to establish whether the clinical group's subjective processing of social rewards was significantly different to the control group. Then, as per hypothesis two, associations between clinical group SRQ scores and dimensional psychopathology were assessed via zero-order correlations (parametric: Pearson's *r*, non-parametric: Spearman's rank order).

To examine differences in behavioural reward processing between groups, two repeated measures ANOVAs were computed with reward type (monetary, social, neutral) as the within-subjects factor and group (clinical, control) as the between-subjects factor. The Greenhouse-Geisser correction was applied if the sphericity assumption was violated, and results include the corrected *p* value when applied. Any statistically significant main or

interaction effects were examined post-hoc with the Bonferroni correction applied. Partial eta squared (η^2_p) was computed as a measure of effect size, with effects defined as small (η^2_p =.01), medium (η^2_p =.06), and large (η^2_p =.14) (Cohen, 1992).

Finally, to test hypothesis four, associations between dimensional psychopathology and MSIDT metrics of reward processing were tested in the clinical group via zero-order correlations.

6.5. Results

6.5.1. Characterisation of Psychopathology

Table 6.2. presents the mean and range scores on each of the measures of psychopathology in clinical and control groups.

Table 6.2. Psychopathology Scores in Clinical and Control Groups

	Clinical Group			Control Group		
	Mean (SD)	Observed Range (Possible Range)	N	Mean (SD)	Observed Range (Possible Range)	N
Schizophrenia Spectrum Traits						
SPQ-BR Cognitive-Perceptual	24.38 (13.43)	2-43 (0-56)	13	13.87 (10.34)	4-42 (0-56)	15
SPQ-BR Interpersonal	19.38 (8.03)	0-32 (0-40)	13	14.07 (6.53)	5-26 (0-40)	15
SPQ-BR Disorganised	14.00 (7.07)	0-25 (0-32)	13	15.20 (7.37)	2-26 (0-32)	15
Affective Symptoms						
PHQ-9 Total	4.45 (5.47)	0-20 (0-27)	11	-	-	-
Psychopathic Traits						

PCL-R Interpersonal	1.79 (1.97)	0-7 (0-8)	14	-	-	-
PCL-R Affective	3.93 (1.82)	1-7 (0-8)	14	-	-	-
PCL-R Lifestyle	4.21 (2.75)	0-8 (0-10)	14	-	-	-
PCL-R Antisocial	3.86 (2.63)	0-8 (0-10)	14	-	-	-
PCL-R Total	14.72 (7.56)	4-25.6 (0-40)	14	-	-	-
BPD Traits						
BPQ Impulsivity	2.87 (1.19)	1-6 (0-9)	15	2.20 (2.27)	0-7 (0-9)	15
BPQ Affective Instability	4.87 (3.04)	0-9 (0-10)	15	2.33 (2.35)	0-9 (0-10)	15
BPQ Abandonment	3.00 (2.14)	0-9 (0-10)	15	1.07 (1.22)	0-4 (0-10)	15
BPQ Relationships	3.00 (2.14)	0-6 (0-8)	15	1.67 (1.59)	0-5 (0-8)	15
BPQ Self-Image	2.20 (2.04)	0-7 (0-9)	15	2.00 (2.20)	0-7 (0-9)	15
BPQ Suicide/Self-Mutilation	2.93 (1.79)	0-5 (0-7)	15	0.13 (0.35)	0-1 (0-7)	15
BPQ Emptiness	2.73 (2.22)	0-7 (0-10)	15	2.07 (1.91)	0-6 (0-10)	15
BPQ Intense Anger	3.73 (2.40)	0-7 (0-10)	15	0.93 (1.62)	0-6 (0-10)	15
BPQ Quasi-Psychotic States	2.07 (1.75)	0-6 (0-7)	15	0.93 (1.44)	0-5 (0-7)	15
ASD Traits						

AQ-10 Total	4.30 (1.64)	2-7 (0-10)	10	-	-	-

Comparing the two groups, the clinical group demonstrated higher scores on several dimensions of psychopathology. The clinical group scored higher on both the Cognitive-Perceptual, $t(26) = 2.34$, $p = .027$, $d = 0.91$, and Interpersonal, $t(26) = 1.93$, $p = .064$, $d = 0.73$, dimensions of the schizophrenia spectrum. Differences between groups were also observed in most BPD dimensions, with the clinical group reporting higher scores on the Impulsivity, $U = 72.00$, $p = .098$, $d = 0.37$, Affective Instability, $t(28) = 2.55$, $p = .016$, $d = 0.93$, Abandonment, $t(28) = 2.55$, $p = .017$, $d = 1.11$, Relationships, $t(28) = 1.94$, $p = .063$, $d = 0.71$, Suicide/Self-Mutilation, $U = 26.50$, $p = <.001$, $d = 2.17$, Intense Anger, $U = 34.50$, $p = .001$, $d = 1.37$, and Quasi-Psychotic States, $t(28) = 1.94$, $p = .063$, $d = 0.71$, dimensions of BPD.

PHQ-9, PCL-R, and AQ-10 scores could not be compared as these measures were completed by the clinical group only. Intra-correlations between psychopathology measures for the clinical group can be found in the appendices (see Appendix 6, page 286).

6.5.2. Psychopathology and Subjective Processing of Social Rewards

6.5.2.1. Comparing Clinical and Control Groups

SRQ scores were compared between clinical and control groups to identify differences in subjective social reward processing (see Table 6.3.). A close-to-threshold trend towards difference in subjective processing of Prosocial Interactions was observed between groups, with the clinical group reporting less processing of Prosocial Interactions than the control group, $t(26) = 1.69$, $p = .103$, $d = 0.63$. Given that this trend has a medium effect size, it perhaps indicates that there may be a meaningful difference between groups in the subjective processing of social rewards involving Prosocial Interactions. None of the other group differences in self-reported social reward processing reached the trend threshold: Admiration, $t(26) = 1.02$, $p = .318$, $d = 0.38$, Negative Social Potency, $t(26) = 1.23$, $p = .229$, $d = .046$, Passivity, $t(26) = .857$, $p = .399$, $d = .032$, Sexual Relationships, $t(26) = .07$, $p = .944$, $d = 0.03$, Sociability, $t(26) = 1.11$, $p = .278$, $d = 0.42$.

Table 6.3. Clinical and Control Group Social Reward Questionnaire Scores

	Clinical Group			Control Group		
	Mean (SD)	Observed Range (Possible Range)	N	Mean (SD)	Observed Range (Possible Range)	N
SRQ Admiration	20.69 (3.99)	14-28 (4-28)	13	22.07 (3.15)	16-27 (4-28)	15
SRQ Negative Social Potency	12.23 (5.00)	5-21 (5-35)	13	10.20 (3.71)	5-17 (5-35)	15
SRQ Passivity	11.62 (3.82)	3-18 (3-21)	13	10.53 (2.85)	4-14 (3-21)	15
SRQ Prosocial Interactions	28.54 (4.70)	20-35 (5-35)	13	31.00 (2.90)	27-35 (5-35)	15
SRQ Sexual Relationships	14.77 (3.83)	8-21 (3-21)	13	14.87 (3.44)	9-21 (3-21)	15
SRQ Sociability	14.46 (3.89)	7-19 (-21)	13	15.87 (2.80)	12-21 (3-21)	15

6.5.2.2. Dimensional Approach in Clinical Group

Zero-order correlations between the dimensional measures of psychopathology and SRQ scores are presented in Table 6.4.

6.5.2.2.1. Schizophrenia Spectrum Traits

As hypothesised, schizophrenia spectrum traits were associated with atypical subjective processing of social rewards. The Cognitive-Perceptual dimension of the SPQ-BR related to reduced subjective processing of social rewards involving Admiration, $r(10) = -.59$, $p = .042$, and Prosocial Interactions, $r(10) = -.58$, $p = .047$, but was also associated with increased subjective processing of Negative Social Potency, $r(10) = .70$, $p = .012$. No other significant associations between schizophrenia spectrum traits and SRQ subscale scores were found. This suggests that higher levels of schizophrenia spectrum traits may be associated with atypical subjective processing of social rewards, and (as in other chapters) the subjective experience of social rewards may vary depending on the subtype of social reward available.

6.5.2.2.2. Affective Symptoms

Affective symptoms were assessed using the PHQ-9. No significant relationships between PHQ-9 scores and subjective social reward processing were found.

6.5.2.2.3. Psychopathic Traits

Psychopathic traits were assessed using the PCL-R via file review. As hypothesised, psychopathic traits were associated with reduced subjective processing of Prosocial Interactions, with negative associations linked to the Affective and Antisocial dimensions, $r(10) = -.50$, $p = .094$, and, $r(10) = -.59$, $p = .044$, respectively, as well as PCL-R total score, $r(10) = -.64$, $p = .025$. No other trends were observed.

6.5.2.2.4. Borderline Personality Disorder Traits

The Intense Anger dimension of BPD was associated with reduced subjective processing of social rewards involving Prosocial Interactions, $r_s(11) = -.61$, $p = .03$, and increased processing of social rewards involving Negative Social Potency, $r_s(11) = .56$, $p = .045$. Several trend associations were also observed. The Self-Image dimension correlated with reduced subjective processing of Admiration, $r_s(11) = -.53$, $p = .064$, and the Impulsivity dimension simultaneously correlated with reduced subjective processing of Negative Social Potency, $r_s(11) = -.51$, $p = .079$, and increased subjective processing of Sociability, $r_s(11) = .50$, $p = .080$.

6.5.2.2.5. Autism Spectrum Disorder Traits

Autism Spectrum Disorder traits were assessed using the AQ-10. No statistically significant associations between AQ-10 scores and self-reported social reward processing were found.

Table 6.4. Correlations Between Scores on Self-Report Measures of Psychopathology and the Social Reward Questionnaire (Clinical Group)

	Admiration	Negative Social Potency	Passivity	Prosocial Interactions	Sexual Relationships	Sociability
Schizophrenia Spectrum Traits						
SPQ-BR Cognitive-Perceptual	-.59**	.70**	.16	-.58**	-.03	-.37
SPQ-BR Interpersonal	-.40	.38	-.06	-.41	.13	-.39
SPQ-BR Disorganised	-.22	.35	.14	.44	.03	-.24
Affective Symptoms						
PHQ-9 Total $_{rs}$	-.34	.47	-.27	-.24	.19	-.35
Psychopathic Traits						
PCL-R Interpersonal $_{rs}$	-.46	.25	-.19	-.41	-.21	-.12
PCL-R Affective	-.37	.47	.09	-.50*	-.30	.35
PCL-R Lifestyle	-.37	.10	.24	-.47	-.19	-.10
PCL-R Antisocial	-.49	.14	.19	-.59**	-.15	-.25
PCL-R Total	-.53*	.31	.16	-.64**	-.23	-.29

BPD Traits						
BPQ Impulsivity $_{rs}$	.20	-.51*	-.16	.32	.37	.50*
BPQ Affective Instability	.25	-.01	-.20	.10	.23	-.10
BPQ Abandonment	-.16	.05	.01	-.11	.12	-.44
BPQ Relationships	-.14	.30	.23	-.14	.26	.08
BPQ Self-Image $_{rs}$	-.53*	.12	-.11	-.26	.09	-.13
BPQ Suicide/Self-Mutilation $_{rs}$	-.19	.20	-.41	-.14	.43	.00
BPQ Emptiness	-.25	.12	-.17	-.16	-.02	-.39
BPQ Intense Anger $_{rs}$	-.26	.56**	-.07	-.61**	-.33	-.34
BPQ Quasi-Psychotic States	-.18	.29	-.15	.03	.33	-.23
ASD Traits						
AQ-10 Total	-.13	-.03	.33	-.49	-.06	-.18

* = significant at p = .10; ** = significant at p = .05; parametric correlation r value stated unless variable marked *rs,* in which case non-parametric is used

Table 6.5. Correlations Between Scores on Self-Report Measures of Psychopathology and MSIDT Task Performance (Clinical Group)

	Monetary RT	Social RT	Neutral RT	Monetary RA	Social RA	Neutral RA	Monetary-Social RT[a]	Neutral-Monetary RT[b]	Neutral-Social RT[c]	Social-Monetary RA[d]	Monetary-Neutral RA[e]	Social-Neutral RA[f]
Schizophrenia Spectrum Traits												
SPQ-BR Cognitive-Perceptual	.14	.06	.28	.26	.32	.28	.14	.11	.34	.13	-.05	.12
SPQ-BR Interpersonal	.23	.09	.22	.33	.22	.31	.24	-.09	.19	-.07	.01	-.08
SPQ-BR Disorganised	.30	.29	.39	.40	.14	.46	.10	.00	.13	-.25	-.12	-.41
Affective Symptoms												
PHQ-9 $_{rs}$	-.26	-.38	-.22	.62**	.72**	.40	.14	-.06	.24	.22	.13	.47
Psychopathic Traits												
PCL-R Interpersonal	.13	.33	.49*	.08	-.09	-.03	-.47*	.34	-.04	-.03	.15	.11
PCL-R Affective	.04	.38	.43	.31	-.13	.04	-.41	.38	.06	-.50*	.35	-.24
PCL-R Lifestyle	.19	.48*	.39	-.29	-.45	-.24	-.31	.15	-.14	-.25	-.04	-.33

PCL-R Antisocial	.00	.36	.29	-.39	-.57**	-.39	-.45	.29	-.11	-.28	.02	-.31
PCL-R Total	.14	.51*	.56**	-.06	-.37	-.20	-.42	.38	.06	-.39	.19	-.27
BPD Traits												
BPQ Impulsivity $_{rs}$	.16	.37	-.18	-.40	-.47*	-.19	-.15	-.15	-.70**	-.14	-.18	-.45
BPQ Affective Instability	.28	.34	-.01	.20	.00	.31	.00	-.36	-.49*	-.22	-.17	-.41
BPQ Abandonment	.24	.30	.26	.13	-.09	.10	-.01	-.04	-.06	-.25	.04	-.25
BPQ Relationships	.54**	.56**	.46*	.25	.26	.36	.14	-.22	-.15	.06	-.17	-.09
BPQ Self-Image $_{rs}$	.22	.22	-.02	-.02	.09	.11	.28	-.47*	-.17	.01	-.16	-.36
BPQ Suicide/Self-Mutilation $_{rs}$	-.18	-.19	-.32	.25	.43	.37	-.16	-.10	-.39	.35	-.29	.19
BPQ Emptiness	.26	.24	.11	.04	-.05	.11	.10	-.22	-.19	-.09	-.10	-.21
BPQ Intense Anger $_{rs}$	-.09	.05	-.07	-.22	-.04	.10	-.46*	.33	-.23	.18	-.07	.06
BPQ Quasi-Psychotic States	.12	.06	.02	.27	.44	.25	.10	-.13	-.06	.26	.01	.31
ASD Traits												

AQ-10 Total	.45	.55	.60*	-.13	-.53	-.13	-.06	.05	-.02	-.53	.02	-.59*

* = significant at *p* =.10; ** = significant at *p* = .05; parametric correlation *r* value stated unless variable marked *rs,* in which case non-parametric is used; RT = reaction time; RA = response accuracy; [a]calculated by subtracting mean RT in social trials from mean RT in monetary trials; [b]calculated by subtracting mean RT in monetary trials from mean RT in neutral trials; [c]calculated by subtracting mean RT in social trials from mean RT in neutral trials; [d]calculated by subtracting monetary response accuracy from social response accuracy; [e]calculated by subtracting neutral response accuracy from monetary response accuracy; [f]calculated by subtracting neutral response accuracy from social response accuracy

6.5.3. Psychopathology and Behavioural Processing of Rewards

6.5.3.1. Comparing Clinical and Control Groups

The MSIDT data from the clinical and control groups are plotted in Figures 6.2. and 6.3. No significant main effect of reward type (monetary, social, neutral) was found for reaction time, F (2, 54) = 1.80, p = .176, η_p^2 = .06, or response accuracy, F (2, 54) = .60, p = .551, η_p^2 = .02. As reflected in Figure 6.2., there was a significant between-subjects effect on reaction time, with faster overall reaction times in the control group than in the clinical group, F (1, 27) = 21.33, p < .001, perhaps reflecting the psychomotor slowing associated with mental illness described in Chapter 3 (see section 3.8., page 68). However, this did not vary significantly based on reward type, with no significant interaction effect between reward type and group found for the reaction time data, F (2, 54) = 1.23, p = .333, η_p^2 = .04, suggesting no specific group-related adjustments in behavioural reward processing. Similarly, no significant interaction effect between reward type and group was found for response accuracy, F (2, 54) = .43, p = .643, η_p^2 = .02.

Figure 6.2. Mean Anticipatory Reaction Time per Reward Type for Clinical and Control Groups (ms)

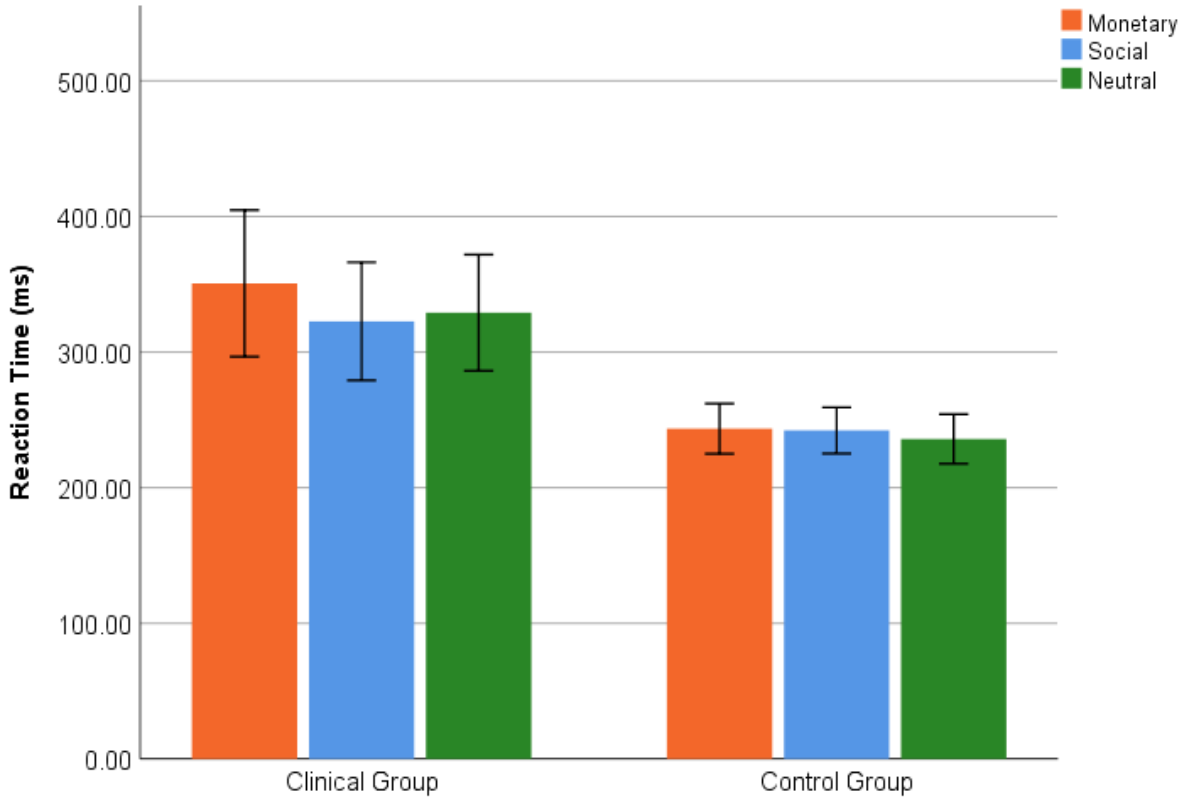
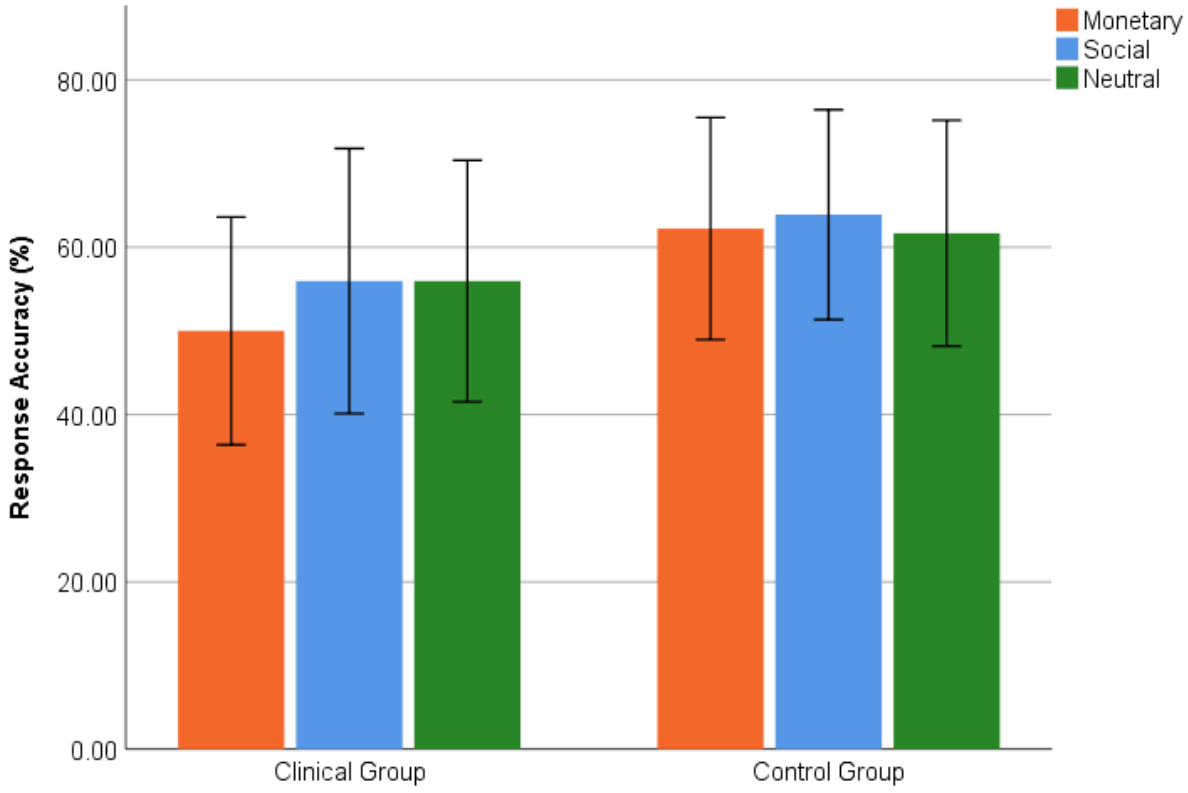


Figure 6.3. Mean Anticipatory Response Accuracy per Reward Type for Clinical and Control Groups (%)



6.5.3.2. Dimensional Approach in Clinical Group

6.5.3.2.1. Schizophrenia Spectrum Traits

Unlike in previous chapters, and thus contrary to hypothesis four, no significant relationships between schizophrenia spectrum traits and behavioural processing of social rewards were observed.

6.5.3.2.2. Affective Symptoms

PHQ-9 scores positively correlated with response accuracy towards monetary, $r(9) = .62$, $p = .042$, and social, $r(9) = .72$, $p = .013$, rewards. This indicates, contrary to hypothesis four, that more marked feelings of depression may be associated with increased behavioural processing of monetary and social rewards.

6.5.3.2.3. Psychopathic Traits

Several correlations between psychopathic traits and MSIDT performance were found, indicating reduced behavioural processing of social rewards in dimensional psychopathy. The Antisocial dimension was associated with significantly poorer anticipatory response accuracy towards social rewards, $r(12) = -.57$, $p = .035$, and a similar trend was observed

with total PCL-R score and anticipatory RTs towards social rewards, $r(12) = .51$, $p = .061$. This reduced behavioural processing of social rewards was also observed in the reward difference data, with the Affective dimension trending towards reduced behavioural processing (response accuracy domain) of social rewards relative to monetary rewards, $r(12) = -.50$, $p = .072$, and the Interpersonal dimension linked to slower anticipatory RTs towards social rewards relative to monetary rewards, $r(12) = -.47$, $p = .091$.

Taken together, these results highlight that, in a forensic psychiatric service user population assessed with the PCL-R, psychopathic traits may be associated with reduced behavioural social reward processing.

6.5.3.2.4. Borderline Personality Disorder Traits

The Relationships dimension of BPD was associated with slower RTs towards social, $r(12) = .56$, $p = .037$, and monetary, $r(12) = .54$, $p = .046$, rewards; indicating that this dimension might be associated with reduced behavioural processing of rewards. In addition to reduced social reward processing linked to the Relationships dimension, the Impulsivity dimension of BPD was associated with reduced behavioural processing of social rewards as indexed by reduced response accuracy towards social rewards, $r_s(12) = -.47$, $p = .091$, and slower RTs towards social rewards relative to neutral stimuli, $r_s(12) = -.70$, $p = .006$. Similar trends towards reduced behavioural social reward processing were seen in Affective Instability, $r(12) = -.49$, $p = .078$, and Intense Anger, $r(12) = -.47$, $p = .094$, BPD dimensions.

6.5.3.2.5. Autism Spectrum Disorder Traits

An association was observed between AQ-10 scores and reduced response accuracy towards social rewards relative to neutral stimuli, $r(8) = -.59$, $p = .075$. There was also a marginal trend towards reduced processing (RT domain) of social rewards, $r(8) = .55$, $p = .101$. An association between AQ-10 score and reduced processing of neutral stimuli was also observed, $r(8) = .60$, $p = .066$. Together, these trends suggest potential links between reduced behavioural social reward processing and dimensional ASD traits in a forensic psychiatric sample.

6.6. Discussion

This pilot study aimed to provide preliminary evidence of atypical social reward processing in a sample of forensic psychiatric service users. It compared age and gender matched clinical and control groups on subjective and behavioural measures of social reward processing and, following the results of the dimensional studies detailed in Chapters 4 and 5, also examined associations between dimensional psychopathology and social reward processing in the clinical group only.

6.6.1. Comparing Social Reward Processing between Clinical and Control Groups

Clinical and control groups were compared on subjective and behavioural measures of social reward processing, with the aim of exploring whether clinical psychopathology is associated with atypical social reward processing. Results revealed a close-to-threshold trend towards reduced subjective processing of Prosocial Interactions in the clinical group in comparison to the control group, with a medium effect size. In addition, although not meeting the trend alpha threshold, a small-medium difference between groups was seen in subjective processing of Negative Social Potency (*d* = .46), with the clinical group self-reporting greater enjoyment of Negative Social Potency in comparison to the control group. Therefore, it may be that the clinical and control groups were meaningfully different to one another in their subjective processing of Prosocial Interactions and Negative Social Potency, but the small sample size may have restricted ability to detect this difference via conventional inferences of statistical significance.

A similar interpretation applies to the behavioural data. Whilst a group effect was found, with the clinical group demonstrating significantly slower RTs overall than the control group, no main or interaction effects of reward type were found. At first look, this may suggest that the task did not function as intended as, unlike in Chapter 4, the task did not elicit greater anticipatory responses for rewards versus neutral stimuli. Although, the RT reward type effect size observed here (η_p^2 = .06) is the same as the effect size reported in Chapter 4, perhaps suggesting that the task may elicit a reward effect if tested in larger samples.

6.6.2. Dimensional Associations in Clinical Group

In addition to trend-level differences between clinical and control groups in subjective processing of social rewards, some preliminary correlations between dimensional psychopathology and subjective and behavioural social reward processing were observed in the clinical group analyses.

In keeping with hypothesis two, the Cognitive-Perceptual dimension of the schizophrenia spectrum was associated with reduced subjective processing of social rewards involving Admiration and Prosocial Interactions. Like previous chapters, the Cognitive-Perceptual dimension was also associated with increased subjective processing of Negative Social Potency. Atypical subjective processing of social rewards linked to this dimension is consistent with the results of previous chapters and suggests that the dimensional relationships between schizophrenia spectrum traits and SRQ scores found in the normative population translate to a forensic psychiatric service user population.

Psychopathic traits were associated with reduced subjective processing of Prosocial Interactions. Associations between reduced enjoyment of Prosocial Interactions and psychopathic traits have been consistently observed across the findings presented in this thesis, suggesting that reduced hedonic value may motivate the reduced preference towards prosocial behaviour that characterises psychopathy.

Furthermore, although not hypothesised, multiple associations were observed between BPD dimensions and subjective social reward processing. The Intense Anger dimension simultaneously correlated with reduced subjective processing of Prosocial Interactions and increased processing of Negative Social Potency. These associations potentially, therefore, identify feelings of anger as a motivating factor within reduced enjoyment of prosocial behaviour and increased enjoyment of antisocial behaviour in forensic samples. Moreover, the Impulsivity dimension was observed to be associated with increased subjective processing of social rewards involving Sociability and reduced processing of Negative Social Potency. Finally, the Self-Image dimension was associated reduced subjective processing of social rewards involving Admiration. Together, these results follow previous chapters in showing that dimensional features of BPD are differently associated with subjective processing of social reward subtypes.

As presented in Table 6.4., none of the hypothesised associations between depression symptoms, ASD traits, and subjective social reward processing were found. This may, however, be in part due to the ways in which psychopathology was assessed here versus the other studies in this thesis (see Limitations and Future Directions, below).

Looking at the behavioural data, several dimensions of psychopathy were associated with reduced behavioural social reward processing. The Antisocial dimension, defined by a low sense of social cohesion and propensity for criminal or antisocial behaviour (Waller et al., 2020), was related to reduced behavioural social reward processing as indexed by anticipatory response accuracy towards social rewards. Associations between total PCL-R score, Affective and Interpersonal dimensions, and reduced behavioural processing of social rewards were also observed. In combination, these behavioural results suggest that the antisocial and asocial behaviour associated with dimensional psychopathy may, in a forensic psychiatric context, be associated with reduced social reward processing.

Analysis revealed trend associations between reduced behavioural social reward processing and the Relationships and Intense Anger dimensions of BPD. The association between reduced behavioural processing of social rewards and the Intense Anger dimension compliments the subjective data in finding that feelings of anger may contribute to reduced social reward processing in forensic samples. Whilst not found in previous chapters, the

Relationships subscale of the BPQ includes items which focus on feelings of (lack of) dependability and trust towards others (Poreh et al., 2006), and thus it is perhaps to be expected that higher scores on this dimension would be associated with reduced processing of social rewards.

Like psychopathic and BPD traits, ASD traits (as assessed by AQ-10) were also found to be associated with reduced social reward processing, as indexed by reduced response accuracy towards social rewards relative to neutral stimuli. This finding is consistent with the relationship between dimensional ASD and reduced behavioural social processing that was observed in Chapter 4.

The remaining significant associations between dimensional psychopathology and behavioural reward processing are slightly more difficult to interpret. PHQ-9 scores (used as a dimensional measure of depression symptomatology) were associated with increased behavioural processing of social and monetary rewards as indexed by anticipatory response accuracy. This finding is both contrary to hypothesis three and the findings of Chapters 3, 4, and 5, which showed that depression symptomatology is associated with reduced processing of social rewards. Given that this finding is not in keeping with the findings of previous studies (Brinkmann et al., 2014; Pechtel et al., 2013), and stems from a small preliminary sample of forensic psychiatric service users (n =11), it should be replicated in larger samples, perhaps with more comprehensive measures of depression symptomatology than the PHQ-9, such as the Beck Depression Inventory (Beck et al., 1996) as well clinician-rated depression.

Similarly, the Impulsivity dimension of BPD correlated with reduced behavioural processing of social rewards, but quite how this aligns with broader conceptualisations of impulsive behaviour in BPD (e.g., Berlin et al., 2005) is unclear. Individuals with higher levels of impulsive traits are characterised as sensation-seeking and thus may be expected to demonstrate increased social reward processing due to increased wanting of social sensations (Torki, 1993). However, the observed association between BPD Impulsivity and reduced behavioural reward processing may represent a more nuanced relationship between impulsivity and reward anticipation. As is seen in a range of externalising disorders (Carré et al., 2013; Kohls, Herpertz-Dahlmann, et al., 2009), phenotypic expressions of impulsive or sensation-seeking behaviour are sometimes related to reduced reward processing at behavioural and neural levels (Bellato et al., 2020; Dichter, Damiano, et al., 2012), which may partly explain the association between Impulsivity and reduced social reward processing observed here. It is also worth noting that the self-report data presented in this chapter revealed associations between Impulsivity and increased subjective

processing of Sociability, and Impulsivity was also associated with increased behavioural processing of social rewards relative to neutral stimuli in Chapter 4. As such, these other findings further reduce confidence in this behavioural finding. Thus, the observed relationship between higher self-reported impulsivity and reduced behavioural social reward processing in forensic samples should be investigated further in larger samples with additional self-report measures of trait impulsivity, such as the Short UPPS-P (Cyders et al., 2014).

In summary, the associations described above highlight that dimensional psychopathology affects subjective and behavioural processing of social rewards in forensic psychiatric samples. Some of the results presented here mirror previous chapters, finding associations between schizophrenia, BPD, and ASD dimensions and reduced social reward processing. The presented results also add new knowledge in identifying that reduced social reward processing in forensic psychiatric samples may be specifically linked to dimensions which capture antisocial behaviour (e.g., dimensions of psychopathy, BPD Intense Anger dimension).

6.6.3. Limitations and Future Directions

There are several limitations within this pilot investigation which should be addressed.

To increase the accessibility of this study for service users, the National Research Ethics Service recommended that longer questionnaires should be replaced by abbreviated versions – meaning that the AQ-10 was used here rather than the AQ, PHQ-9 was used rather than the DASS-21 and SPIN, and psychopathic traits were rated using the PCL-R via file review rather than the SRP-4-SF (when perhaps using both would have provided the most comprehensive insight into links between psychopathic traits and social reward processing). As a result, clinical and control groups could only be compared on SPQ-BR and BPQ scores, limiting the degree to which comprehensive comparisons between the groups could be made. Furthermore, using abbreviated versions of the measures meant that some of the nuanced findings observed in the previous chapters (e.g., associations between Communications/Mindreading dimension of AQ and reduced social reward processing) could not be investigated here. Future research should, therefore, replicate the approach used here but employ extended versions of the self-report measures, rather than the abbreviated versions.

A second limitation within this pilot study is the use of the SRQ to assess forensic psychiatric service users' subjective processing of social rewards. The SRQ has been used throughout this thesis (see Chapter 2, section 2.2.1., page 32, for description of measure) and has shown good utility in measuring hedonic experience of the social reward subtypes in the

normative population. However, to-date the SRQ has not been used within a forensic psychiatric context and its items may be less applicable to this clinical population.

For example, the Sexual Relationships subscale includes many items (*e.g., "I enjoy having an active sex life"*) which do not apply to inpatient forensic psychiatric populations. Similarly, many forensic psychiatric service users may have limited opportunity to take part in the social events that are referenced in the Sociability subscale (e.g., *"I enjoy going to parties"*); particularly if they have had extended periods in institutional care from a young age, as is frequently the case for this patient group (Glimmerveen et al., 2018). Moreover, the Negative Social Potency subscale asks participants to endorse antisocial beliefs and behaviours, which is likely to elicit social desirability responses in a clinical group who are receiving psychological therapies around managing and eliminating antisocial behaviours. Overall, whilst tentative, these suggestions highlight that the SRQ may be less specific to the social reward experiences of forensic psychiatric service users. In response, our research group has been developing a clinician-rated interpersonal reward checklist designed to assess some of these shortcomings within the SRQ.

Third, as described in Chapter 3 (section 3.7.2., page 65), long-term psychotropic medication use can affect reward system function. Given that all participants were using psychotropic medications at the point of participation (and had been for some time), medication use may have influenced the findings presented here, including perhaps masking MSIDT effects. The psychotropic effects may also extend to the completion of the self-report measures, perhaps affecting the accuracy of the measures by altering self-insight, self-reported symptomatology, or participant alertness/attention. The appropriateness of using self-report measures of psychopathology within forensic psychiatric samples, a sample often defined by insincere, dishonest, or deceitful behaviour, is (of course) a broader consideration.

Small sample size is an obvious final limitation within this study which restricts confidence in its findings, compounded by the poor completion rate of some of the self-report measures within the clinical group. Indeed, as described earlier, many of the measures employed here were affected by missing values and thus any significant findings presented here should be interpreted with extreme caution. It is worth noting that data collection for this study was significantly impacted by the COVID-19 pandemic and subsequent restrictions on in-person research within the NHS, and larger samples (with less missing values) would have been collected had circumstances been different. There is a clear need, therefore, to develop the preliminary results presented here and recruit larger clinical samples with more complete data. This is particularly important given sample size recommendations for detecting clinical

and control group differences in behavioural reward processing (minimum n = 57 per group; see Chapter Three, section 3.7.5., page 67) and the lack of research to-date investigating social reward processing within forensic psychiatric samples.

6.7. Chapter Summary

The pilot study presented in this chapter investigated social reward processing within a forensic psychiatric service user sample. A close-to-threshold trend difference between groups in subjective processing of social rewards involving Prosocial Interactions was observed, which furthers the postulation that forensic psychiatric service users may extract less feelings of reward from prosocial scenarios in comparison to healthy controls. Furthermore, dimensional associations between psychopathology and social reward processing were somewhat in keeping with the hypotheses and extended the findings of previous chapters. Within this, the dimensional findings observed suggest that BPD Intense Anger and psychopathic dimensions may contribute to simultaneous increased enjoyment of antisocial behaviour and reduced enjoyment of prosocial behaviour in forensic samples. Having provided a range of evidence of atypical social reward processing linked to psychopathology, the next (and final) empirical chapter of this thesis aims to examine whether intranasally administered oxytocin may have some therapeutic potential in addressing psychopathology-related adjustments in social reward processing.

7. The Effect of Acute Intranasal Oxytocin Administration on Social Reward Processing in Dimensional Psychopathology

7.1. Chapter Aims and Overview

The previous three chapters found that dimensional psychopathology is associated with atypical social reward processing at subjective and behavioural levels. This chapter aims to develop these findings and explore whether intranasal oxytocin administration modulates social reward processing in psychopathology. To do so, this study employed a double-blind repeated measures design and investigated associations between modified Monetary and Social Incentive Delay Task (MSIDT) performance, following administration of oxytocin versus placebo, and self-reported psychopathic, borderline personality disorder (BPD), and autism spectrum disorder (ASD) traits. The chapter includes an overview of existing research on social reward processing, oxytocin, and psychopathology, before presenting associations between the dimensions of psychopathology and task performance. With future research in mind, a discussion of how this study should be expanded and refined to offer a more comprehensive investigation of the effect of oxytocin on social reward processing in psychopathology is also provided.

7.2. Introduction

Oxytocin is a neuropeptide implicated in several aspects of social behaviour and social cognition (Donaldson et al., 2017; Hurlemann & Scheele, 2016). It is produced in the hypothalamus and is secreted into the blood via the posterior lobe of the pituitary gland (Ross et al., 2009). Oxytocin receptors are found across a range of brain regions and within the central nervous system (Kanat et al., 2014). The distribution of oxytocin receptors is said to modulate a range of core physiological and psychological processes (Kanat et al., 2014), including breastfeeding, orgasm, and social bonding (MacDonald & MacDonald, 2010; Young & Wang, 2004). In humans, oxytocin receptors are expressed across a range of brain areas, including the social decision-making network comprising the nucleus accumbens, amygdala, ventral tegmental area (VTA), and regions of the hypothalamus (Grinevich et al., 2016). Given that these brain areas are associated with a variety of social processes (including social reward processing – see Chapter 1, section 1.2., page 15), a wealth of research has aimed to show that increasing exogenous oxytocin (e.g., Leppanen et al., 2017) can increase social cognition (emotion recognition: e.g., Shahrestani et al., 2013; theory of mind: e.g., Domes et al., 2007) and engagement with the social environment. Within this, there is preliminary evidence that the administration of intranasal oxytocin may positively alter social reward-related processes (Shamay-Tsoory & Abu-Akel, 2016) and,

thus, intranasal oxytocin administration may have the potential to ameliorate the atypical social reward processing that characterises psychopathology (e.g., Dölen, 2015).

7.2.1. Oxytocin and Social Reward

The social salience hypothesis of oxytocin (Shamay-Tsoory & Abu-Akel, 2016) posits that oxytocin increases the salience of (and thereby attention given to) social stimuli by interacting with the dopaminergic system. Previous studies (review, Bromberg-Martin et al., 2010) have shown that the salience of social stimuli is coded by dopamine neurons projecting from the VTA to the nucleus accumbens. The social salience hypothesis, therefore, proposes that oxytocin increases the salience of social stimuli by altering the dopaminergic coding signal of social cues (Modi & Young, 2012). As outlined in Chapter 1, the activity of the dopaminergic system – and its interplay with the mesocorticolimbic pathway - plays a central role in the coding, anticipation, and consumption of rewards (Rademacher et al., 2010). This suggests that oxytocin may, therefore, have the potential to increase social reward circuitry responses by modulating the salience of socially relevant cues (Groppe et al., 2013). This is most likely to affect the anticipation phase of reward processing (Bethlehem et al., 2014) as reward anticipation depends on the ability to detect and respond to cues which indicate that social rewards may be available (Berridge et al., 2009). The social salience hypothesis and the interaction between the dopaminergic and oxytocinergic systems is illustrated in Figure 7.1.

The interaction between oxytocin and social reward circuitry described above was first demonstrated by Groppe et al. (2013). They employed a double-blind parallel-group design and asked participants to complete a social incentive delay task with smiling faces as social rewards. Participants were allocated to either an oxytocin group or a placebo group. Whilst they observed no effect of oxytocin versus placebo on behavioural processing of social rewards, they did find that VTA activity during social reward anticipation was significantly greater in participants who were administered intranasal oxytocin in comparison to those who received placebo. This association between oxytocin and increased social reward processing has since been supported by other research which has shown that oxytocin can increase prosocial tendencies (e.g., Hung et al., 2017), and neural reward system responses towards romantic partners (Scheele et al., 2013) and sexual stimuli (Gregory et al., 2015).

In contrast to the prosocial effects described above, other studies have suggested that (depending on context) oxytocin may paradoxically stimulate antisocial behaviour. Indeed, increasing oxytocin levels can elicit more jealous or gloating behaviours (Shamay-Tsoory et al., 2009), increase propensity for aggression towards others (Beery, 2015), and increase out-group ethnocentrism (De Dreu et al., 2011). Moreover, whilst most studies report positive

associations between oxytocin administration and social reward processing, others (e.g., Clark-Elford et al., 2014) have found that oxytocin administration impedes reward learning from socially relevant cues such as happy faces. This mixed selection of evidence highlights that links between oxytocin and social reward processing are not fully clear and that further research delineating the effects of oxytocin on social reward processing is thus needed.

It could be that the mixed findings described above are in-part due to underlying differences in participant personality and psychopathology (Bartz et al., 2011; Groppe et al., 2013; Hecht et al., 2017). Indeed, Weisman and Feldman (2013) argue that oxytocin may more dramatically improve social functioning and social responses in individuals with lower levels of social proficiency or social motivation, rather than those who demonstrate more typical social behaviours. As such, it may be that the effect of oxytocin on social reward processing is more readily observed in samples with lower baseline levels of social reward processing or in those who demonstrate atypical interpersonal behaviour. Therefore, the coming section offers a brief review of the effect of oxytocin on social reward in three dimensional psychopathologies of interest, namely psychopathic traits, BPD traits, and ASD traits.

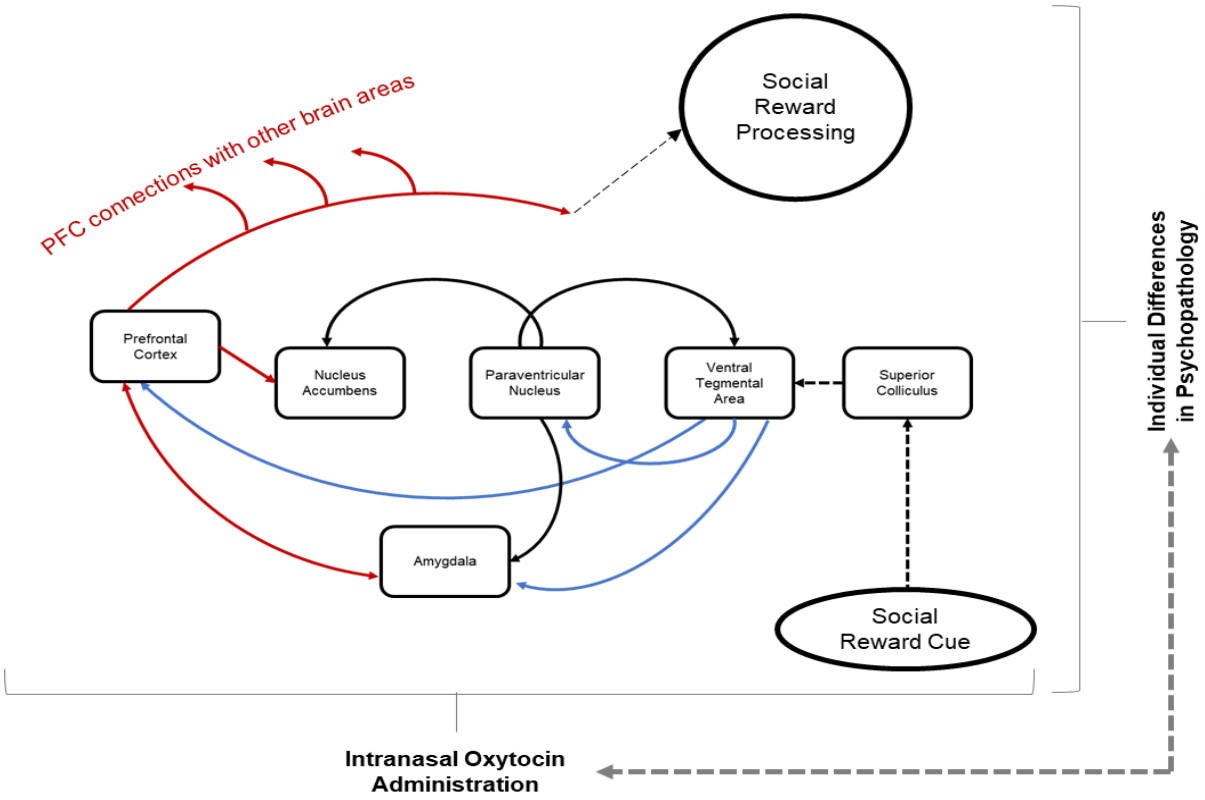
7.2.2. Oxytocin, Social Reward and Psychopathy

As described in previous chapters, psychopathy is defined by callous and unemotional behaviour, as well as a propensity for deceitfulness and irresponsibility (Hare, 2003). Developmental perspectives on psychopathy (e.g., Waller & Wagner, 2019) propose that the development of psychopathic traits may be influenced be polymorphisms in the oxytocin receptor gene *OXTR* (Dadds, Moul, et al., 2014), leading to reduced oxytocinergic activity and oxytocin production during adolescence (Verona et al., 2018). Given that oxytocin is implicated in social bonding and social affiliation (MacDonald & MacDonald, 2010), Dadds et al. (2014) argue that reduced oxytocinergic activity contributes to the lower sense of social affiliation and prosociality that characterises the development of psychopathic traits (Waller & Wagner, 2019). If psychopathy is associated with lower levels of endogenous oxytocin, it may be that increasing exogenous oxytocin (for example through intranasal administration) has the potential to adjust oxytocinergic activity and thereby promote more prosocial behaviours in people with more pronounced psychopathic traits.

Despite its potential clinical utility, Marsh et al. (2020) recently identified that little work to-date has investigated the effect of oxytocin on social processes in psychopathy. They argue that this may be due to unreported non-significant findings in clinical trials or may more broadly reflect the imbalance in research on psychopathy versus other dimensions of psychopathology (e.g., schizophrenia spectrum conditions or affective disorders). Although not on psychopathy specifically, research investigating constructs related to psychopathy

(e.g., Gedeon et al., 2019) has found that increasing levels of oxytocin may increase propensity for aggression in individuals with antisocial personality disorder (Alcorn et al., 2015) and elicits decreased social compliance in some healthy individuals (e.g., Gross & De Dreu, 2017). The present study is, thus, the first to-date to investigate the modulation of social reward processing by acutely administered oxytocin in relation to psychopathy.

Figure 7.1. Illustration of Social Salience Hypothesis of Oxytocin and its Interaction with the Dopaminergic and Oxytocinergic Systems. The dopaminergic system is drawn in black. The oxytocinergic system is drawn in blue. The dark red lines represent the interactions between dopaminergic and oxytocinergic systems and motivational and attentional mechanisms via the prefrontal cortex. This figure is based on diagrams given in Gordon et al. (2016) and Shamay-Tsoory and Abu-Akel (2016).



7.2.3. Oxytocin, Social Reward and BPD

Prominent features of BPD include affective instability, impulsivity, intense and volatile interpersonal relationships, and risk of self-injury (Paris, 2018). As described in previous chapters, BPD individuals often demonstrate atypical interpersonal behaviours which may, in part, be due to adjusted social reward processing. The findings of the behavioural studies presented in Chapters 4 (see 4.5.4.4., page 94) and 5 (see 5.5.3., page 124) suggest that social reward processing may be dimensionally affected in BPD, reflected in a tendency

towards hypo/hyperanticipation of social reward cues. Moreover, the behavioural findings of the previous chapters indicate this may be influenced by the subtype of social reward being anticipated and which dimensions of BPD symptomatology are most elevated.

In their recent systematic review of studies examining oxytocin administration in BPD, Peled-Avron et al. (2020) found inconsistent evidence of the effect of oxytocin in BPD. In support of the social salience hypothesis, they propose that the modulation of social cues by oxytocin in BPD is likely to be influenced by the social cue context (e.g., threatening or not) and the trauma/abuse history of the participant (Peled-Avron et al., 2020), but they argue that the number of studies available for review is too small to draw any robust conclusions regarding the relationship between oxytocin and BPD. As in psychopathy, some BPD studies have shown that oxytocin administration in BPD has an inverse effect, meaning oxytocin administration reduces prosociality, with BPD participants demonstrating less trust (Bartz et al., 2011; Ebert et al., 2013) and less affiliative behaviour (Brüne, 2016; Brüne et al., 2015) following oxytocin administration in comparison to placebo.

As oxytocin administration appears to affect the social cognitions of individuals with BPD in the opposite way to normative samples (Herpertz & Bertsch, 2015; Stanley & Siever, 2010) it will be important to establish whether this inverse effect translates to social reward processing specifically. Within this, the previous chapters have shown that dimensions of BPD are differentially related to social reward processing, and thus this study will explore relationships between the different dimensions of BPD and social reward processing following oxytocin administration. Following the above suggestion that oxytocin administration may follow an inverse effect in BPD, it may be that BPD symptomatology paradoxically links to reduced social reward processing following oxytocin administration in comparison to placebo. The current study aims to provide preliminary insight into this postulation.

7.2.4. Oxytocin, Social Reward and ASD

Social communication deficits are a hallmark of ASD (Frith, 2003). As described in previous chapters, individuals with ASD may extract reduced feelings of reward from the social environment, leading to reduced social motivation and atypical interpersonal behaviour (Chevalier et al., 2012). The systematic review and meta-analytic findings presented in Chapter 3, alongside the findings presented in Chapters 4 and 6, suggest that ASD traits are associated with reduced subjective and behavioural processing of social rewards. Following the social salience hypothesis, it may be that reduced social reward processing in ASD is amenable to oxytocin (Andari et al., 2016) because, as described above, oxytocin may

increase the salience of socially relevant cues, thereby potentially leading to increased social reward processing.

Most research investigating the effect of intranasal oxytocin administration in ASD has focused on social cognition more broadly, including tests of emotion recognition ability (Dadds, MacDonald, et al., 2014) and theory of mind (Aoki et al., 2014). However, evidence for an improving effect of oxytocin in ASD participants is inconclusive, with several meta-analyses (Huang et al., 2021; Keech et al., 2018; Phaik Ooi et al., 2017) reporting different study results depending on participant sample demographics (e.g., gender, age) and the type of social function assessed (e.g., empathising, mentalising, emotion recognition) (Huang et al., 2021; Mayer et al., 2021).

Only a small number of studies have focused specifically on social reward processing and oxytocin in ASD. The effect of oxytocin administration on reward system responses in ASD was first measured by Gordon et al. (2013). They compared neural activations when viewing socially meaningful versus nonmeaningful stimuli in a small sample of children with ASD. They found that, in comparison to placebo, oxytocin administration elicited increased neural activation in reward-related areas, including the striatum. Similarly, Kruppa et al. (2019) found that oxytocin administration increased ASD participants' ability to learn from socially relevant cues during a reward learning task. This is contrasted by Mayer et al. (2021) who recently, using an incentive delay task, found no association between oxytocin/placebo administration and social reward processing in clinical versus control groups, and Greene et al. (2018) who showed that oxytocin administration only increases non-social, rather than social, reward processing in ASD.

Consequently, as with other social cognitions in ASD, how oxytocin administration influences social reward processing in ASD is currently unclear. There is, thus, a need for more research which examines associations between oxytocin administration, social reward processing, and ASD (Mayer et al., 2021). Furthermore, given that most social reward studies have employed between-group approaches (comparing clinical and control groups), it is important to establish whether the influence of oxytocin on social reward processing in ASD extends dimensionally across the ASD continuum.

7.3. Rationale and Aims

This study aimed to explore the effect of acute oxytocin administration on social reward processing on its own and in relation to dimensional psychopathology. Specifically, it aimed to (i) compare reward processing (as indexed by MSIDT performance) in placebo versus oxytocin conditions, and (ii) examine links between the modulation of reward processing by oxytocin (relative to placebo) and self-reported psychopathic, BPD, and ASD traits.

Specifically, this study tested the following hypotheses:

1. There will be a significant interaction between reward type (monetary, social, neutral) and drug condition (placebo or oxytocin), with significantly faster anticipatory reaction times (RTs) and greater response accuracy towards social rewards in the oxytocin condition in comparison to the placebo condition. A smaller effect will be seen for monetary rewards, and no effect for neutral stimuli.
2. BPD traits will be associated with an inverted oxytocin effect, with more pronounced BPD traits relating to reduced behavioural social reward processing (hypoanticipation) in the oxytocin condition relative to the placebo condition.
3. ASD traits will correlate with increased behavioural social reward processing (hyperanticipation) in the oxytocin condition relative to the placebo condition, suggesting that more pronounced ASD traits are associated with a greater benefit of oxytocin administration on social reward processing.

Due to lack of prior research, no hypotheses were made regarding the links between psychopathic traits and modulation of reward processing by oxytocin.

7.4. Materials and methods

7.4.1. Ethics Statement

All participants provided written informed consent prior to participating in this study. All procedures were approved by the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS), Brunel University London. After finishing their participation, all participants had the opportunity to enter a draw to win one of two £50 Amazon vouchers. Course credits were also available to those entering the study through the Division of Psychology.

7.4.2. Participants and Procedure

Nineteen participants (42.1% male-identifying, remaining female-identifying) were recruited into this study via volunteer sampling. The mean age of the sample was 21.47 years (SD = 1.28, range = 19-24). Following a repeated measures double-blind cross-over design, participants received 24 IUs of acute intranasal oxytocin (Syntocinon) or placebo (a matched spray containing identical ingredients to the Syntocinon, except the active oxytocin) across the course of two research sessions, conducted with an average interval of 21 days (range 3-63). The drug was expected to stay active for approximately 48 hours, and thus oxytocin/placebo sessions were conducted a minimum of 48 hours apart. Sprays were prepared and supplied by a pharmaceutical company (Victoria Apotheke Zurich;

Switzerland). Participants self-administered 24 IUs of the oxytocin or placebo spray (3 inhalations per nostril). The order of the sessions in which the participants received oxytocin or placebo was counterbalanced (9 participants received the placebo first, 10 received the oxytocin first).

Participants completed the modified MSIDT in both sessions and completed the self-report measures of psychopathology across the two sessions. All self-report measures were completed pre-inhalation. After inhalation, there was a 45-minute rest period in which participants were instructed to relax by reading, working, listening to music, or talking on the phone. Once the 45-minute rest period had elapsed, the participant completed a series of computer-based tasks, including the modified MSIDT.

All participants were non-smokers (at induction into the study it was confirmed that they were not smoking at the point of participation) and had not consumed food, drink (other than water), or caffeine up to two hours ahead of participation. Participants meeting the following exclusion criteria were unable to participate: (1) history of heart conditions or cardiovascular diseases, (2) history of neurological conditions such as epilepsy or traumatic brain injury, (3) current use of psychoactive medications, (4) pregnant or breastfeeding, (5) known allergy to active oxytocin, and (6) shown adverse reactions to oxytocin in previous session.

7.4.3. Self-Report Measures of Psychopathology

Dimensional psychopathic traits were assessed using the Self-Report Psychopathy Scale - Short Form (SRP-4-SF; Paulhus et al., 2016). The SRP-4-SF has 29 items which participants respond to using a five-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). The scale generates a total score for overall level of psychopathic traits plus scores for each of the four dimensions of psychopathy described by Hare (2003): Interpersonal, Affective, Lifestyle and Antisocial. Higher scores indicate more prominent psychopathic traits. The SRP-4-SF was also used to measure psychopathic traits in the empirical investigations presented in Chapters 4 and 5.

BPD traits were assessed dimensionally using the Borderline Personality Questionnaire (BPQ; Poreh et al., 2006). Participants are presented with 80 statements about their beliefs and emotions which they are asked to rate as True (1) or False (0). The BPQ has nine subscales, assessing the different dimensions of BPD: Impulsivity, Affective Instability, Abandonment, Relationships, Self-Image, Suicide/Self-Mutilation, Emptiness, Intense Anger, and Quasi-Psychotic States. Higher scores indicate more pronounced BPD traits. The BPQ was also employed in Chapters 4-6.

ASD traits were measured using the Autism Quotient (AQ; Baron-Cohen et al., 2001). It has 50 items which are rated using a four-point Likert scale (Definitely agree – Definitely disagree). The measure is scored using 1 or 0 per item, with a 1 given any time a non-neurotypical response is endorsed. The AQ generates total and subscale scores which capture the three dimensions of ASD as described by Hurst et al. (2007): Social Skills, Details/Patterns, and Communication/Mindreading. Higher scores indicate a greater degree of ASD traits. The AQ was also used in Chapters 4 and 5.

7.4.4. Self-Reported Mood

Participant mood throughout both research sessions was assessed using the Multidimensional Mood State Questionnaire (MDMQ; Steyer et al., 1997). The MDMQ has 30 self-report items which are rated on a six-point scale (1 = Definitely not, 6 = Extremely). It generates three subscale scores: Good-Bad, Awake-Tired, and Calm-Nervous. The MDMQ was used to index participant mood three times during both sessions (pre-inhalation, after 45-minute break, after completion of modified MSIDT), generating six MDMQ scores per participant.

7.4.5. Behavioural Processing of Monetary and Social Rewards

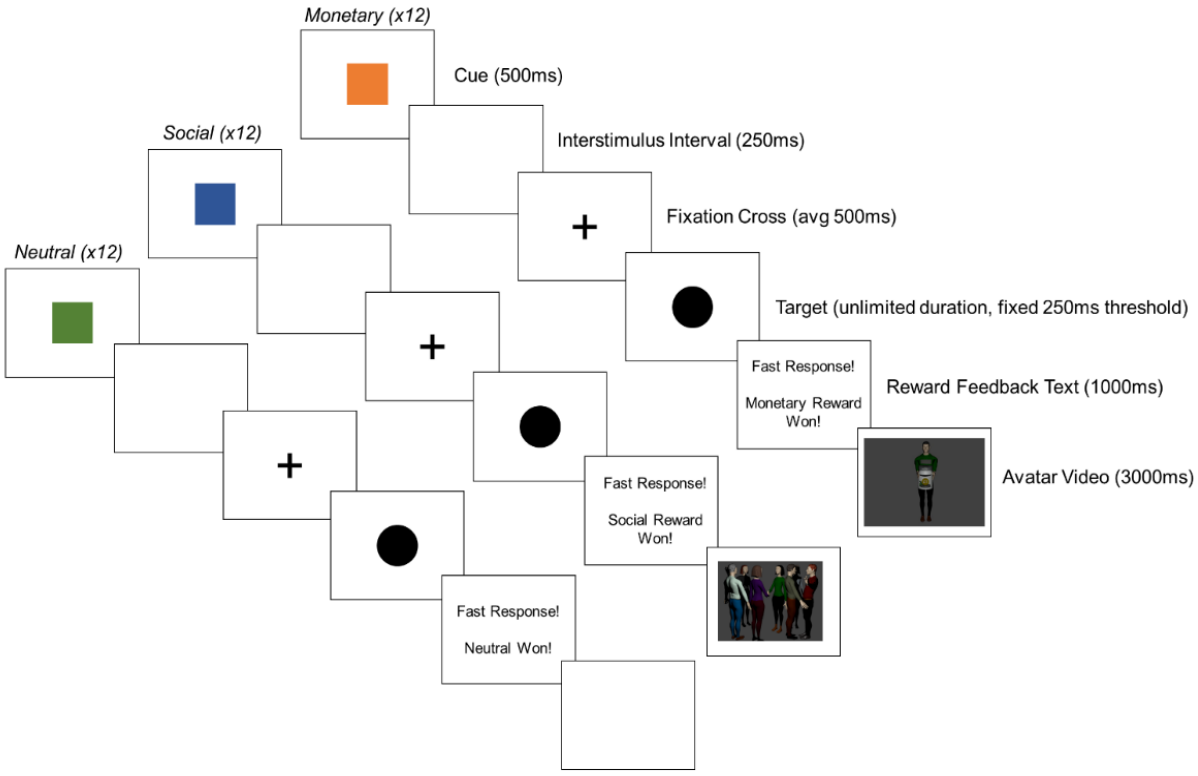
Behavioural processing of monetary and social rewards was assessed via the modified MSIDT presented online via Testable (www.testable.org). The task assesses behavioural anticipation of rewards (monetary, social, neutral) through measuring reaction time (RT) and response accuracy towards a cued target. Full information on the development of the task is provided in Chapter 2 (see section 2.4.1., page 38). This task was also employed in Chapters 4 and 6.

The modified MSIDT gave participants the opportunity to win monetary and social rewards presented via video. Monetary rewards showed the avatar receiving a coin into a money jar and social rewards presented the avatar engaging in four different subtypes of social reward (Admiration, Negative Social Potency, Passivity and Sociability). As per previous chapters, each animation was accompanied by a corresponding sound (e.g., Monetary = Cash register). All rewards were administered via video and no actual reward was associated with task performance.

As shown in Figure 7.2., there were some subtle differences in the format of the MSIDT employed in this chapter in comparison to previous chapters. This was due to limitations within the task programming software (Testable) that meant that the task could not be implemented as per Chapters 4 and 6. Firstly, the software would not allow the setting of a bespoke RT threshold using practice trials and so, following other research using incentive

delay tasks with fixed performance thresholds (e.g., Barman et al., 2015), the RT threshold for winning rewards was set as ≤250ms. Second, the neutral stimuli used in the previous chapters were not compatible with the software and thus, rather than showing a neutral stimuli animation, a white screen was shown for 3000ms. Finally, no pixelated stimuli were presented following misses due to software incompatibility issues and thus the written prompt "*Oops! Too slow. Please respond faster to obtain reward"* was presented instead. All other features of the modified MSIDT remained the same as other chapters[2].

Figure 7.2. Monetary and Social Incentive Delay Task



7.4.5.1. Indexing Task Performance on the modified MSIDT

Task performance was indexed using anticipatory RTs (ms) and anticipatory response accuracy (%), with faster RTs and greater response accuracy indicating increased reward processing. Mean RT and response accuracy were calculated for each reward type (monetary, social, neutral).

[2] These adjustments did not affect how MSIDT data were extracted and analysed. As per other chapters, anticipatory response accuracy was calculated against the average reaction time recorded during practice trials, not the 250ms window that was used for stimuli presentation purposes.

7.4.6. Data Screening

Data screening was performed using SPSS Version 26. Data were screened for both missing values and presence of outliers. The distribution of variables (normal or non-normal) was also assessed at this stage via the Shapiro-Wilk test. Not all nineteen participants provided complete usable data for the self-report measures of psychopathology, meaning that subscale scores could not be calculated for these participants, and thus final samples for the self-report measures were fifteen (psychopathic traits, SRP-4-SF), sixteen (BPD traits, BPQ), and fifteen (ASD traits, AQ) respectively. All nineteen participants provided complete MSIDT data from both placebo and oxytocin sessions. However, three participants with mean RTs >1000ms for any reward type in either condition were identified as outliers. Thus, MSIDT data from these three participants were excluded from subsequent MSIDT analyses (final n = 16). This meant that the total sample sizes for analyses studying associations between psychopathology and task performance were n = 13 (psychopathic traits), n = 13 (BPD traits), and n = 14 (ASD traits).

Shapiro-Wilk tests of normality identified the following self-report variables as non-normally distributed: SRP-4-SF Antisocial, BPQ Impulsivity, BPQ Abandonment, BPQ Relationships, BPQ Self-Image, BPQ Suicide/Self-Mutilation, BPQ Emptiness, BPQ Intense Anger. Mean anticipatory RTs towards monetary and neutral rewards in the oxytocin condition were also identified as non-normally distributed. All other self-report and task variables were found to be normally distributed. Therefore, in subsequent correlational analyses, Pearson's *r* was employed when using normally distributed variables, and Spearman rank order correlations run when testing relationships between non-normally distributed variables.

7.4.7. Data Analysis

All analyses were performed using SPSS Version 26 with statistical significance set at $p = .05$. Scores on the self-report measures of psychopathology were characterised for the full sample, including computation of descriptive statistics and intra-correlations between measures. Then, repeated measure ANOVAs were computed to assess main and interaction effects of reward type (within-subjects: monetary, social, neutral) and drug condition (within-subjects: placebo or oxytocin) on MSIDT task performance. Session order (placebo first or oxytocin first) was first entered as a between-subjects variable within the analyses and then removed if no significant main or interaction effects were found. The Greenhouse-Geisser correction was applied if the sphericity assumption was found to be violated (results include corrected *p* value when correction applied). Statistically significant main and interaction effects were examined post-hoc using the Bonferroni correction. Effect

sizes were calculated as partial eta squared (η^2_p) and interpreted as small ($\eta^2_p = .01$), medium ($\eta^2_p = .06$), and large ($\eta^2_p = .14$) (Cohen, 1992).

After establishing MSIDT main and interaction effects using RT and response accuracy data per reward type, a series of linear regressions were run with neutral anticipatory RTs and response accuracy entered as the independent variable, and with RTs and response accuracy for monetary and social reward types as the dependent variable. This provided a regression equation (and generated unstandardised residuals) for each participant, with MSIDT neutral performance plotted against monetary and social reward performance. This was computed for both placebo and oxytocin conditions. This enabled the subtraction of residuals between placebo and oxytocin conditions, with calculations structured so that positive values would indicate increased reward processing in the oxytocin condition relative to the placebo condition. Therefore, this calculation (hereon referred to as 'relative residual difference') enabled the effect of oxytocin administration on reward processing to be quantified, with positive values indicating increased reward processing (faster RTs, greater response accuracy) in the oxytocin condition relative to the placebo condition.

The calculation of relative residual difference was informed by recommendations given in DeGutis et al. (2013). They argue that regressing against the control (in this case neutral stimuli) is important when studying how individual differences relate to differences in performance between multiple conditions (in this case placebo and oxytocin). This is because it is both important to capture variation in reward versus neutral responses, and placebo versus oxytocin responses. This means that a simple subtraction to calculate reward difference (as per the other chapters e.g., Placebo Monetary RT – Oxytocin Monetary RT) would not capture the full variation in task performance incurred by oxytocin administration. Thus, calculating relative residual difference is necessary (DeGutis et al., 2013) to assess how increases/reductions in reward processing following oxytocin administration may be linked to the dimensional experience of psychopathology.

Relationships between relative residual difference scores and dimensional psychopathology were assessed via zero-order correlations. The Hochberg (1988) correction was applied as per Chapters 4 and 5 to account for the number of correlations being computed (see Chapter 4, section 4.4.7., page 83, for explanation of Hochberg correction).

Finally, changes in mood across sessions were compared via repeated measures ANOVAs. Three separate comparisons were run examining differences in MDMQ Good-Bad, Awake-Tired, and Calm-Nervous subscale scores with session timepoint (pre-inhalation, after 45-minute break, end of session) entered as the within-subjects variable and drug condition (placebo or oxytocin) as the between-subjects variable. This was to establish if drug

inhalation affected self-reported mood and thus contributed to changes in reward processing following oxytocin administration.

7.5. Results

7.5.1. Characterisation of Psychopathology

Mean and range scores for the full sample on each of the self-report measures of psychopathology are presented in Table 7.1.

Table 7.1. Scores on Self-Report Measures of Dimensional Psychopathology

	Mean (SD)	Observed Range (Possible Range)	N
Psychopathic Traits			
SRP-4-SF Interpersonal	13.67 (3.44)	7-20 (7-35)	15
SRP-4-SF Affective	14.07 (3.06)	11-22 (7-35)	15
SRP-4-SF Lifestyle	16.80 (4.52)	9-25 (7-35)	15
SRP-4-SF Antisocial	9.80 (1.70)	8-12 (7-35)	15
SRP-4-SF Total	54.33 (9.66)	36-98 (29-145)	15
BPD Traits			
BPQ Impulsivity	2.75 (1.48)	0-7 (0-9)	16
BPQ Affective Instability	4.44 (3.37)	0-10 (0-10)	16
BPQ Abandonment	2.00 (2.19)	0-8 (0-10)	16
BPQ Relationships	2.19 (2.61)	0-8 (0-8)	16
BPQ Self-Image	2.69 (2.24)	0-8 (0-9)	16
BPQ Suicide/Self-Mutilation	1.25 (1.98)	0-5 (0-7)	16
BPQ Emptiness	3.00 (3.18)	0-10 (0-10)	16
BPQ Intense Anger	3.31 (3.32)	0-9 (0-10)	16
BPQ Quasi-Psychotic States	1.19 (1.11)	0-3 (0-7)	16
ASD Traits			

AQ Social Skills	3.27 (2.09)	0-6 (0-13)	15
AQ Details/Patterns	4.07 (2.15)	1-7 (0-7)	15
AQ Communication/Mindreading	3.20 (2.34)	0-7 (0-8)	15
AQ Total	19.60 (7.38)	9-31 (0-50)	15

The intra-correlations between the self-report measures of dimensional psychopathology are presented in Table 7.2. Most of the significant correlations between dimensions occurred within psychiatric categories (for example correlations between the ASD trait dimensions), but a significant correlation was also observed between the Interpersonal dimension of psychopathy and the Suicide/Self-Mutilation dimension of BPD symptomatology, $r_s(13) = .52$, $p = .047$. A significant correlation between SRP-4-SF total scores and scores on the Quasi-Psychotic States dimension of the BPQ was also observed, $r(13) = .52$, $p = .049$. These correlations suggest that there may be some similarities in presentation between these dimensions and are also consistent with the intra-correlations presented in Chapter 4 (see Table 4.2.). No other significant transdiagnostic intra-correlations were found.

7.5.2. Task Performance

The mean RT and response accuracy data per reward type (monetary, social, neutral), per condition (placebo or oxytocin) are presented in Figures 7.3 and 7.4.

No significant main or interaction effects of session order on reaction time were found: Main effect: F (1, 14) = 0.69, $p = .420$, $\eta_p^2 = .047$; order*reward type: F (1, 28) = 0.30, $p = .743$, $\eta_p^2 = .021$; order*drug condition: F (2, 14) = 1.24, $p = .153$, $\eta_p^2 = .14$; order*reward type*drug condition: F (2, 28) = 0.24, $p = .792$, $\eta_p^2 = .02$. This was also the case for response accuracy. Main effect: F (1, 14) = 1.75, $p = .207$, $\eta_p^2 = .111$; order*reward type: F (2, 28) = 0.56, $p = .946$, $\eta_p^2 = .004$; order*drug condition: F (1, 14) = 1.45, $p = .248$, $\eta_p^2 = .09$; order*reward type*drug condition: F (2, 28) = 0.60, $p = .554$, $\eta_p^2 = .04$. Thus, session order was not included in subsequent task performance analyses.

No significant main effects of reward type or drug condition were found for anticipatory RTs [reward type: F (2, 30) = 0.84, $p = .919$, $\eta_p^2 = .01$; drug condition: F (1, 15) = 3.37, $p = .087$, $\eta_p^2 = .18$] or response accuracy [reward type: F (2, 30) = 0.56, $p = .579$, $\eta_p^2 = .04$; drug condition: F (1, 15) = 0.28, $p = .608$, $\eta_p^2 = .02$]. However, a significant interaction effect was found between reward type and drug condition for the RT data, F (2, 30) = 3.42, $p = .046$, $\eta_p^2 = .19$. Post-hoc repeated measures revealed that this interaction effect was driven by significantly slower RTs towards neutral stimuli in the oxytocin condition (M = 454.81 ±

200.05) than the placebo condition (M = 326.26 ± 93.10), t(15) = 2.44, p = .028. No other post-hoc differences in anticipatory RTs towards monetary or social rewards were found between placebo and oxytocin conditions. No significant interaction effect was found for the response accuracy data, F (2, 30) = 0.82, p = .451, η_p^2 = .05.

Figure 7.3. Mean Anticipatory Reaction Time per Reward Type and per Drug Condition with 95% CI Error Bars (ms)

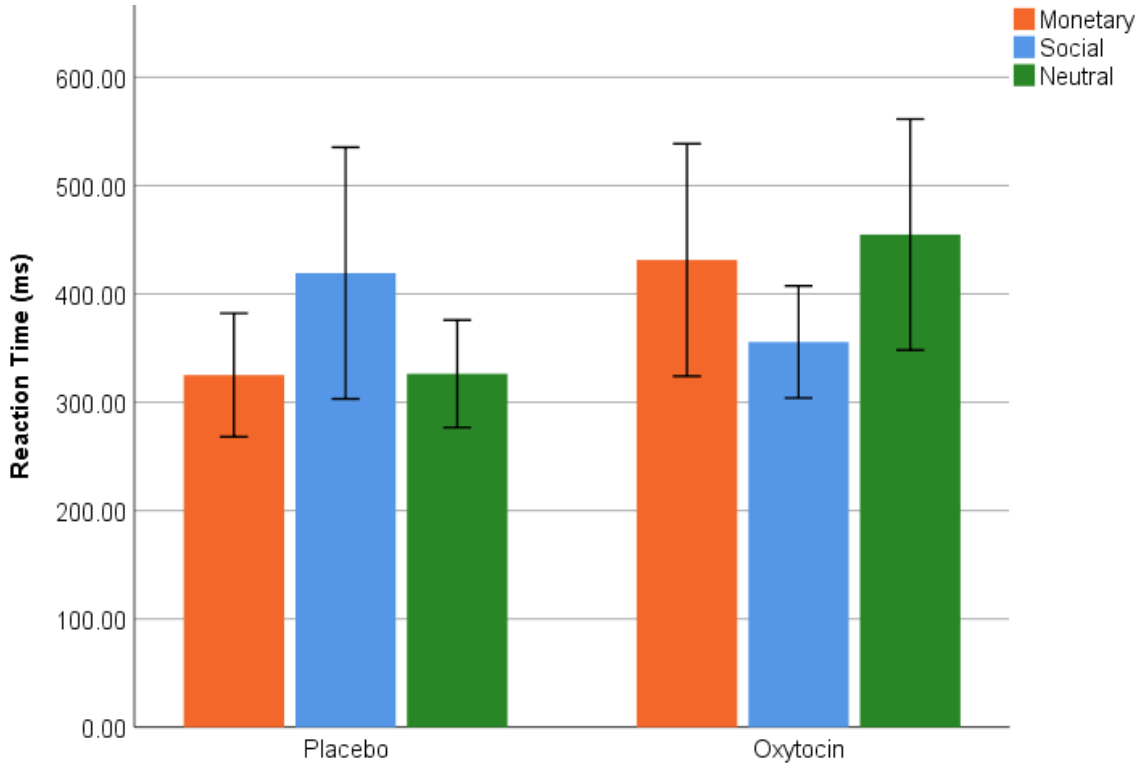


Figure 7.4. Mean Anticipatory Response Accuracy per Reward Type and per Drug Condition with 95% CI Error Bars (%)

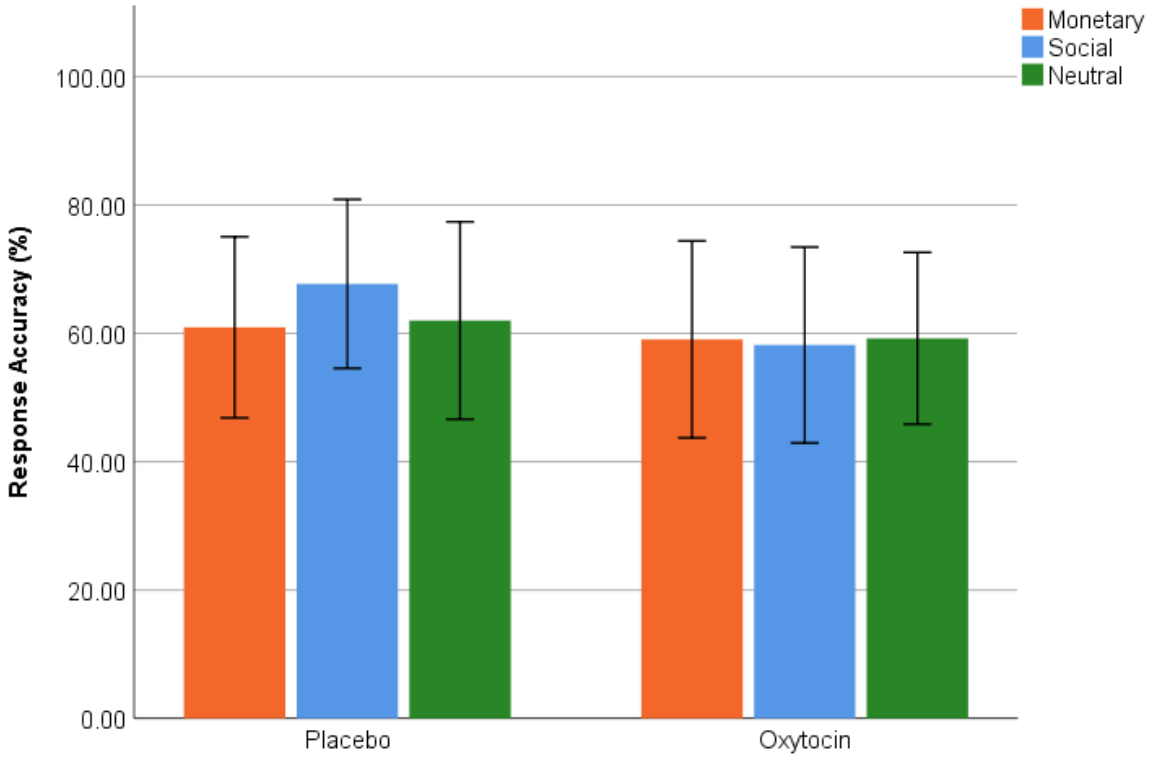


Table 7.2. Intra-Correlations Between Dimensional Measures of Psychopathology

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. SRP-4-SF Interpersonal	-	*.68***	*.46*	.33	*.84***	.15	*.19*	.19	.20	.23	.52*	.42	-.12	*.34*	*.11*	*.30*	*.10*	*.35*
2. SRP-4-SF Affective	*.68***	-	*.53**	.60*	*.88***	.32	*.04*	-.18	.08	.26	.12	.05	-.10	*.48*	*.21*	*.49*	*.14*	*.35*
3. SRP-4-SF Lifestyle	*.46*	*.53**	-	-.16	*.77***	.46	*.45*	.28	.33	.36	.37	.45	.46	*.49*	*.30*	*.27*	*.37*	*.55*
4. SRP-4-SF Antisocial	.33	.60*	-.16	-	.47	.08	-.04	-.15	-.08	-.03	-.09	-.14	-.16	.12	.05	.53	-.03	.14
5. SRP-4-SF Total	*.84***	*.88***	*.77*	.47	-	.40	*.29*	.04	.11	.14	.22	.27	.20	*.52**	*.26*	*.46*	*.25*	*.51*
6. BPQ Impulsivity	.15	.32	.46	.08	.40	-	.56*	-.05	.01	.33	.01	.29	.47	.25	.44	-.24	.33	.23
7. BPQ Affective Instability	*.20*	*.04*	*.45*	-.04	*.29*	.56*	-	.72**	.39	.20	.37	.56*	.80**	*.26*	.26	.05	-.08	.24
8. BPQ Abandonment	.19	-.05	.50	-.15	.04	-.05	.72**	-	.51*	.24	.63**	.56*	.50*	.11	-.15	.25	-.30	.14
9. BPQ Relationships	.20	-.18	.28	-.08	.11	.01	.39	.51*	-	.43	.61*	.45	.26	.20	-.02	.33	-.22	.06
10. BPQ Self-Image	.23	.08	.33	-.03	.14	.33	.20	.24	.43	-	.41	.73**	-.01	.16	.28	.29	.46	.53
11. BPQ Suicide/Self-Mutilation	.52*	.26	.36	-.09	.22	.01	.37	.63**	.61*	.41	-	.55*	.06	.42	-.15	.31	-.26	.18
12. BPQ Emptiness	.42	.12	.37	-.14	.27	.29	.56*	.56*	.45	.73**	.55*	-	.19	.41	.01	.13	.16	.32
13. BPQ Intense Anger	-.12	.05	.45	-.16	.20	.47	.80**	.50*	.26	-.01	.06	.19	-	.16	.39	.08	.16	.32

14. BPQ Quasi-Psychotic States	*-.12*	*-.10*	*.46*	.12	*.52**	.25	*.26*	.11	.20	.16	.42	.41	.16	-	*-.09*	*.18*	*.09*	*.14*
15. AQ Social Skills	*.11*	*.21*	*.30*	.05	.26	.44	*.26*	-.15	-.02	.28	-.15	.02	.39	*-.09*	-	*.33*	*.75***	*.82***
16. AQ Details/Patterns	*.30*	*.49*	*.27*	.53	.46	-.24	*.05*	.25	.33	.29	.31	.13	.08	*.18*	*.33*	-	*.22*	*.61**
17. AQ Communication/Mindreading	*.10*	*.14*	*.37*	-.03	.25	.33	*-.08*	-.30	-.22	.46	-.26	.16	.16	*.09*	*.75***	*.22*	-	*.80***
18. AQ Total	*.35*	*.35*	*.55*	.14	.51	.23	*.24*	.14	.06	.53	.18	.32	.32	*.14*	*.82***	*.61**	*.80***	-

* = significant at p = .05; ** = significant at p =.01; r_s unless italicised

7.5.2.1. Relative Residual Difference

As described above, relative residual difference scores were calculated to quantify task performance differences in placebo versus oxytocin conditions. Correlation analyses revealed a significant positive correlation between relative residual difference scores for response accuracy towards monetary rewards and social rewards, $r(14) = .67$, $p = .004$, suggesting that increased monetary reward processing in the oxytocin condition correlated with increased social reward processing in the oxytocin condition. No other significant correlations between relative residual difference scores were found for the RT or response accuracy data per reward type.

7.5.3. Task Performance and Dimensional Psychopathology

Relative residual difference scores were correlated with the scores on the dimensional measures of psychopathology. This was with the intention of investigating associations between dimensional psychopathology and the effect of oxytocin administration on reward processing. The full results are presented in Table 7.3. Very few statistically significant relationships between dimensional psychopathology and relative residual difference scores were found. A very strong negative association between the Self-Image dimension of BPD and anticipatory RTs towards social rewards in the oxytocin condition relative to the placebo condition was found, $r_s(11) = -.80$, $p = .001$ [survived correction, $p\text{^} = .001$], suggesting reduced behavioural processing of social rewards linked to the Self-Image dimension following oxytocin administration. A similar relationship was observed between the Details/Patterns dimension of ASD and response accuracy towards monetary rewards, with reduced accuracy in the oxytocin condition relative to the placebo condition correlating with Details/Patterns scores $r(12) = -.54$, $p = .047$ [survived correction, $p\text{^} = .047$].

Table 7.3. Correlations between MSIDT Relative Residual Difference Scores and Dimensional Psychopathology

	Monetary RT Difference	Social RT Difference	Monetary RA Difference	Social RA Difference
Psychopathic Traits				
SRP-4-SF Interpersonal	-.21	-.19	.30	.17
SRP-4-SF Affective	-.31	-.16	.18	-.02
SRP-4-SF Lifestyle	.01	-.41	.15	.16
SRP-4-SF Antisocial $_{rs}$	-.29	-.04	-.15	-.29

SRP-4-SF Total	-.22	-.30	.20	.09
BPD Traits				
BPQ Impulsivity *rs*	.18	-.04	-.06	-.17
BPQ Affective Instability	-.16	.05	-.17	-.29
BPQ Abandonment *rs*	-.30	-.21	-.31	-.10
BPQ Relationships *rs*	-.23	-.17	-.02	-.16
BPQ Self-Image *rs*	-.26	-.80**^	-.22	.13
BPQ Suicide/Self-Mutilation *rs*	-.26	-.37	.28	.29
BPQ Emptiness *rs*	-.24	-.39	-.22	.17
BPQ Intense Anger *rs*	.03	.08	-.36	-.35
BPQ Quasi-Psychotic States	-.40	-.04	.12	.15
ASD Traits				
AQ Social Skills	.34	-.09	-.36	-.44
AQ Details/Patterns	-.10	.07	-.54*^	-.37
AQ Communication/Mindreading	.19	-.17	-.20	.12
AQ Total	.27	-.19	-.32	-.23

* = significant at *p* = .05; ** = significant at *p* =.01*;* ^ = survived Hochberg correction; *r* unless marked *rs*

7.5.4. Changes in Mood

A significant main effect of timepoint on MDMQ Awake-Tired scores was found, F (2, 26) = 3.98, p = .03, η_p^2 = .234, with participants reporting feeling less awake at the end of the session (M = 35.39 ± 2.30) than after the 45-minute post-inhalation rest period (M = 39.75 ± 2.11), but this difference was not found to be statistically significant post-hoc, p = 0.53. Despite the main effect of timepoint on Awake-Tired scores, no significant interaction between timepoint and drug condition was observed for the Awake-Tired subscale of MDMQ, F (1.31, 17.01) = 0.17, p = .752, η_p^2 = .013. No other significant main or interaction effects of timepoint or drug condition on MDMQ scores were observed (all p > .05). This

indicates that drug administration did not affect subjective feelings of mood, and thus suggests that associations between MSIDT performance, psychopathology, and oxytocin may be independent of oxytocin-related changes in mood.

7.6. Discussion

This chapter aimed to provide preliminary evidence on the effect of oxytocin administration on social reward processing in psychopathology. To do so, participants were recruited into a double-blind repeated measures design and received intranasal oxytocin and placebo over the course of two sessions. Participants completed self-report measures of psychopathic traits, BPD traits, and ASD traits, and provided responses on the modified MSIDT. Reward processing was indexed through relative residual difference scores which compared anticipatory RTs and response accuracy towards monetary and social rewards at oxytocin relative to placebo.

The first hypothesis (interaction effect between reward type and drug condition) was partially met, but not in the predicted direction. Although a significant interaction was found, post-hoc tests revealed that this was driven by slower anticipatory RTs towards neutral stimuli in the oxytocin condition in comparison to placebo. Inspection of the plot of mean RTs (Figure 7.3) showed that anticipatory RTs were slower in the oxytocin condition for both monetary rewards and neutral stimuli, but that, for social rewards, anticipatory RTs were (non-significantly) faster in the oxytocin condition than in the placebo condition. Perhaps this trend of faster social reward RTs in the oxytocin condition would be borne out in larger samples, but this is difficult to infer without further testing. In summary, it appears that intranasal oxytocin modulated task performance, but it took a different form to what was hypothesised, with slower RTs towards neutral stimuli in the oxytocin condition and no significant difference between drug conditions in behavioural processing of social or monetary rewards.

As described earlier, several researchers (Bartz et al., 2011; Groppe et al., 2013; Hecht et al., 2017) have proposed that overall oxytocin effects may be washed out or obscured by individual differences in personality or psychopathology. Therefore, rather than suggesting that oxytocin does not modulate social reward processing, it may be that the lack of difference in social reward processing between drug conditions instead reflects the importance of accounting for individual differences when studying oxytocin effects.

Alternatively, it may be that the task set-up contributed to the absence of the hypothesised effect of oxytocin administration on reward processing. As described above (see section 7.4.5., page 171), minor adjustments were made to the MSIDT which may have affected participant experience of the task and thereby masked differences in behavioural processing between reward types across conditions. For example, the neutral stimuli were not

presented in the same way as previous chapters, nor were the prompts following missed trials. This means that the task may have felt different for the participant, perhaps restricting comparisons of behavioural processing across reward types. Indeed, a main effect of reward type on behavioural processing of rewards was observed in Chapter 4 (greater processing of monetary and social rewards in comparison to neutral stimuli) but this was not reflected in the placebo data presented here. This may, in part, be attributable to the small sample size of this study but may also reflect a broader issue with regards to the presentation of the reward stimuli. Future research looking to compare oxytocin-related processing across reward types should, therefore, ensure greater consistency and comparability across reward stimuli than was possible here.

Focusing on the relationship between task performance, drug condition, and psychopathology, the results were in keeping with the second hypothesis. A significant association was found between the Self-Image dimension of BPD and reduced social reward processing in the oxytocin condition relative to the placebo condition. This extends the findings of previous research reporting an inverted effect of oxytocin in BPD (e.g., (Herpertz & Bertsch, 2015) by showing i) that differences between clinical and control groups translate dimensionally and ii) that inverted oxytocin effects may be specifically linked to the Self-Image dimension of BPD symptomatology.

Poreh et al. (2006) argue that the Self-Image dimension of BPD captures interpersonal difficulties related to identity, for example a tendency towards peer comparison and a sense of discomfort with oneself when comparing to others. It also often manifests in feelings of emptiness and excessive self-criticism (Gold & Kyratsous, 2017). Supporting this, Dammann et al. (2011) conducted a qualitative analyses of Self-Image phenomenology and found that, when asked about self, BPD individuals described themselves as sensitive, altruistic, and suffering, but others as egoistic and aggressive. The finding that the Self-Image dimension was associated with oxytocin-induced reduced social reward processing is consistent with this clinical conceptualisation and the social salience hypothesis described earlier. As it increases social salience, increasing oxytocin can exacerbate interpersonal insecurities (Herpertz & Bertsch, 2015) and thereby reduce social reward processing in individuals with more pronounced interpersonal difficulties (such as those higher in the Self-Image dimension of BPD).

The third hypothesis predicted that ASD traits would positively correlate with increased social reward processing in the oxytocin condition relative to placebo. This was not reflected in the results. The only statistically significant association between MSIDT performance and ASD traits was between the Details/Patterns dimension and reduced anticipatory response

accuracy towards monetary rewards in the oxytocin condition relative to placebo. This is an exploratory finding and should be replicated by future research before attempting to interpret its potential meaning. Overall, these results suggest that increased social reward processing following oxytocin administration in ASD (Gordon et al., 2013; Kruppa et al., 2018) does not translate dimensionally. As shown in the sample characterisation table (Table 7.1), the mean AQ total score for this sample was higher than the normative population mean (17, CI 16.4-17.4) but was still far below the mean for samples with ASD diagnoses (35.19) (Ruzich, Allison, Smith & Watson, 2015) with none of the sample meeting the AQ clinical threshold (AQ total score of 32/50) as defined by Baron-Cohen et al. (2001). Therefore, this finding supports the Weisman and Feldman (2013) assertion that oxytocin-related effects may be dulled in nonclinical samples who do not present with lower levels of social proficiency or social motivation.

No hypotheses were made regarding the effect of oxytocin on social reward processing in dimensional psychopathy. The findings presented in the previous chapters highlighted associations between dimensional psychopathic traits and atypical social reward processing, but quite how this atypical social reward processing would be affected by oxytocin administration was unclear based on existing research. No significant associations between psychopathic traits and relative reward difference scores were found, suggesting that oxytocin does not seem to have an improving or reducing effect on social reward processing in psychopathy. Having said that, looking at the placebo data in isolation, the Antisocial dimension of psychopathy was associated with reduced social reward processing (as indexed by slower anticipatory RTs towards social rewards), $r_s(11) = .57$, $p = .042$. However, this same trend was not seen in the oxytocin data, $r_s(11) = .24$, $p = .433$. This could tentatively suggest that oxytocin administration marginally increased social reward processing in more antisocial individuals, but this should (of course) be replicated in larger samples using the relative residual difference approach described above.

7.7. Considerations for Future Study Development

This pilot study has provided some meaningful preliminary evidence on the effect of intranasal oxytocin administration on social reward processing in dimensional psychopathology. However, with the aim of informing future study development, there are some considerations and limitations within its methodological and theoretical approach that should be discussed.

7.7.1. Measuring Social Reward Processing

This study employed the modified MSIDT as a measure of behavioural social reward processing, with reward processing indexed as anticipatory RTs and response accuracy

towards monetary rewards, social rewards, and neutral stimuli. Previous chapters incorporated additional measures of social reward processing that could have contributed unique insight here also. For example, the Social Reward Questionnaire (SRQ; Foulkes, Viding, et al., 2014) is a measure of subjective social reward processing that has been used in tandem with the MSIDT throughout this thesis. As described previously, the SRQ assesses subjective processing of the different subtypes of social reward (Admiration, Negative Social Potency, Passivity, Prosocial Interactions, Sexual Relationships and Sociability) and, following the findings presented in Chapters 3 to 6, atypical processing of these different social reward subtypes may be linked to increased presence of dimensional psychopathology. Considering the results of this pilot study, including the SRQ within future oxytocin and reward studies would help to identify whether oxytocin administration affects social reward processing at the subjective level and whether oxytocin-psychopathology effects are specific to a particular subtype of social reward.

An additional consideration with the MSIDT in relation to oxytocin is that computerised social paradigms may be less effective at eliciting oxytocin effects than real-life or interactive paradigms (Borland et al., 2019). Although avatar-based reward stimuli are perhaps more engaging than static reward stimuli (Fulford et al., 2018), it is possible that the computerised nature of the task, plus its lack of tangible monetary or social reward, may have restricted oxytocin effects. Future research could look to address this by incorporating actual rewards within MSIDT paradigms, for example by giving certificates to participants as per Wang et al. (2017).

7.7.2. Gender-Related Effects

There is growing evidence to suggest that oxytocin administration differently affects social reward processing in males and females. Borland et al. (2019) propose an inverted U relationship between oxytocin dosage, social reward, and mesolimbic-dopaminergic activity, and argue that this dose-response relationship starts at lower doses in females than in males. As the dose-response relationship is initiated earlier in females, Borland et al. (2019) postulate that oxytocin administration may reduce social reward processing in females whilst increasing social reward processing in males. Furthermore, Bartz et al. (2019) highlighted that this male-female difference may vary depending on psychopathology. They found that oxytocin administration improved the empathic accuracy of males with higher AQ scores, but not those with lower AQ scores, and found no effect of oxytocin administration on empathic accuracy in female participants, irrespective of AQ score. This shows that the interactions between gender, psychopathology, and oxytocin should be accounted for when examining the effect of oxytocin administration on social processes (including social reward

processing). Whilst the pilot study presented in this chapter had a relatively even ratio of male-identifying participants to female-identifying participants, it was beyond its scope to examine gender-related effects statistically due to the small size of the participant sample. Future research should, therefore, recruit larger samples of male-identifying and female-identifying participants to compare social reward processing effects after administration of oxytocin in men and women separately.

A second limitation within this pilot study related to gender is the lack of statistical power to control for/examine oxytocin effects at different stages of the menstrual cycle. In their meta-analytic review of fluctuations in oxytocin across the menstrual cycle in healthy women, Engel et al. (2019) report that concentrations of oxytocin significantly increase from the early follicular phase of the menstrual cycle to ovulation, and then significantly decrease from ovulation to the mid-luteal phase. Therefore, participant menstrual cycle phase could have influenced baseline levels of oxytocin and thereby affected the dose-response relationship between oxytocin and reward processing described above (Borland et al., 2019).

7.7.3. Additional Dimensions of Psychopathology

This study investigated the effect of oxytocin administration on social reward processing in dimensional psychopathology, focusing specifically on psychopathic, BPD, and ASD traits. Whilst measuring psychopathic, BPD, and ASD traits captures some of the symptom dimensions of general psychopathology (Kotov et al., 2017), some aspects of psychopathology are not addressed here that could be associated with both oxytocinergic activity and reward processing. For example, this study did not include any measure of thought-disorder or schizophrenia spectrum symptomatology, but the studies presented throughout this thesis have highlighted that more pronounced schizophrenia spectrum traits may be associated with atypical social reward processing. This proposal to include measures of schizophrenia spectrum traits in future oxytocin and social reward studies is supported by preliminary evidence that oxytocin administration increases social reward motivation in schizophrenia (Bradley et al., 2019). Therefore, the pilot study presented in this chapter should be expanded to include a measure of schizophrenia spectrum traits.

It may also be important to account for individual differences in anxiety. This is because dimensional anxiety is associated with reduced social reward processing (see Chapter 4) but also because several studies (e.g., Churchland & Winkielman, 2012) have argued that oxytocin increases social responsiveness by reducing feelings of anxiety, rather than increasing social salience. The MDMQ was employed here as a measure of mood and captures some aspects of dimensional anxiety (through the Calm-Nervous subscale), but no significant associations between drug condition and Calm-Nervous scores were found.

Whilst this could suggest that feelings of anxiety did not play a role in the observed relationships between social reward processing, oxytocin administration, and psychopathology, this assertion should be addressed more specifically by future research. Indeed, research aiming to develop this pilot study could look to follow the individual differences approach employed here and include a specific dimensional measure of state/trait anxiety, such as Generalised Anxiety Disorder scale (Spitzer et al., 2006). This would potentially contribute further knowledge to the debate regarding social salience versus anxiety-reduction effects, whilst also accounting for the influence of feelings of anxiety on social reward processing.

7.7.4. Oxytocin Administration and Research Design

Intranasal oxytocin administration was used to increase participant levels of exogenous oxytocin. Intranasal administration works by inhaling oxytocin into the central nervous system, thereby increasing central concentrations of oxytocin, and stimulating increased activity at central oxytocin receptors (Quintana et al., 2018). Although, Kou et al. (2021) recently suggested that orally administered oxytocin may be more effective at increasing reward system responses than intranasal oxytocin. Perhaps future developments of this pilot study could, therefore, test Kou et al.'s (2021) suggestion and include orally administered oxytocin rather than intranasal.

Furthermore, Quintana et al., (2021) made a series of suggestions for oxytocin research which should be remembered when critiquing this pilot study and planning its future development. They recommend employing within-subject, rather than between-subject, approaches and recommend collecting data from both male and female participants. They also suggest that psychopathology should be examined dimensionally rather than categorically, as has been done here. Of course, the sample size of this study (n = 16) is far less than is recommended by Quintana et al. (2021) (n = 156 for within-subjects research). Having said that, this pilot study, and its suggestions for future study development, may provide a framework for future research to comprehensively (and robustly) examine the effect of oxytocin administration on social reward processing in psychopathology.

7.7.5. Potential Clinical Applications

Finally, the results presented here have preliminary implications for clinical practice and the use of intranasal oxytocin in the treatment of atypical interpersonal behaviour in psychopathology. The finding that administering oxytocin decreases social reward processing in individuals with more pronounced BPD Self-Image traits suggests that oxytocin should not be used as an all-purpose treatment option; oxytocin could, in fact, exacerbate the interpersonal symptoms of some psychopathologies. Instead, a more

targeted approach is needed which accounts for the interplay between psychopathology and individual differences in responses to oxytocin. Feng et al. (2015) propose that responses to oxytocin are modulated by the *OXTR* gene. Given that polymorphisms in the *OXTR* have been found across a range of psychopathologies (Feldman et al., 2016), it will be important for future work to explore exactly how intranasal oxytocin administration interacts with *OXTR* polymorphisms; and thereby identify whether oxytocin administration has therapeutic potential in cases where *OXTR* polymorphisms are present.

7.8. Chapter Summary

Having identified that several dimensions of psychopathology are associated with atypical social reward processing, this chapter explored the effect of intranasal oxytocin administration on MSIDT performance in dimensional psychopathology. Its findings provide some preliminary evidence of the inverted oxytocin effect in BPD, with reduced social reward processing following oxytocin administration associated with the Self-Image dimension of BPD. However, no significant relationships were found between psychopathic or ASD traits and social reward processing following oxytocin administration. This is the final empirical chapter of this thesis, and so the next chapter will summarise the data-based findings of Chapters 3-7, before moving into a broader discussion of social reward processing in psychopathology.

8. General Discussion

8.1. Chapter Aims and Overview

This chapter reviews the findings of the empirical investigations reported in this thesis. It will first summarise findings per psychopathology (schizophrenia spectrum, affective symptoms, psychopathy, borderline personality disorder, autism spectrum disorder) before outlining a series of conceptual, clinical, and methodological implications stemming from this work.

8.2. Summary of Thesis Findings

This thesis aimed to develop the findings of previous research by examining associations between subjective and behavioural measures of social reward processing and psychopathology. Psychopathology was assessed both categorically (comparing clinical and control groups, Chapters 3 and 6) and dimensionally (via self-report questionnaires, Chapters 3, 4, 5, 6, and 7). The research questions, hypotheses, and main findings presented in each of the empirical chapters are summarised in Table 8.1.

The findings observed in these chapters were broadly in keeping with the hypotheses and those reported in previous research. The data presented suggest that psychopathology is associated with atypical social reward processing. Furthermore, this seems to be dependent on the subtype of social reward available and which dimensions of psychopathology are elevated. The findings presented in this thesis will now be synthesised for each of the psychopathologies, with the aim of providing a comprehensive picture of how psychopathology affects social reward processing. This synthesis will draw on findings from all empirical chapters where possible (Chapter 7 only focused on three of the psychopathologies – see Chapter 7, section 7.7.3., page 187, for commentary on this).

Table 8.1. Overview of Thesis Findings

Chapter	Research Question	Objectives / Hypotheses	Methodology	Summary of Main Findings
3	*Is atypical social reward processing a transdiagnostic characteristic of psychopathology?*	1. Investigate the extent to which atypical social reward anticipation is a feature of psychopathology when a clinical group is compared to a group of healthy controls. 2. Compare social reward anticipation across clinical groups and clarify whether atypical social reward anticipation is a transdiagnostic marker of psychopathology. 3. Consider the implications of atypical social reward anticipation for clinical practice and identify potential directions for future research.	Systematic review and meta-analysis (k = 42) comparing clinical and control groups on subjective, behavioural, and neural correlates of social reward anticipation.	Meta-analytic evidence of behavioural social reward hypoanticipation (RT domain) in schizophrenia spectrum conditions, ASD, and ADHD. Social reward hypoanticipation as transdiagnostic characteristic, reflected in overall slower RTs towards social rewards in pooled clinical group versus control group. Narrative synthesis of available self-report and neuroimaging data found similar pattern of atypical social reward processing in psychopathology – including potential social reward hyperanticipation in BPD. Critical evaluation of current evidence included: i) critique of social reward stimuli, ii) use of psychotropic

				medications, iii) gender-related effects, iv) cognitive deficits, v) sample size implications, and vi) clinical implications.
4	*Do clinical versus control group differences in social reward processing translate dimensionally within the normative population?*	1. Schizophrenia spectrum traits, affective symptoms (specifically depression and social anxiety), and ASD traits will be associated with reduced subjective processing of social rewards involving Prosocial Interactions or Sociability. 2. Schizophrenia spectrum and ASD traits will correlate with reduced behavioural processing (hypoanticipation) of social rewards, reflected in slower reaction times (RTs) or response accuracy towards social rewards.	Examined associations between dimensional psychopathology and subjective and experimental measures of social reward processing in a general population sample (n = 154). Psychopathology assessed using a range of self-report measures. Social reward processing indexed subjectively using the Social Reward Questionnaire and behaviourally via the modified MSIDT.	Schizophrenia spectrum traits associated with atypical subjective social reward processing. Observed associations between Cognitive-Perceptual and Interpersonal dimensions and reduced subjective processing of social rewards involving Sociability, and positive associations between Cognitive-Perceptual and Disorganised dimensions and subjective processing of social rewards involving Negative Social Potency and Sexual Relationships. Affective symptoms (depression, anxiety, stress, social anxiety) associated with reduced subjective processing of Prosocial Interactions and Sociability.

	3. Psychopathic traits will positively correlate with subjective processing of social rewards involving Admiration and Negative Social Potency. They will also be associated with reduced subjective processing of Prosocial Interactions. 4. Psychopathic traits related to interpersonal behaviour (i.e., Interpersonal dimension) will be associated with increased behavioural processing (hyperanticipation) of social rewards. 5. The impulsivity aspect of schizophrenia spectrum, psychopathic, and BPD	Exploratory dimensional transdiagnostic approach included, with the model generated via EFA and CFA. Model included four transdiagnostic factors: 1) Interpersonal Anhedonia, 2) Externalising-Antagonising, 3) Mood, 4) Thought Disorder.	Psychopathic traits associated with increased subjective processing of Negative Social Potency, with the Lifestyle dimension also related to increased subjective processing of social rewards involving Sociability. Reduced subjective processing of Prosocial Interactions observed across psychopathy dimensions. BPD traits (Impulsivity and Intense Anger dimensions) negatively correlated with subjective processing of Prosocial Interactions. Several dimensions (Affective Instability, Self-Image, and Emptiness) associated with reduced subjective processing of social rewards involving Sociability. Five BPD dimensions (Impulsivity, Abandonment, Suicide/Self-Mutilation, Intense Anger, Quasi-Psychotic States) related to increased subjective processing of Negative Social

	traits will be associated with increased behavioural processing (hyperanticipation) of monetary rewards.	Potency. Reduced behavioural processing of social rewards linked to Intense Anger dimension of BPD, but increased processing linked to Impulsivity and Suicide/Self-Mutilation dimensions. Social Skills dimension of ASD associated with reduced subjective processing of Admiration, Prosocial Interactions, and Sociability. Increased subjective processing of Passivity linked to Social Skills dimension. Increased subjective processing of Negative Social Potency associated with Details/Patterns and Communication/Mindreading dimensions. Reduced behavioural processing of social rewards linked to the Communication/Mindreading dimension.

				Interpersonal Anhedonia transdiagnostic dimension associated with reduced subjective processing of Sociability. Mood dimension associated with reduced subjective processing of Sociability and Prosocial Interactions. Externalising-Antagonising, Mood, and Thought Disorder dimensions associated with increased subjective processing of Negative Social Potency.
5	*Are dimensions of psychopathology differently related to the behavioural processing of different social reward subtypes?*	1. Schizophrenia spectrum traits, affective symptoms, BPD traits, and ASD traits will be associated with reduced behavioural processing (hypoanticipation) of social rewards involving Admiration, reflected in slower reaction times (RTs) or lower response accuracy. 2. Psychopathic traits will be associated with increased behavioural processing	Tested a subset of the sample who participated in the study detailed in Chapter 4 (n = 42) and assessed social reward processing using the SRS-IDT, which assessed behavioural anticipation of four subtypes of social reward: Admiration, Negative Social Potency, Passivity and Sociability.	Schizophrenia spectrum traits, specifically Cognitive-Perceptual dimension, associated with reduced behavioural processing of social rewards involving Admiration and Sociability. The Cognitive-Perceptual dimension was also associated with increased processing of social rewards involving Passivity. Stress dimension of DASS-21 associated with reduced behavioural

	(hyperanticipation) of social rewards involving Negative Social Potency, reflected in faster RTs or greater response accuracy. 3. Schizophrenia spectrum traits, affective symptoms, and ASD traits will be associated with increased behavioural processing (hyperanticipation) of social rewards involving Passivity, reflected in faster RTs or greater response accuracy. 4. Schizophrenia spectrum traits, affective symptoms, and ASD traits will be associated with reduced behavioural processing (hypoanticipation) of social rewards involving Sociability, reflected in slower RTs or lower response accuracy.	processing of Admiration. Anxiety and Stress dimensions associated with increased behavioural processing of Passivity. Anxiety dimension associated with increased behavioural processing of Sociability. Lifestyle dimension of psychopathy associated with increased behavioural processing of social rewards involving Sociability. Antisocial dimension associated with reduced processing of Admiration. Abandonment dimension of BPD associated with increased processing of Passivity. Self-Image dimension associated with increased processing of Sociability. No significant associations observed between ASD traits and behavioural

				processing of the social reward subtypes.
6	*Are dimensional relationships between social reward processing and psychopathology detectable in a preliminary sample of forensic psychiatric service users?*	1. Clinical group SRQ scores will be different to the control group, with the clinical group reporting reduced subjective processing of social rewards involving Admiration, Prosocial Interactions, and Sociability. Negative Social Potency scores will be higher in the clinical group than the control group, suggesting increased subjective processing of Negative Social Potency in the clinical group. 2. Within the clinical group, dimensional measures of schizophrenia spectrum traits, affective symptoms, psychopathic traits, and ASD traits, will correlate with reduced subjective processing of social rewards involving Prosocial Interactions. Schizophrenia spectrum traits and	Repeated the approach employed in Chapter 4 and investigated social reward processing in a pilot sample of participants recruited from a medium secure forensic psychiatric service (n = 15). Employed categorical approach comparing clinical and control groups on subjective and behavioural measures of social reward processing. Employed dimensional approach and examined associations between psychopathology and	Trend towards reduced subjective processing of Prosocial Interactions in the clinical group in comparison to the control group, with a medium effect size. No significant reward type*group interaction when examining behavioural reward processing. Cognitive-Perceptual dimension of the schizophrenia spectrum associated with reduced subjective processing of social rewards involving Admiration and Prosocial Interactions, and increased processing of Negative Social Potency. Dimensional depression (PHQ-9) linked to increased processing of social and monetary rewards.

	ASD traits will be associated with reduced subjective processing of Sociability. Psychopathic traits will also correlate with increased subjective processing of social rewards involving Negative Social Potency. 3. Analysis of behavioural processing of rewards will show an interaction between group (clinical or control) and reward type (monetary, social, neutral), with the clinical group demonstrating reduced behavioural processing (hypoanticipation) of social rewards in comparison to the control group. 4. Dimensional psychopathology will be associated with reduced processing (hypoanticipation) of social rewards, with schizophrenia spectrum traits, affective symptoms, and ASD traits, correlating with	social reward processing in the clinical group only. Statistical trends ($p < .10$) reported due to small sample and exploratory nature of study.	Psychopathic traits (PCL-R Affective and Antisocial dimensions plus total score) correlated with reduced subjective processing of Prosocial Interactions. Reduced behavioural processing of social rewards linked to multiple psychopathy dimensions, as well as PCL-R total score. BPD Intense Anger dimension associated with reduced subjective processing of Prosocial Interactions and increased processing of Negative Social Potency. It was also associated with a trend towards reduced behavioural social reward processing. Self-Image dimension associated with reduced subjective processing of Sociability. BPD Impulsivity dimension related to reduced subjective processing of Negative Social Potency, increased subjective processing of Sociability, and reduced

		slower anticipatory reaction times (RTs) and response accuracy towards social rewards.		behavioural processing of social rewards. Relationships dimension associated with reduced behavioural processing of both social and monetary rewards. ASD traits (AQ-10) related to reduced behavioural processing of social rewards.
7	*How does intranasal oxytocin administration influence social reward processing in dimensional psychopathology?*	1. There will be a significant interaction between reward type (monetary, social, neutral) and drug condition (placebo or oxytocin), with significantly faster anticipatory reaction times (RTs) and greater response accuracy towards social rewards in the oxytocin condition in comparison to the placebo condition. A smaller effect will be seen for monetary rewards, and no effect for neutral stimuli. 2. BPD traits will be associated with an inverted oxytocin effect, with	Tested a pilot sample recruited from the general population (n = 17, repeated measures) in both placebo and oxytocin drug conditions. Examined associations between social reward processing and psychopathic traits, BPD traits, and ASD traits.	Significant interaction between reward type and drug condition, with significantly slower RTs towards neutral stimuli in oxytocin condition in comparison to placebo condition. No other significant main or interaction effects were observed. No significant effect of drug (placebo or oxytocin) administration on participant self-reported mood. BPD Self-Image dimension associated with reduced behavioural processing

	more pronounced BPD traits relating to reduced behavioural social reward processing (hypoanticipation) in the oxytocin condition relative to the placebo condition. 3. ASD traits will correlate with increased behavioural social reward processing (hyperanticipation) in the oxytocin condition relative to the placebo condition, suggesting that more pronounced ASD traits are associated with a greater benefit of oxytocin administration on social reward processing. 4. Due to lack of prior research, no hypotheses were made regarding the links between psychopathic traits and modulation of reward processing by oxytocin.	Social reward processing was assessed in both placebo and oxytocin drug conditions using the modified MSIDT.	of social rewards following oxytocin administration. Details/Patterns dimension of ASD associated with reduced behavioural processing of monetary rewards in oxytocin condition relative to the placebo condition

8.2.1. Schizophrenia Spectrum Conditions

Overall, the findings suggest that the schizophrenia spectrum is characterised by atypical social reward processing. As summarised in Table 8.1., the synthesis and meta-analysis of existing research (Chapter 3) found marked differences in social reward processing (RT domain) between clinical and control groups, with the clinical group demonstrating significant behavioural hypoanticipation of social rewards in comparison to the control group. This between-groups approach was extended by the results of Chapters 4 and 5, which observed correlations between the Interpersonal and Cognitive-Perceptual dimensions of the schizophrenia spectrum and reduced subjective processing of social rewards involving Sociability. The association between the Cognitive-Perceptual dimension and reduced subjective processing of social rewards also translated to the behavioural data presented in Chapter 5, with scores on this dimension correlating with reduced behavioural processing of social rewards involving Admiration and Sociability. In Chapter 6, the Cognitive-Perceptual dimension of the schizophrenia spectrum again related to reduced subjective processing of social rewards involving Admiration and Prosocial Interactions. However, no significant associations between dimensional schizophrenia spectrum traits and behavioural reward processing (social or monetary rewards) were observed. Together, these findings indicate that the schizophrenia spectrum may be characterised by reduced subjective and behavioural processing of social rewards (particularly rewards involving Admiration and Sociability) and that reduced reward processing may be specifically linked to the Cognitive-Perceptual dimension of schizophrenia spectrum symptomatology. The data, therefore, develop existing knowledge (e.g., Hanewald et al., 2017; Xie et al., 2014) by providing further evidence of reduced social reward processing in schizophrenia and provide specific insight in showing that reductions in reward processing may specifically involve less subjective and behavioural processing of social rewards that involve large crowds or being the centre of attention.

An additional finding of note is the observed association between schizophrenia spectrum traits and increased subjective processing of social rewards involving Negative Social Potency (Chapters 4 and 6). As reported previously, Mason et al. (1995) and Eysenck (1992) include antisociality as feature of the schizophrenia spectrum and thus it is perhaps reasonable that dimensional schizophrenia spectrum traits might be associated with increased enjoyment of witnessing or enacting cruelty towards others. However, this association was not hypothesised and thus should be replicated and investigated dimensionally in larger samples. Within this, as noted in Chapter 4, it may be important to account for overlaps between schizophrenia spectrum and psychopathic traits and/or study

differences in reward value between witnessing or enacting physical versus psychological cruelty towards others (see Chapter 5, section 5.6.6., page 133).

8.2.2. Affective Symptoms

The findings presented in Chapters 3 to 6 provide mixed evidence regarding links between affective symptoms and social reward processing. Only studies on social anxiety disorder reported behavioural data that could be included in the meta-analysis of social reward anticipation (Chapter 3), where no significant meta-analytic behavioural evidence of reduced social reward processing in clinical versus control groups with social anxiety disorder was found. However, despite no significant meta-analytic evidence of differences in behavioural anticipation between groups, some descriptive evidence of significantly attenuated social reward processing in affective disorders was found, particularly regarding differences in reward-related neural activations in clinical versus control groups.

The inconclusive findings regarding (un)affected social reward processing in affective disorders continued into the dimensional data presented throughout this thesis. At the self-report level, dimensional Alexithymia (Chapter 3), Depression (Chapter 4), General Anxiety (Chapter 4, Chapter 6), Social Anxiety (Chapter 4), and Stress (Chapter 4), were found to correlate with reduced subjective processing of social rewards involving Admiration, Prosocial Interactions and/or Sociability. In contrast to this pattern of reduced subjective social reward processing linked to affective symptoms, the results of the behavioural investigations using the modified MSIDT (Chapter 4, Chapter 6) and SRS-IDT (Chapter 5) were mixed. No significant associations between behavioural social reward processing and affective symptoms were observed in Chapter 4. However, Chapter 5 presented associations between affective symptoms and reduced behavioural processing of social rewards involving Admiration (Chapter 5) and increased processing of social rewards involving Passivity. Some potential explanations of these mixed findings were offered in Chapter 4, section 4.6.2., page 105, and Chapter 5, section 5.6.2., page 130. It may be that these mixed findings reflect the assessment tools used to assess affective symptoms. Most chapters employed DASS-21, but its broad three factor structure (Depression, Anxiety, Stress; Lovibond & Lovibond, 1995) means that some of the more particular features of affective disorders (e.g., melancholy, anhedonia, emotion dysregulation) could not be studied. Therefore, using a series of specific affective symptom measures in combination would perhaps provide a more detailed understanding of links between affective symptomatology and social reward processing, and in doing so address some of the inconclusive findings presented here.

8.2.3. Psychopathic Traits

The hypotheses included in this thesis pertaining to psychopathy were formulated following Foulkes, McCrory, et al. (2014) and conceptual descriptions of interpersonal behaviour in psychopathy (e.g., Viding & McCrory, 2019; White, 2014). Based on the findings of Chapters 4-7, it appears that social reward processing in psychopathy may vary depending on which dimension of psychopathy is elevated and the subtype of social reward available. As expected, psychopathic traits (including dimensions and total score) were simultaneously associated with reduced subjective processing of Prosocial Interactions and increased subjective processing of social rewards involving Negative Social Potency (Chapter 4). Associations between the Lifestyle dimension and increased subjective (Chapter 4) and behavioural (Chapter 5) processing of social rewards involving Sociability were also observed. Thus, the findings presented (see Table 8.1. for summary) not only indicate that psychopathic traits are correlated with increased enjoyment of witnessing or enacting cruelty to others (e.g., March, 2019) but also suggest that reduced feelings of reward may motivate less prosocial behaviour in psychopathy. Indeed, in identifying that the behaviours that characterise psychopathy (antisociality, less prosocial behaviour, and heightened interpersonal sensation-seeking/gregariousness) may have an intrinsic reward value, these findings have implications for therapeutic regimes which aim to engage and address the atypical interpersonal behaviours of individuals with higher levels of psychopathic traits (see section 8.3.4.1., page 207). Following this, the pilot investigation in Chapter 7 tested whether atypical social reward processing in dimensional psychopathy may be amenable to intervention via oxytocin. It examined associations between psychopathic traits, behavioural social reward processing, and oxytocin administration, but found no evidence for the improving/reducing effect of oxytocin administration on social reward processing in dimensional psychopathy.

8.2.4. Borderline Personality Disorder Traits

Like psychopathy, limited work to-date has investigated social reward processing in BPD and thus the findings presented in Chapters 3 to 7 contribute new knowledge regarding how BPD traits relate to specific aspects of social reward processing. Throughout this thesis, a differential pattern of social reward processing in dimensional BPD has been observed, with some dimensions associated with increased social reward processing, and others associated with reduced social reward processing. For example, comparing clinical and control groups revealed neural hyperanticipation of social rewards in BPD individuals (Chapter 3) which translated dimensionally to increased subjective processing of Negative Social Potency linked to several BPD traits (Chapter 4, Chapter 6) as well as increased

behavioural processing of social rewards involving Passivity linked to the Abandonment dimension (Chapter 5). In contrast to the increased processing of social rewards linked to some dimensions of BPD, other dimensions were found to be associated with reduced subjective processing of social rewards involving Prosocial Interactions and Sociability (Chapter 4, Chapter 6), as well reduced behavioural processing of social rewards linked to the Intense Anger dimension (Chapter 4, Chapter 6). Together, these findings reflect the complexities of interpersonal behaviour in BPD (Furnham et al., 2014) and how certain features of BPD may be differently associated with reduced/heightened social reward processing depending on social reward subtype.

The pilot investigation of oxytocin administration in dimensional BPD (Chapter 7) revealed an interesting preliminary association between oxytocin administration and reduced social reward processing linked to the Self-Image dimension of BPD. Whilst this finding should be replicated in larger samples, it perhaps has implications for work aiming to address atypical social reward processing in psychopathology through psychopharmacological interventions (see section 8.3.4.2., page 208).

8.2.5. Autism Spectrum Disorder

The data presented in Chapters 3 and 4 were consistent with previous research which has shown that ASD traits are associated with atypical social reward processing, but this was not the case for the other chapters. As presented in Table 8.1., comparing clinical and control groups (Chapter 3) revealed significant meta-analytic evidence of reduced behavioural social reward processing (hypoanticipation) in ASD. This reduced social reward processing in clinical groups was also reflected dimensionally in Chapter 4. Chapter 4 reported associations between the Social Skills dimension and reduced subjective processing of social rewards involving Admiration, Prosocial Interactions, and Sociability, as well as reduced behavioural processing of social rewards linked to the Communications/Mindreading dimension of ASD. Moreover, like in the schizophrenia spectrum, dimensions of ASD (Details/Patterns, Communication/Mindreading) were associated with increased subjective processing of social scenarios involving Negative Social Potency. However, these relationships did not translate to atypical behavioural processing of the social reward subtypes as assessed by the SRS-IDT (Chapter 5), but trend associations between overall ASD traits and reduced behavioural social reward processing were observed in the pilot study of forensic psychiatric service users (Chapter 6). Like psychopathy, no significant effect of oxytocin administration on social reward processing linked to ASD traits was found (Chapter 7). As such, these results partly support existing

evidence for atypical social reward processing in ASD, but not to the extent that was hypothesised across most chapters.

8.3. Implications and Future Directions

8.3.1. Transdiagnostic Implications

As described in Chapter 1, section 1.5.2., page 28, there is increasing emphasis on using transdiagnostic frameworks within psychopathology research and practice. These transdiagnostic frameworks seek to identify the traits and behaviours which might cut-across traditional psychiatric boundaries and then examine their shared psychological and neural correlates (Michelini et al., 2021). Importantly for this thesis, both RDoC and HiTOP include individual differences in reward processing within their transdiagnostic frameworks, and thereby identify reward processing as a transdiagnostic feature of psychopathology which may have implications for symptom development and maintenance: RDoC includes reward responsiveness (including reward anticipation and consumption phases) as part of the positive valence system and HiTOP includes high/low reward sensitivity as a relevant trait within several of its psychopathological spectra (Perkins et al., 2020).

Whilst not investigating RDoC or HiTOP frameworks specifically, the findings presented in this thesis have important implications for work aiming to understand the transdiagnostic nature of reward processing in psychopathology (e.g., Bradley et al., 2017; Lambert et al., 2018). First, the pooled meta-analysis of social reward processing (Chapter 3) found that several pooled clinical groups (including participants diagnosed with schizophrenia spectrum conditions, ASD, affective disorders, and ADHD) demonstrate reduced behavioural processing (hypoanticipation) of social rewards in comparison to healthy controls. Second, the exploratory transdiagnostic approach employed in Chapter 4 extracted four underlying dimensions (Interpersonal Anhedonia, Externalising-Antagonising, Mood, Thought Disorder) which were differentially related to subjective social reward processing. Together, these results highlight the importance of adopting transdiagnostic approaches within social reward research and provide preliminary evidence that, like monetary rewards, social reward processing may be differently related to externalising, thought disorder and mood spectra (Michelini et al., 2021).

Integrating transdiagnostic approaches within social reward research is not without challenge, however. From a measurement standpoint, no single measure of the HiTOP framework is currently available (Ruggero et al., 2019) and thus researchers wishing to assess multiple dimensions of psychopathology simultaneously will need employ to a wide range of dimensional measures. This could pose a variety of practical challenges including

participant time, study resources, and ability to access appropriate measurement tools. Similarly, the HiTOP framework is multi-levelled, descending from superspectra (general psychopathology factor) to individual symptoms/traits, meaning that transdiagnostic approaches could be applied at a broader level (assessing internalising, externalising, and thought disorder spectra) through to a trait level (such as risk-taking). Conceptually, this poses a challenge for researchers aiming to transition from DSM or ICD classifications, as measures will need to be selected according to which aspects of psychopathology are ostensibly most associated with social reward processing – which, as reflected throughout this thesis, is not currently clear. Finally, as summarised in Chapter 1, section 1.5.3., page 28, Ruggero et al. (2019) state that dimensional transdiagnostic approaches are not yet fully embedded within clinical practice, and thus social reward research adopting a transdiagnostic approach should detail the clinical applications of its findings. This will both strengthen efforts to include transdiagnostic approaches within practice and, with treatment in mind, help identify links between transdiagnostic symptoms, social reward processing, and interpersonal behaviour.

8.3.2. Neural Correlates

Chapters 1 and 3 synthesised a range of studies which have investigated the neural correlates of social reward processing. Chapter 1 identified brain regions which are implicated in the anticipation and consumption of social rewards, and Chapter 3 reviewed existing evidence of clinical and control group differences in neural activation during social reward anticipation. This comparison of clinical and control groups revealed that psychopathology alters neural processing of social rewards, with some clinical groups demonstrating reduced activation (e.g., ASD) in reward-related areas (e.g., ventral striatum) and others (e.g., BPD) demonstrating increased activation.

The findings of Chapter 3 suggest that including a neuroimaging component within future replications of Chapters 4-7 might be informative. It would be interesting for future research to investigate i) whether the self-report and behavioural findings presented here are reflected neurobiologically, ii) whether, as per Schwarz et al. (2020), similar neural activations are observed across diagnostic categories, and iii) whether neural responses to social rewards vary depending on the subtype of social reward available.

8.3.3. Adolescence and Emergence of Psychopathology

Aside from Chapter 3, which reviewed studies investigating social reward processing in all age groups, all other empirical investigations presented in this thesis had participant samples over the age of 18.

In their review of social reward sensitivity in adolescence, Foulkes and Blakemore (2016) propose that social rewards are more salient for adolescents than adults, and that subjective experience of social reward and punishment is heightened during this life stage. Altikulaç et al. (2019) added that this heightened sensitivity to social rewards in adolescence depends on the social reward subtype available: they found that subjective processing of social rewards involving Admiration peaked in late adolescence, with enjoyment of Prosocial Interactions increasing linearly with age. This increased sensitivity to social rewards is likely linked to increased dependence on peer-learning and peer-support during adolescence (Foulkes & Blakemore, 2016; Ladd et al., 2014); social scenarios which are, conversely, also linked to the development and onset of psychiatric symptoms (Costello et al., 2011; Walker et al., 2017).

It may be, therefore, that heightened sensitivity to social rewards contributes to the development of psychiatric symptoms during adolescence (for example sensitivity to peer-feedback, such as praise or criticism; Guyer, 2020). Whilst several studies have investigated social reward processing in adolescent samples with psychiatric diagnoses (see Chapter 3, Appendix 3) less work to-date has investigated whether i) adolescent psychopathology is associated with atypical processing of specific social reward subtypes, and ii) if changes in social reward sensitivity (and thereby processing) predict the emergence of psychopathology. Future research could, thus, look to investigate these research gaps, perhaps using the methods employed in this thesis.

8.3.4. Clinical Implications and Considerations

Some potential clinical considerations stemming from the findings presented in this thesis were described previously in Chapter 3 (see section 3.7.6., page 67) and Chapter 7 (see section 7.7.5., page 188). They will be raised again here, starting with implications for psychological interventions.

8.3.4.1. Psychological Interventions

If social reward processing is affected across psychopathologies, it raises the question of whether atypical social reward processing might be amenable to psychological interventions. Such interventions might look to increase social motivation by exploring opportunities for the patient to experience social rewards, thereby increasing the intrinsic reward value of social scenarios. The findings presented in Chapters 4 and 5 highlight the importance of considering social reward subtypes within this. For example, psychological interventions could look to incentivise social behaviour by emphasising the availability of the social reward subtypes that are appealing to the individual (e.g., *"you can let others take the lead, if you would like" [Passivity], "this will make you feel important" [Admiration]*). This may then

increase social motivation and social participation. Alternatively, interventions could make use of the feelings of reward that are experienced during one type of social interaction and look to transfer them to another by labelling the social rewards typically experienced (e.g., "*you seem to be enjoying this party [Sociability], does it feel good to see other people enjoying it too?" [Prosocial Interactions]*).

An alternative suggestion relates to the section on adolescence above. As social reward sensitivity is heightened in adolescence (Guyer, 2020), psychological interventions targeting the emergence of psychiatric symptoms in adolescence could offer more focus to social reward experiences. For example, systemic interventions (which aim to change the social structures underpinning the patients' psychopathology) could address the feedback that the patient is receiving from family and peers and, as enjoyment of Admiration peaks in adolescence, frame feedback in a way that might tap into feelings of Admiration (e.g., *"I was impressed", "You set a good example for your peers"*).

Finally, several associations between psychopathology and increased subjective processing of Negative Social Potency were presented in Chapters 3 and 4. Given that Negative Social Potency involves the enjoyment of witnessing or enacting cruelty to others, this suggests that antisocial behaviour in psychopathology may sometimes be motivated by feelings of pleasure (i.e., being antisocial feels rewarding), rather than anger, fear, or disinhibition (Chester et al., 2019). This has potential implications for those conducting psychological therapies within forensic services (like Chapter 6). These therapies aim to reduce antisocial behaviour through the learning of anger management strategies and the adoption of prosocial attitudes and behaviours. However, if the antisocial behaviour is motivated by feelings of reward, it may be that a different therapeutic approach is required - such as pairing prosocial behaviour (or a lack of antisocial behaviour) with a form of reward that is incentivising for the individual (e.g., tokens, increased free time).

Of course, these examples are speculative but highlight potential ways in which the thesis findings could be applied within psychological interventions.

8.3.4.2. Pharmacological Interventions

As described in Chapter 7, oxytocin administration has previously demonstrated some utility in addressing atypical social reward processing in psychopathology. Although no significant effect of oxytocin administration on social reward processing was observed overall, the findings of Chapter 7 remind us that oxytocin may not be an all-purpose treatment, as it has the potential to exacerbate some interpersonal symptoms. As an alternative to oxytocin, the reward-related effects of typical and atypical antipsychotic medications are well-documented (Chapter 3), and there is increasing evidence to suggest that SSRI and MDMA

administration may also promote social behaviour in some individuals (Bedi et al., 2009; Young et al., 2014). As with most pharmacological interventions, it is likely that a combination of pharmacological and psychological intervention will elicit the most meaningful change in social reward responses (Schwartz et al., 2019).

8.3.4.3. Limitations of Viewing Social Reward Processing as Atypical

From a social constructivist perspective, it is also important to question how helpful it is to view social reward processing (and subsequent interpersonal behaviour) as atypical. It may be that many of the behaviours that we characterise as atypical may not be so, and there may well be a disconnect between researcher/clinician attributions of social reward-related behaviour and the lived experience of people with mental health diagnoses. Indeed, Jaswal and Akhtar (2018) argue that many people with ASD diagnoses are misidentified as socially disinterested because they demonstrate social behaviours which, from an ableist perspective, are associated with social disinterest (e.g., reduced eye contact, reduced gesture, reduced conversational animation). In response, Jaswal and Akhtar (2018) propose that many individuals with ASD are socially interested or motivated, but perhaps express this interest in non-conventional ways. This has implications for the ways in which social reward processing is assessed and then treated within clinical practice. For example, many of the items included in the Social Reward Questionnaire, and then displayed in the MSIDT and SRS-IDT, are based on neurotypical definitions of rewarding social interactions (such as attending large gatherings) rather than those that may be more inclusive of neurodiverse or clinical populations – who might prefer computer-based fantasy-related interactions, for example (Kohls et al., 2012). Conceptualisations of social reward processing in psychopathology should, therefore, perhaps account for the lived experience of the individual within definitions of ‘typical’ social reward experience. This will also help to shift focus towards the aspects of social interaction which individuals find rewarding, rather than pathologizing the aspects of social interaction which they may enjoy less (Jaswal & Akhtar, 2018).

8.3.5. Operationalising Social Reward Processing

The findings in this thesis have centred around the Foulkes, Viding et al. (2014) classification of social rewards. Whilst comprehensive, social interactions are so complex that it is difficult to succinctly define their hedonic value. There may be aspects of social interaction which are commonly rewarding but have not been identified here. Moreover, as social interactions are constantly evolving, the feelings of reward associated with social interaction may change moment-to-moment and vary depending on so many extraneous factors (Jaswal & Akhtar, 2018), but the tools used to assess social reward processing here are less able to account

for this. Therefore, it could be interesting for future research to develop ecological momentary assessments of the reward value of social interactions; this would provide a more nuanced understanding of how social reward fluctuates depending on the nature of the social interaction and would better incorporate the individuals' lived experience (see section 8.3.4.3., page 209).

Furthermore, it may be that the Foulkes, Viding et al. (2014) classification of social rewards misses other key elements of social reward experience. In their comprehensive conceptual review of social reward constructs, Matyjek et al. (2020) posit that it is important for social reward research to account for social reward primacy, temporal proximity, duration, familiarity, source, tangibility, naturalness, and magnitude. These are currently not included in the Foulkes, Viding et al. (2014) classification. For example, their classification does not explicitly differentiate between social reward familiarity (e.g., Prosocial Interactions with friends/family versus strangers) or duration (e.g., short-lived Admiration versus extended Admiration). Similarly, there are likely to be reward value differences in witnessing versus enacting Negative Social Potency (Foulkes, 2019) which, following the findings presented in this thesis, will be important to investigate further. As such, expanding the Foulkes, Viding et al. (2014) classification to include these elements will help clarify whether social reward processing in psychopathology not only varies depending on the subtype of social reward available (as has been emphasised through the findings presented in this thesis), but also the nature of the social reward subtype (e.g., social interactions with strangers, duration of social interaction).

8.3.6. Critical Evaluation of Behavioural Tasks

The development of two new behavioural assessments of social reward processing (MSIDT, SRS-IDT) is a novel, important, contribution of this thesis. The tasks were found to be associated with dimensional psychopathology across chapters (4-7, MSIDT; 5, SRS-IDT), with analysis of task performance data also revealing reward type effects in Chapters 4 and 5. Taken together, these findings indicate that the tasks functioned as intended and elicited reward-related behavioural effects – including finding associations between dimensional psychopathology and behavioural reward processing (which are often difficult to detect, see Chapter 3).

The use of avatar-based rewards helps advance current understanding of how to examine social reward processing experimentally using more ecologically valid stimuli. The stimuli were created and developed following the Foulkes, Viding et al. (2014) classification of social reward, meaning that they address some of the critique typically attached to experimental measures of social reward processing (see Chapter 3, section 3.7.1., page 65).

Furthermore, the tasks benefited from a development process which included the stimuli and tasks being rated, redeveloped, and piloted in consultation with other researchers, mental health service users, and university and NHS ethics committees. As described in Chapter 2 (section 2.4., page 37) the development process was motivated by a desire to increase the construct validity of the tasks whilst maximising their utility and accessibility in clinical and normative samples. As such, the tasks appear to offer a conceptually relevant way of assessing behavioural social reward processing that may be appropriate for use in both clinical and university settings. Although the tasks have contributed new knowledge on how to assess behavioural social reward processing in dimensional psychopathology, there are several limitations within the tasks that should be addressed by future research. Addressing these limitations may stimulate future studies of social reward processing and thereby progress this important, but still developing, area of psychopathology research.

The first limitation within the tasks that should be addressed by future research is the lack of consistent task (reward type) effects across chapters. As explained earlier in the thesis, it may be this is a consequence of small sample sizes (Chapters 6 and 7) and/or adjustments made to task format (Chapter 7). Future research should, thus, adopt the tasks used here and test their ability to detect reward type effects in larger normative and clinical samples. A second conceptual and methodological limitation that could not be assessed during piloting was the actual reward value of the avatar-based videos. Although spontaneous qualitative feedback indicated that the rewards were seen as desirable and enjoyable, it was beyond the scope of this thesis to examine this empirically or systematically. Future studies should, therefore, adopt these reward stimuli and ask participants to rate their reward value and valence. This will help to validate the stimuli as rewarding and thereby increase their usefulness for researchers wishing to assess social reward processing experimentally. Third, both the MSIDT and SRS-IDT assess social reward anticipation by measuring RT and response accuracy towards a cued target. However, it could also be useful to employ behavioural measures of reward consumption within the paradigms, so that they not only assess reward anticipation but also how much participants enjoyed receiving the reward.

It may also be important for future research to adapt the avatar-based reward videos used here. As described in Chapter 2, stimuli denoting Prosocial Interactions and Sexual Relationships were not used in this thesis. However, the self-report associations between these social reward subtypes and psychopathology observed across chapters (see Chapters 4 and 6) suggest that future evolutions of these tasks should include these subtypes. Within this, it will be important to follow the stimuli development and rating process detailed in Chapter 2 section 2.5., page 41, to ensure that the stimuli are conceptually and ethically

valid. Furthermore, the stimuli could be developed to include the Matyjek et al. (2020) social reward elements described earlier, for example using avatars to represent family members versus strangers (to assess familiarity effects). Finally, the avatar-based stimuli are potentially suitable for integration within larger virtual environments, for example virtual reality paradigms. Embedding the stimuli within virtual environments could allow researchers to observe 'real-life' social reward preference, anticipation, and consumption behaviours, as opposed to assessing anticipation experimentally through incentive delay paradigms, for example. Overall, the stimuli provide a good starting-point for upcoming social reward research, and it is hoped that, with time, the stimuli might be developed into interactive, fully validated, representations of the Foulkes, Viding et al. (2014) social reward subtypes.

8.4. Conclusion

This chapter has raised several considerations for future work investigating social reward processing in psychopathology. It first highlighted the potential integration of transdiagnostic approaches within social reward research and the implications and practicalities of doing so were discussed. As well as including a transdiagnostic focus, future research should investigate whether the subjective and behavioural findings presented throughout this thesis translate neurobiologically. Furthermore, accounting for participant age (particularly the emergence of psychopathology in adolescence) is likely to be important within these future investigations. A series of clinical implications have been explored, including how adjustments in social reward processing could be integrated in (and perhaps addressed by) psychological interventions. This suggestion of potential clinical implications also stimulated a brief, but important, discussion regarding creating more inclusive conceptualisations of reward-related interpersonal behaviour.

This thesis aimed to clarify links between psychopathology and social reward processing. The pursuit and enjoyment of social rewards has a substantial impact on social motivation and engagement, and so this thesis sought to understand whether atypical interpersonal behaviour may be motivated by adjustments in social reward processing. It has included a range of methods and approaches, spanning clinical and normative populations, and has followed a line of enquiry from identifying social reward processing differences in clinical groups (Chapter 3), to exploring these dimensionally in normative (Chapters 4 and 5) and clinical (Chapter 6) samples, and finally investigating whether oxytocin administration can address atypical social reward processing in dimensional psychopathology (Chapter 7). Larger samples are, of course, needed to substantiate the findings presented but, overall, this thesis has found support for the following:

- Social reward processing is affected (with behavioural and neurobiological hypoanticipation or hyperanticipation) in clinical groups with mental health diagnoses.
- Dimensional psychopathology is associated with atypical social reward processing, with social reward processing indexed both subjectively and behaviourally.
- The type of social reward available is important – reduced processing of Sociability and Prosocial Interactions, and increased processing of Negative Social Potency, observed most frequently across psychopathologies.
- Oxytocin administration may be associated with an inverse effect in dimensional BPD.
- Social reward processing may be affected across traditional psychiatric categories, and thus dimensional approaches could be useful in identifying which shared features of psychopathology are associated with atypical social reward processing.

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10. Appendices

Appendix 1: Chapter 3 Systematic Review Search Strategy

Search Terms

(((“social reward” OR “social incentive delay task” OR “social reward anticipation”)) AND (schiz* OR psychosis OR psychotic OR bipolar OR depression OR depress* OR anxi* OR “mood disorder” OR anorexia OR “eating disorder” OR “feeding disorder” OR autis* OR asd OR “post-traumatic stress disorder” OR PTSD OR “attention-deficit hyperactivity disorder” OR ADHD OR “neurodevelopmental disorder” OR substance OR addict* OR “neurocognitive disorder” OR dementia OR psychopath* OR antisoci* OR criminal OR forensic OR “conduct disorder” OR “personality disorder” OR personality OR paraphil* OR obsessive OR compulsive OR “dissociative disorder” OR “somatic symptom*” OR encopresis OR “sleep” OR “gender dysphoria” OR “sexual”)) AND (adult* OR child* OR adolesc*)

DSM-5 chapters:

- Neurodevelopmental Disorders
- Schizophrenia Spectrum and Other Psychotic Disorders
- Bipolar and Related Disorders
- Depressive Disorders
- Anxiety Disorders
- Obsessive-Compulsive and Related Disorders
- Trauma- and Stressor-Related Disorders
- Dissociative Disorders
- Somatic Symptom Disorders
- Feeding and Eating Disorders
- Elimination Disorders
- Sleep-Wake Disorders
- Sexual Dysfunctions

- Gender Dysphoria
- Disruptive, Impulse Control and Conduct Disorders
- Substance Use and Addictive Disorders
- Neurocognitive Disorders
- Personality Disorders
- Paraphilic Disorders
- Other Disorders

Appendix 2: Chapter 3 Inter-Rater Coding Table for Systematic Review

	Author(s)	Country of Origin	N	Psychopathology of Interest	Design (Between-Groups or Dimensional)	Social Reward Anticipation Measure	RT Data Reported (Y or N)	Response Accuracy Data Reported (Y or N)	Neuroimaging Data Recorded (Y or N)	Number of disagreements between coders	Inter-coder reliability index (%)
C 1											
C 2											
C 1											
C 2											
C 1											
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C 1											
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Add rows											

Appendix 3: Chapter 3 Extracted Data from Reviewed Studies

Data extracted from reviewed studies (n = 42)

	Diagnosis[1]	Sample	Task	Design	Clinical Measure[1]	N[1,2]	Mean age	Key Findings[1,2,3]
Barman et al. (2015)	ASD	Normative Population	Monetary and Social Incentive Delay Task(s)	Dimensional	AQ	63	male = 25.6(2.90); female =23.5 (2.19)	1. Significantly faster anticipation of non-social rewards in comparison to social rewards. 2. Including AQ and Gender as covariates had no significant effect on RTs or hit rates. 3. Social rewards elicited less striatal activation than non-social rewards. 4. Social rewards elicited greater activation within the default mode network structures than non-social rewards. 5. AQ scores were not significantly different between males and females.
Cox et al. (2015)	ASD	Normative Population	Incentive Delay Task with Social Rewards and Candy as non-social reward	Between Groups	SRS-Adult	Low SRS-= 18; High SRS= 17	24	1. RTs were significantly faster for non-social rewards in comparison to non-rewards. No other significant differences in task performance were found between incentive types. 2. There were no significant main or interaction effects of group or reward on behavioural measures of reward anticipation. 3. Individuals with higher ASD traits demonstrated significantly lower P3 amplitude during social reward anticipation than low SRS group. No difference in P3 amplitude was found for non-social rewards. 4. Significant negative correlation between ASD traits and peak P3 amplitude during social reward anticipation. This correlation was not found for non-social rewards.
Cremers et al. (2015)	SAD	Clinical Population	Social Incentive Delay Task	Between Groups	MINI-5; LSAS	CG = 20; HC = 20	CG = 29.1 (7.5); HC = 27.7 (7.7)	1. Significant effect of condition, with faster reaction times towards social rewards than control stimuli. 2. Both CG and HC demonstrated increased putamen and thalamus activation during reward anticipation in comparison to baseline. 3. No significant correlations between reaction time, symptomatology, and neural activity were found in CG.

Delmonte et al. (2012)	ASD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	ADOS; ADI-R; SRS; SCQ	CG = 21; TD = 21;	CG = 17.64 (3.45); TD = 17.00 (3.37)	1. No significant differences in behavioural measures of social reward anticipation between CG and TD. 2. No significant difference between groups in anticipatory RTs or response accuracy towards non-social rewards. 3. Significant main behavioural effect of reward magnitude, with faster RTs and greater response accuracy for larger rewards, independent of reward type. 4. No significant differences between groups in neural activation during social and non-social reward anticipation.
Demurie et al. (2011)	ASD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	ADI-R; ADOS-G; CARS	CG = 31; TD = 40	CG = 11.35 (1.79); TD = 12.13 (2.35);	1. RTs towards social rewards were significantly slower than towards non-social rewards. 2. CG responded significantly faster to non-social rewards than social rewards, but this effect was not present in the TD group. 3. CG were significantly less accurate than TD and obtained significantly fewer social rewards as a result. 4. Medication use had no significant effect on task performance.
Demurie et al. (2011)	ADHD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	DSM-IV; DBDRS	CG = 35; TD = 40	CG = 12.47 (2.13); TD = 12.13 (2.35);	1. CG had significantly slower RTs than TD. 2. Non-social rewards associated with faster RTs than social rewards across groups. 3. CG showed faster RTs for non-social than social rewards, but TD did not. 4. Inattentive subtype of CG responded faster to all rewards than the combined subtype. 5. Medication had no significant effect on task performance
Demurie et al. (2016)	ASD	Clinical Population	Monetary and Social Incentivised Go/No-Go task	Between Groups	ADOS-G; ADI-R; CARS	CG = 36; TD =41	(age in months) CG = 136.42 (26.31); TD = 137.39 (22.23)	1. Overall effect of reward type, with faster RTs during the anticipation of non-social rewards. 2. No significant difference between CG and TD in anticipatory RTs or response accuracy towards social or non-social rewards.
Demurie et al. (2016)	ADHD	Clinical Population	Monetary and Social Incentivised Go/No-Go task	Between Groups	DSM-IV DBDRS	CG = 34; TD = 41	(age in months) CG = 137.41 (22.14); TD = 137.39 (22.23)	1. No significant differences between CG and TD in behavioural anticipation of social and non-social rewards. RTs were faster towards non-social rewards across groups.

Dichter et al. (2012)	ASD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	ADOS-G; AQ; RBS-R; SRS-SR	CG = 16; TD = 20	CG = 26.0 (9.1); TD = 25.4 (7.0)	1. RTs were faster for non-social rewards than social rewards. 2. No significant effect of group on RTs. 3. CG demonstrated hypoactivation of the right nucleus accumbens during non-social reward anticipation in comparison to TD. 4. CG demonstrated reduced activity in right OFC and anterior cingulate cortex during non-social reward anticipation in comparison to TD. 5. However, there were no clusters with relatively reduced activation during social reward anticipation in CG in comparison to TD. 5. Relatively greater response in right nucleus accumbens during non-social anticipation (vs social) in TD group but not CG.
Doell et al. (2020)	BPD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	DSM-V; SCID-II	CG = 21; HC = 24	CG = 27.43 (5.22); HC = 24.71 (5.50)	1. No significant differences between CG and HC on anticipatory RTs towards social or non-social rewards. 2. Compared to HC, CG showed increased STS activation during social versus non-social reward anticipation. 3. Raw beta estimates extracted from STS peaks found evidence for greater anticipatory activation towards social rewards in CG in comparison to HC.
Dutra et al. (2015)	Bipolar Disorder	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	DSM-IV; YMRS; IDS-C	CG =24; HC = 25	CG = 31.38 (11.86); HC = 29.44 (8.84)	1. Elevated reward sensitivity across non-social and social rewards in bipolar disorder, reflected in hyper-striatal activity during reward anticipation and outcome. 2. HC demonstrated more OFC activation during reward anticipation than CG. 3. Comparisons were consistent when accounting for antipsychotic medication use.
Dutra et al. (2017)	Bipolar Disorder	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups & Within Groups	DSM-IV; YMRS; IDS-C	CG =24; HC = 25	CG = 31.38 (11.86); HC = 29.44 (8.84)	1. No neuroimaging findings were reported for reward anticipation phase of task. 2. Increased functional connectivity between ventral striatum and OFC during reward receipt in CG in comparison to HC.
Foulkes et al. (2014) (Study 1)	Psychopathy	Normative Population	Social Reward Questionnaire	Correlation	SPR-SF	505	34.0 (12.2)	1. Positive correlation between all facets of psychopathy, psychopathy total score, and anticipation of opportunities for negative social potency. 2. All aspects of psychopathy were negative correlated with anticipation of prosocial interactions. 3. Lifestyle facet positively associated with sociability. 4 Interpersonal facet score positively associated with anticipation of social

								rewards involving admiration. 5. All scores apart from antisocial facet scores were positively correlated with enjoyment of sexual relations score.
Foulkes et al. (2014) (Study 2)	Psychopathy	Normative Population	Monetary and Social Incentive Delay Task(s)	Dimensional	SRP-SF	110	22.45 (4.07)	1. No significant associations between psychopathy score and task performance for either social or non-social rewards. 2. As interpersonal dimension scores increased, anticipatory RTs towards social rewards became faster relative to the non-social rewards.
Foulkes et al. (2014) (Study 2)	Psychopathy	Normative Population	Social Reward Questionnaire	Correlation	SPR-SF	110	22.45 (4.07)	1. Positive correlation between all facets of psychopathy, psychopathy total score, and negative social potency score. 2. Affective and antisocial facet scores negatively associated with anticipation of opportunities for prosocial behaviour. 3. Interpersonal, affective, and lifestyle facets were all positively associated with self-reported enjoyment of sexual relations. 4. Interpersonal facet scores positively associated with admiration and passivity scores.
Foulkes et al. (2015)	ASD	Normative Population	Social Reward Questionnaire	Correlation	AQ	472	35.4	1. AQ scores significantly predicted self-reported reduced anticipation of multiple social reward types (admiration, prosocial interactions, sexual relationships, sociability). 2. Alexithymia did not account for these associations when controlled for. 3. AQ scores positively predicted self-reported increased anticipation of negative social potency and passivity.
Foulkes et al. (2015)	Alexithymia	Normative Population	Social Reward Questionnaire	Correlation	TAS-20	472	35.4	1. Alexithymia scores significantly predicted reduced self-reported anticipation of multiple social rewards (admiration, prosocial interactions, sociability). 2. Alexithymia scores significantly predicted increased enjoyment of social rewards that include negative social potency.

Foulkes et al. (2017)	Conduct Disorder	Normative Population	Social Reward Questionnaire - Adolescent Version	Correlation	CUSAP-SD	568	12.89 (1.18)	1. CU traits positively correlated with negative social potency scores and negatively associated with prosocial interactions. 2. CU traits negatively associated with self- reported enjoyment of admiration and passivity.
Fussner et al. (2018)	Eating Disorder	Normative Population	SPSRQ	Correlation	EDE-Q; EDI-2;	110	18.66 (0.89)	1. Restrictive ED symptoms positively correlated with self- reported anticipation of social rewards. 2. Binge/purge symptoms positively correlated with self-reported anticipation of social rewards
Goerlich et al. (2017)	Alexithymia	Normative Population	Monetary and Social Incentive Delay Task(s)	Dimensional	TAS-20; EQ; TCI	45	24.1 (3.2)	1. RTs significantly faster for non-social than social rewards. 2. Negative correlation between alexithymia scores and performance on control trials in social reward condition. 3. No other significant relationships between anticipatory RTs and alexithymia. 4. Difficulty identifying feelings facet of alexithymia scale linked to more activation in the perigenual anterior cingulate cortex, subgenual anterior cingulate cortex, and vmPFC. 5. Alexithymia scores negatively correlated with activity in ventral tegmental area during non-social reward anticipation. 5. No significant links between EQ scores and neural activation during anticipation of either reward type.
Gola et al (2017)	Paraphilia and Sex Addiction	Clinical Population	Monetary and Erotic Image Incentive Delay Task	Between Groups	SAST-R	CG = 28; HC = 24	CG = 30.96 (6.51); HC = 30.49 (7.55)	1. Group x reward type interaction, whereby CG demonstrated fastest RTs when anticipating erotic rewards. 2. No significant main effects of group or reward type. 3. Main effect of magnitude, with more substantial rewards eliciting faster anticipatory RTs. 4. CG demonstrated significantly greater ventral striatum activity than HC during erotic (social) reward anticipation. 5. The responsiveness of the ventral striatum in CG group was modulated by the magnitude of the reward being anticipated. 6. No difference between groups in ventral striatum activity during non-social reward anticipation. 7. Ventral striatum activity was significantly correlated with SAST-R scores (measure of compulsive sexual behaviour).

Han et al. (2019)	ASD	Clinical Population	ACIPS; TEPS	Between Groups	ADOS-2; SCID-5; MINI 5; SRS	CG = 49; TD = 28	CG = 23.98 (26.23); TD = 25.32 (5.28)	1. CG self-reported significantly lower levels of social and non-social anticipatory pleasure than TD. 2. SRS-2 total scores significantly predicted lower scores on the ACIPS and TEPS.
Han et al. (2019)	MDD	Clinical Population	ACIPS; TEPS	Between Groups	ADOS-2; SCID-5; MINI 5; SRS;	CG = 30; HC = 28	CG = 26.23 (4.67); HC = 25.32 (5.28)	1. CG self- reported experiencing significantly lower anticipatory pleasure from rewards of both types than HC. 2. CG did not significantly differ from the ASD group (above) in terms of their self-reported experience of pleasure during reward anticipation.
Hanewald et al. (2017)	SSC	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	PANSS	CG=54; HC=54	CG=35.6 (9.8); HC=35.4 (11.3)	1. Faster overall RTs to social stimuli than non-social stimuli during the incentive delay task. 2. Slower RTs for CG than HC, irrespective of reward type. 3. Negative correlations between anticipatory RTs towards both reward types and the negative subscale of PANSS. 4. No significant difference between the response accuracies of HC and CG. 5. No significant interaction between group and reward type for response accuracy.
He et al. (2019)	MDD	Normative Population	Monetary and Social Incentive Delay Task(s)	Between Groups	SDS	CG = 21; HC = 20	CG = 19.76 (1.92); HC = 19.45 (1.57)	1. Main effect of reward valence with faster RTs for reward conditions in comparison to control conditions. 2. Both social and non-social reward anticipation was associated with significant neural reward-circuitry responses across both groups.3. CG group demonstrated significantly more subgenual anterior cingulate cortex activation during social reward anticipation than HC.
Kohls et al. (2009)	ADHD	Clinical Population	Incentivised Go/No-Go Task	Between Groups	K-DIPS; CBCL; FBB-HKS	CG = 16; TD = 16	CG = 10.7 (1.6); TD = 10.2 (1.3)	1. CG demonstrated significantly more accuracy for social rewards than non-social rewards. 2. CG responded significantly slower for non-social rewards than TD. 3. No significant difference in task performance between ADHD subtypes.

Kohls et al. (2011)	ASD	Clinical Population	Monetary and Social Incentivised Go/No-Go task	Between Groups	ADOS-G; ADI-R; SCQ; SRS	CG = 16; TD = 20	CG = 14.9 (2.8); TD = 14.2 (2.8)	1. Main effect of reward, with fastest times in the non-social reward condition. 2. No significant main or interaction effects of group in relation to behavioural anticipation. 3. CG were less accurate overall. 4. TD demonstrated larger P3 responses during non-social reward anticipation, whereas P3 response in CG was significantly reduced for social rewards relative to non-social rewards. 5. Negative correlations between the ADOS-G Reciprocal Social Interactions subscale and P3 differential for both non-social and social reward types.
Kohls et al. (2013)	ASD	Clinical Population	Monetary and Social Incentivised Go/No-Go task	Between Groups	ADOS-G; ADI-R; SCQ; SRS	CG= 15; TD = 17	CG = 14.6 (3.3); TD = 13.9 (3.0)	1. No significant group effect was found for anticipatory RTs or response accuracy towards non-social and social rewards between CG and TD. 2. Across both groups, reward circuitry activation was stronger for non-social rewards than it was for social rewards. 3. CG demonstrated less amygdala and ventral anterior cingulate cortex activity when anticipating social rewards in comparison to TD. 4. No significant associations between dimensional ASD traits and brain activity during reward anticipation were found.
Kohls et al. (2014)	ADHD	Clinical Population	Monetary and Social Incentivised Go/No-Go task	Between Groups	K-SADS-P; CBCL	CG= 16; HC = 17	CG = 14.5 (2.6); HC = 13.9 (3.0)	1. No significant differences were found in behavioural task performance between CG and TD. 2. CG responded equally strongly in the ventral striatum to both reward types, but TD responded more to non-social rewards. 3. Relative to TD, CG showed more medial PFC activation during social reward outcome.
Li et al. (2016)*	SSC	Normative Population	Affective Incentive Delay Task	Between Groups	CSAS	HSA=16; LSA =80; HC =17	HSA=21.88(2.26); LSA=n/a; HC = 19.82 (1.59)	1. Significant main effect of condition, with faster RTs in the reward and punishment conditions in comparison to the neutral conditions. 2. The high social anhedonia groups (HSA) demonstrated significantly slower anticipatory RTs than the low social anhedonia (LSA) group towards social rewards. 3. There was no significant difference in response accuracy between the groups.

Nawijn et al. (2017)	PTSD	Clinical Population	Social Incentive Delay Task	Between Groups	CAPS; SCID-5	CG = 35; HC =37	CG = [M = 42.29 (9.83), F = 38.21 (9.85)]; HC = [M = 41.11 (10.86), F = 38.06 (9.08)]	1. No significant main or interaction effects of clinical group (CG versus HC) or gender (M versus F) on behavioural or neural measures of social reward anticipation. 2. CG showed significantly less anterior insula activity during reward outcome. 3. CAPS symptoms negatively correlated with putamen responses during reward outcome phase.
Oumezian e et al. (2019)	MDD	Normative Population	Monetary and Social Incentive Delay Task(s)	Dimensional	CES-D	102	19 (1.15)	1. Participants responded significantly faster towards non-social rewards than social rewards. 2. Participants were significantly quicker on social reward trials in comparison to neutral trials. 3. Both social and non-social rewards elicited morphologically similar ERPs during reward anticipation. 4. Depression symptomatology was associated with reduced stimulus-preceding negativity responses for both social and non-social rewards.
Pankert et al. (2014)	ASD	Clinical Population	Visual and Auditory Incentivised Go/No-Go task	Between Groups	SCQ; SRS; MBAS	CG = 17; TD = 17	CG = 11.6 (1.2); TD = 11.7 (1.2)	1. No significant main or interaction effects found when testing anticipatory RTs in CG relative to HC in the visual modality of non-social and social rewards. 2. Main effect of reward was found in the auditory condition, with faster RTs when unfamiliar social reward was used in comparison to familiar social reward.
Perry et al. (2015)	bvftD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	MMSE; CDR	CG = 14; HC = 41	CG= 58.4 (8.84); HC = 70.5 (5.14)	1. Significant main effect of reward type, with faster RTs for non-social rewards. 2. CG anticipated social loss more than social win trials. 3. Although CG had slower response times overall, they responded much more quickly when a non-social reward was available rather than any other type. 4. RT difference between social and non-social rewards was much more marked for CG than HC.

Richey et al. (2014)	ASD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	ADOS-G	CG = 16; TD = 19	CG = 26.0 (9.1); TD = 26.9 (5.3)	1. Slower anticipatory RTs towards social rewards than non-social rewards across groups. 2. No significant differences between CG and HC on anticipatory RTs towards non-social and social rewards. 3. Less nucleus accumbens activation during anticipation of social rewards in CG in comparison to HC. 4. No significant difference between nucleus accumbens activation during social and non-social reward anticipation in CG or HC.
Richey et al. (2014)	SAD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	DSM-IV; LSAS; STAI-T	CG = 15; HC = 19	CG = 26.9 (5.3); HC = 25.3 (7.0)	1. No significant difference between groups on RTs during social reward anticipation. 2. CG group demonstrated less nucleus accumbens activity during social reward anticipation than HCs. 3. No significant difference in behavioural or neural responses during social versus non-social reward anticipation in either group. 4. Correlation between STAI-T scores and bilateral amygdala cluster during social reward anticipation
Richey et al. (2017)	SAD	Clinical Population	Monetary and Social Incentive Delay Task(s)	Between Groups	DSM-IV; LSAS; BDI	CD = 21; HC = 22	CD = 25.67 (7.61); HC = 26.50 (7.98)	1. Significantly slower RTs in non-social reward anticipation in CG in comparison to HC, but no significant differences between groups in behavioural anticipation of social rewards. 2. CG demonstrated significantly less nucleus accumbens activity than HC during social reward anticipation, and this was only observed for social rewards and not for non-social rewards. 3. More severe symptomatology associated with lower levels of right nucleus accumbens activity during anticipation of social rewards.
Ruta et al. (2017)	ASD	Clinical Population	Reward Preference Task	Between Groups	-	CG = 21; TD = 37	(age in months) CG = 39.9 (11.5); TD = 45.5 (10.7)	1. CG demonstrated significantly lower proportion of button presses towards social rewards in comparison to HC. 2. CG (who demonstrated a lower preference for social rewards) showed less real-life eye contact and were less animated when viewing the social stimuli.

Scott-Van Zeeland et al. (2010)	ASD	Clinical Population	Monetary and Social Reward Learning Task	Between Groups	ADOS-G; ADI-R	CG = 16; TD = 16	CG= 12.4 (2.14); TD = 12.3 (1.76)	1. The performance of TD significantly improved as the task went on, but CG never performed above chance level. 2. Anticipatory RTs or accuracy were not significantly different between groups for either reward type. 3. Social rewards elicited significantly less ventral striatum activity in CG in comparison to TD. 4. No significant correlations between SRS scores and VS activity during social or non-social reward anticipation.
Sescousse et al. (2013)	Pathological Gambling	Clinical Population	Monetary and Erotic Image Incentive Delay Task	Between Groups	SOGS-Q	CG = 18; HC = 20	CG = 34.1 (11.6); HC = 31 (7.3)	1. Significant group x reward interaction, with CG showing slower RTs during anticipation of social than non-social rewards. 2. Increased reward magnitude was significantly associated with faster anticipatory RTs across both groups. 3. No significant main or interaction effects for accuracy. 4. CG showed less bilateral ventral striatum activity during the anticipation of social rewards than non-social - although this was due to decreased response to social cues rather than increased response to non-social cues. 5. Positive correlation between striatal region activity and SOGS-Q score in CG.
Stavropoulos et al. (2018)	ASD	Clinical Population	Card Guessing Game	Between Groups	ADOS-2; SRS	CG = 20; TD = 23	Age range of 6-8	1. Used event-related spectral perturbations to investigate reward anticipation. 2. More severe ASD symptomatology was associated with less left-dominant alpha band suppression during social reward anticipation. 3. Individuals within CG that demonstrated greater left-hemisphere alpha suppression during social reward anticipation showed less alpha suppression when receiving reward outcome.
Xie et al. (2014)	SSC	Normative Population	Monetary and Social Incentive Delay Task(s)	Between Groups	CSAS; SPQ	HSA = 28; HC = 38	HSA = 20.89 (2.21); HC=20.58 (1.95)	1. Overall RTs were slower for social rewards than non-social rewards.2. The HSA group demonstrated significantly slower anticipatory RTs towards social rewards than HC. 3. Significant positive correlations between CSAS and SPQ scores, and anticipatory RTs towards social rewards. 4. Response accuracy was not significantly different between groups or for reward types.

[1]ACIPS = Anticipatory and Consummatory interpersonal Pleasure Scale (Gooding & Pflum, 2011); ADHD = Attention-Deficit/Hyperactivity Disorder; ADI-R = Autism Diagnostic Interview – Revised (Lord et al., 1994); ADOS-G/2 = Autism Diagnostic Observation Schedule (Lord et al., 2000); AQ = Autism Quotient (Baron-Cohen et al., 2001); ASD = Autism Spectrum Disorder; BDI = Beck Depression Inventory (Beck, Steer & Brown, 1996); bvftD = Behavioural Variant Frontotemporal Dementia; CAPS = Clinician-Administered PTSD Scale for DSM-5; CARS = Childhood Autism Rating Scale (Schopler, Reichler, DeVellis & Daly, 1980); CBCL = Child Behaviour Checklist (Achenbach, 1992); CDR = Clinical Dementia Rating scale (Hughes, Berg, Danziger, Coben & Martin, 1982); CSAS = Chapman Social Anhedonia Scale; CUSAP-SD = Callous-Unemotional Scale of Antisocial Process Screening Device (Frick & Hare, 2001); DBDRS = Disruptive Behaviour Disorder Rating Scale (Silva et al., 2005); EDE-Q = Eating Disorder Examination Questionnaire (4.0) (Mond et al., 2004) ; EDI-2 = Eating Disorder Inventory (Garner, Olmstead & Polivy, 1983); EQ = Empathy Quotient Baron-Cohen & Wheelwright, 2004); FBB-HKS = German Parental Report on ADHD symptoms (Döpfner, M., & Lehmkuhl, 1998) ; IDS-C = Inventory Depressive Symptoms – Clinician rated (Rush et al., 1996); K-DIPS = German semi-structured diagnostic interview (Unnewehr Schneider & Margraf, 1995); K-SADS = Kiddie Schedule for Affective Disorders and Schizophrenia (Puig-Antich & Ryan, 1986); LSAS = Liebowitz Social Anxiety Scale (Liebowitz, 1987); MBAS = Marburg Rating Scale for Asperger's Syndrome (Kamp-Becker et al., 2005); MINI 5 = Mini International Neuropsychiatric Interview (Sheehan et al., 1998); MMSE = Mini Mental State Examination (Folstein, Robins & Helzer, 1983); PANSS = Positive and Negative Symptoms Scale (Kay et al., 1989); PTSD = Post-Traumatic Stress Disorder; RBS-R = Repetitive Behaviours Scale – Revised (Bodfish et al., 1999); SAD = Social Anxiety Disorder; SAST-R = Sexual Addiction Screening Test – Revised (Carnes et al., 2010); SCID-5 = Structured Clinical Interview for DSM-5; SCQ = Social Communication Questionnaire (Rutter et al., 2003); SPQ = Schizotypal Personality Questionnaire (Raine, 1991); SPSRQ = Sensitivity to Punishment and Sensitivity to Reward Questionnaire (Torrubia et al., 2001); SDS = Self-rating Depression Scale (Zung et al., 1965); SRP-SF = Self-Report Psychopathy Scale – Short Form (Paulhus et al., 2016; SRS = Social Responsiveness Scale (Constantino, 2013); TEPS = Temporal Experience of Pleasure Scale (Gard et al., 2006); SOGS-Q = South Oaks Gambling Screen Questionnaire (Lesieur & Blume, 1987); STAI-T = State Trait Anxiety Inventory (Speilberger, 1983); TAS-20 = Toronto Alexithymia Scale (Bagby et al., 1994); TCI = Temperament and Character Inventory (Cloninger, 1994); YMRS -= Young Mania Rating Scale (Young et al., 1978)

[2]CG = Clinical Group; HC = Healthy Controls; HSA = High Social Anhedonia; LSA = Low Social Anhedonia; TD = Typically Developing

[3] RTs = Reaction Times; OFC = Orbitofrontal Cortex; PFC = Prefrontal Cortex; STS = Superior Temporal Sulcus; vmPFC = Ventromedial Prefrontal Cortex

*Li et al. (2016) were testing the effectiveness of a working memory intervention using an incentive delay task with social stimuli. They included comparisons between the high social anhedonia group and a low social anhedonia group (the control group included high social anhedonia individuals that did not receive the intervention).

Appendix 4: Chapter 3 Medication Use in Reviewed Studies

Psychotropic medication use in reviewed studies (n=42)

		Sample	Medication use information available for review	Management strategy	Characterisation of medication use in sample	Medication use accounted for within analyses
Barman et al. (2015)	ASD	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Cox et al. (2015)	ASD	Normative Population	Yes	Medication use included in exclusion criteria and thus all participants were medication-free	N/A	N/A
Cremers et al. (2015)	SAD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	2 participants with SAD were using SSRIs at time of testing All control participants had no history of psychotropic medication use	Analysis included medication use as covariate and medication use was found to have no significant effect on performance
Delmonte et al. (2012)	ASD	Clinical Population	Yes	Medication use included in exclusion criteria and thus all participants were medication-free	N/A	N/A
Demurie et al. (2011)	ASD	Clinical Population	Yes	Participants using stimulant medication were asked to discontinue use for at least 24 hours prior to testing	4 participants with ASD were medicated with methylphenidate (1 using long-acting type) Control participants were medication-free at time of testing	Analysis examined effect of medication use on task performance
Demurie et al. (2011)	ADHD	Clinical Population	Yes	Participants using stimulant medication were asked to	28 participants with ADHD had history of using methylphenidate (of which 7 were the long-acting type)	Supplementary analysis examined effect of medication use on task performance,

				discontinue use for at least 24 hours prior to testing	Control participants were medication-free at time of testing	despite participants discontinuing medication use, and medication did not have a significant effect on behavioural anticipation
Demurie et al. (2016)	ASD	Clinical Population	Yes	Participants were asked to discontinue stimulant medication use at least 24 hours prior to testing. This was verified before any testing took place	4 participants with ASD were routinely using methylphenidate prior to testing Control participants were medication-free at time of testing	Influence of medication use on task performance not analysed
Demurie et al. (2016)	ADHD	Clinical Population	Yes	Participants were asked to discontinue stimulant medication use at least 24 hours prior to testing. This was verified before any testing took place	22 participants with ADHD were routinely using methylphenidate prior to testing Control participants were medication-free at time of testing	Influence of medication use on task performance not analysed
Dichter et al. (2012)	ASD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	7 participants with ASD were not using psychotropic medication at the time of testing Of the remaining 9 participants with ASD, 4 were taking Abilify; 1 was taking Adderall; 1 was taking Celexa; 1 was taking Prozac; 1 was taking Risperdal; 1 was taking both Adderall and Prozac Control participants were not taking psychotropic medications at the time of testing	Influence of medication use on task performance not analysed
Doell et al. (2020)	BPD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	13 participants with BPD were using antidepressants at the time of testing (11=SSR1, 2=SSNRI) 5 participants were using antipsychotic medication 3 participants were using benzodiazepines 3 participants were using methylphenidates	Researchers indexed 'medication load' per participant which was then accounted for when analysing neural responses during reward anticipation. Medication use did not have a significant effect on reward anticipation

					Control participants were medication-free at time of testing	
Dutra et al. (2015)	Bipolar Disorder	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	Medication use in the sample of bipolar disorder individuals included antidepressants, lithium, benzodiazepines, and atypical neuroleptics Control participants were medication-free at time of testing	Results remained when antipsychotic medication use was included as covariate within analyses
Dutra et al. (2017)	Bipolar Disorder	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	Medication use in the sample of bipolar disorder individuals included antidepressants, lithium, benzodiazepines, and atypical neuroleptics Control participants were medication-free at time of testing	Results remained when antipsychotic medication use was included as covariate within analyses
Foulkes et al. (2014) (Study 1)	Psychopathy	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Foulkes et al. (2014) (Study 2)	Psychopathy	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria	N/A	N/A	N/A

			within the manuscript			
Foulkes et al. (2014) (Study 2)	Psychopathy	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Foulkes et al. (2015)	ASD	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Foulkes et al. (2015)	Alexithymia	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Foulkes et al. (2017)	Conduct Disorder	Normative Population	Study conducted within normative	N/A	N/A	N/A

			sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript			
Fussner et al. (2018)	Eating Disorder	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Goerlich et al. (2017)	Alexithymia	Normative Population	Yes	No participants were taking psychotropic medication at the time of testing	N/A	N/A
Gola et al (2017)	Paraphilia and Sex Addiction	Clinical Population	Yes	All participants in the clinical and control groups were medication-free at the time of testing	N/A	N/A
Han et al. (2019)	ASD	Clinical Population	No information on medication use in sample provided	N/A	N/A	N/A
Han et al. (2019)	MDD	Clinical Population	No information on medication use in sample provided	N/A	N/A	N/A
Hanewald et al. (2017)	SSC	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	25 participants with schizophrenia were using 1 atypical antipsychotics at the time of testing; 13 were using 2 atypical antipsychotics; 9 were using 1 typical antipsychotic and 1 atypical antipsychotic; 6 were using one	The authors descriptively acknowledge that atypical antipsychotic use may rebalance reward anticipation deficits, but this was not

					typical and two atypical antipsychotics. 1 participant with schizophrenia was using no psychotropic medication at the time of testing. All control participants were medication-free at the time of testing	analysed statistically within their manuscript
He et al. (2019)	MDD	Normative Population	Yes	Previous psychotropic medication use included as exclusion criteria	N/A	N/A
Kohls et al. (2009)	ADHD	Clinical Population	Yes	No participants with ADHD used psychotropic medication other than stimulants, which were discontinued at least 48 hours prior to testing All control participants were medication-free at the time of testing	N/A	N/A
Kohls et al. (2011)	ASD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	2 participants with ASD were taking atypical neuroleptic medications at the time of testing All control participants were medication-free at the time of testing	Influence of medication use on task performance not analysed
Kohls et al. (2013)	ASD	Clinical Population	Yes	All participants in the clinical and control groups were medication-free at the time of testing	N/A	N/A
Kohls et al. (2014)	ADHD	Clinical Population	Yes	Participants with ADHD that were using psychostimulant medication discontinued use at least 48 hours prior to testing All control participants were medication-free at the time of testing	N/A	N/A

Li et al. (2016)	SSC	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A
Nawijn et al. (2017)	PTSD	Clinical Population	Yes	Daily use of psychotropic medication was included as exclusion criteria and thus both clinical and control groups were medication-free at time of testing	N/A	N/A
Oumeziane et al. (2019)	MDD	Normative Population	Yes	Psychotropic medication use was included as exclusion criteria and so all participants were medication-free	N/A	N/A
Pankert et al. (2014)	ASD	Clinical Population	Yes	Two participants with ASD were using short-acting methylphenidate but discontinued use 24 hours prior to testing No other participants with ASD were using psychotropic medication All control participants were medication-free at the time of testing	N/A	N/A
Perry et al. (2015)	bvftD	Clinical Population	No information on medication use in sample provided	N/A	N/A	N/A
Richey et al. (2014)	ASD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate	7 participants with ASD were not using psychotropic medication at the time of testing	Influence of medication use on task performance not analysed

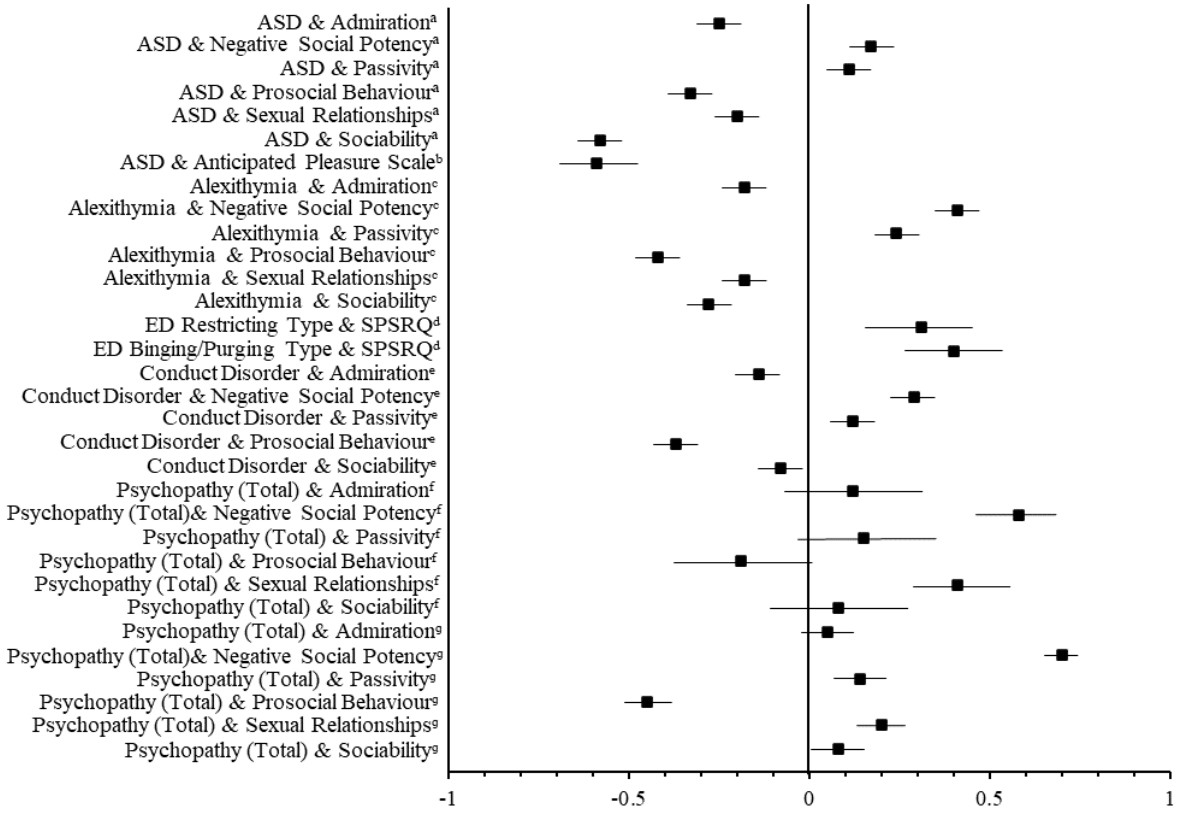
				without discontinuing medication use prior to testing	Of the remaining 9 participants with ASD, 4 were taking Abilify; 1 was taking Adderall; 1 was taking Celexa; 1 was taking Prozac; 1 was taking Risperdal; 1 was taking both Adderall and Prozac Control participants were not taking psychotropic medications at the time of testing	
Richey et al. (2014)	SAD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	13 participants with SAD were not taking psychotropic medication at the time of testing One participant with SAD was taking Prozac and another was taking Celexa Control participants were not taking psychotropic medications at the time of testing	Influence of medication use on task performance not analysed
Richey et al. (2017)	SAD	Clinical Population	Yes	Current psychotropic medication use was included in the exclusion criteria and so all clinical and control participants were medication free at the time of testing	N/A	N/A
Ruta et al. (2017)	ASD	Clinical Population	No information on medication use in sample provided	N/A	N/A	N/A
Scott-Van Zeeland et al. (2010)	ASD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	7 participants with ASD were not taking any psychotropic medication at the time of testing Of the remaining participants with ASD, 2 were taking atypical antipsychotics only; three were taking both antipsychotic and psychostimulant medication; one was taking a SSRI; one was taking an atypical antidepressant; and	Correlations between medication status and neural responses reported descriptively and no significant associations found

					medication status was unknown for one participant All participants in the control group were medication-free at the time of testing	
Sescousse et al. (2013)	Pathological Gambling	Clinical Population	Yes	Participants in clinical and control groups were medication-free at the time of testing	N/A	N/A
Stavropoulos et al. (2018)	ASD	Clinical Population	Yes	Participants using psychotropic medication were eligible to participate without discontinuing medication use prior to testing	2 participants with ASD were taking psychotropic medication at the time of testing No participants in the control group were taking psychotropic medication at the time of testing	Influence of medication use on task performance not analysed
Xie et al. (2014)	SSC	Normative Population	Study conducted within normative sample and thus assumed to be medication-free However, psychotropic medication use is not reported as exclusion criteria within the manuscript	N/A	N/A	N/A

ADHD = Attention-Deficit/Hyperactivity Disorder; ASD = Autism Spectrum Disorder; BPD = Borderline Personality Disorder; bvftD = Behavioural Variant Frontotemporal Dementia; MDD = Major Depressive Disorder; N/A = Not Applicable; PTSD = Post-Traumatic Stress Disorder; SSC = Schizophrenia Spectrum Conditions; SSNRI = Serotonin–Norepinephrine Reuptake Inhibitor; SSRI = Selective Serotonin Reuptake Inhibitor

Appendix 5: Chapter 3 Forest Plot of Correlations

Forest plot of correlation coefficients for measures of social reward anticipation and dimensional psychopathology. More positive scores indicate greater levels of self-reported anticipation of social reward. [a]Data from Foulkes et al. (2015); [b]Data from Han et al. (2019); [c]Data from Foulkes et al. (2015); [d]Data from Fussner et al. (2018); [e]Data from Foulkes et al. (2017); [fg]Data from Foulkes, Viding, et al. (2014).



Appendix 6: Chapter 6 Clinical Group Intra-Correlations

Clinical Group Scores on Psychopathology Measure Intra-Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. SPQ Cognitive-Perceptual	-	.81**	.68*	.49	.12	.47	.03	.35	.37	-.52	.39	.73**	.68**	.38	.07	.65*	.47	.69**	.39
2. SPQ Interpersonal	.81**	-	.77**	.51	-.09	.55	.04	.19	.29	-.59	.52	.83**	.64*	.61*	.01	.77**	.34	.60*	.40
3. SPQ Disorganised	.68*	.77**	-	.11	.05	.61*	.07	.27	.34	-.39	.67*	.70**	.76**	.25	-.07	.63*	.35	.26	.65*
4. PHQ-9_{rs}	.49	.51	.11	--	-.28	.24	-.24	-.26	-.05	-.33	.15	.41	.25	.34	.66*	.20	.03	.76**	-.27
5. PCL-R Interpersonal	.12	-.09	.05	-.28	-	.17	.29	.43	.58*	.12	-.40	-.31	.07	-.19	.02	-.36	.19	-.11	.23
6. PCL-R Affective	.58*	.55	.61*	.24	.17	-	.37	.47	.66*	-.11	.47	.62*	.48	.15	.09	.44	.57*	.34	.67*
7. PCL-R Lifestyle	.03	.04	.07	-.24	.29	.37	-	.77	.85**	.31	-.25	.18	.04	.22	-.21	-.15	.12	-.25	.73*
8. PCL-R Antisocial	.35	.19	.27	-.26	.43	.47	.77**	-	.88**	.12	-.13	.30	.17	.15	-.21	.07	.39	-.11	.77*
9. PCL-R Total	.37	.29	.34	-.05	.58*	.66*	.85**	.88**	-	.09	-.12	.31	.25	.27	-.11	.04	.32	-.05	.84**
10. BPQ Impulsivity	-.52	-.59	-.39	-.33	.12	-.11	.31	.12	.09	-	-.16	-.23	-.24	.09	.18	-.26	-.20	-.17	.05
11. BPQ Affective Instability	.39	.52	.67*	.15	-.40	.47	-.25	-.13	-.13	-.16	-	.60*	.68**	.16	.31	.75**	.38	.52*	.24
12. BPQ Abandonment	.73**	.83**	.70**	.41	-.31	.62*	.18	.30	.31	-.23	.60*	-	.60*	.52*	.21	.74**	.43	.69**	.54
13. BPQ Relationships	.68*	.64*	.76**	.25	.07	.48	.04	.17	.25	-.24	.68**	.60*	-	.26	.35	.59*	.37	.63*	.34

14. BPQ Self-Image$_{rs}$	.38	.61*	.25	.34	-.19	.15	.22	.15	.27	.09	.16	.52*	.26	-	.07	.56*	-.15	.16	.22
15. BPQ Suicide/Self-Mutilation$_{rs}$	.07	.01	-.07	.66*	.02	.09	-.21	-.21	-.11	.18	.31	.21	.35	.07	-	.06	.31	.59*	-.41
16. BPQ Emptiness	.65*	.77**	.62*	.20	-.36	.44	-.15	.07	.04	-.26	.75**	.74**	.59*	.56*	.06	-	.41	.57*	.30
17. BPQ Intense Anger$_{rs}$	.47	.34	.35	.03	.19	.57*	.12	.39	.32	-.20	.38	.43	.37	-.15	.31	.41	-	.32	.11
18. BPQ Quasi-Psychotic States	.69**	.60*	.26	.76**	-.11	.34	-.25	-.11	-.05	-.17	.52*	.69**	.63*	.16	.59*	.57*	.32	-	-.28
19. AQ Total	.30	.40	.65*	-.27	.23	.67*	.73*	.77*	.84**	.05	.24	.54	.34	.22	-.41	.30	.11	-.28	-

*= significant at p = .05; **= significant at p = .01