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Atypical social reward anticipation as a transdiagnostic characteristic of psychopathology: A meta-analytic review and critical evaluation of current evidence

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Abstract

Several psychopathologies (e.g. schizophrenia spectrum conditions, autism spectrum disorders) are characterised by atypical interpersonal and social behaviour, and there is increasing evidence to suggest this atypical social behaviour is related to adjusted behavioural and neural anticipation of social rewards. This review brings together social reward anticipation research in psychopathology (k=42) and examines the extent to which atypical social reward anticipation is a transdiagnostic characteristic. Meta-analyses of anticipatory reaction times revealed that, in comparison to healthy controls, attention-deficit/hyperactivity disorder, autism spectrum disorder, and schizophrenia spectrum conditions are associated with significantly reduced behavioural anticipation of social rewards. The pooled meta-analysis of anticipatory reaction times found that the full clinical sample demonstrated significant social reward hypoanticipation in comparison to the healthy control group with a medium effect size. A narrative synthesis of meta-analytically ineligible behavioural data, self-report data, and neuroimaging studies complemented the results of the meta-analysis, but also indicated that bipolar disorder, eating disorders, and sexual addiction disorders may be associated with social reward hyperanticipation. The evaluation of existing evidence suggests that future research should better account for factors that affect reward anticipation (e.g. gender, psychotropic medication) and highlights the importance of using stimuli other than happy faces as social rewards.

Key words: social reward; anhedonia; social motivation; interpersonal; monetary reward

Defined as the opportunity to want, detect and pursue rewards (Wilson et al., 2018), reward anticipation is positioned as a key motivational factor within human behaviour (McClure, Laibson, Loewenstein & Cohen, 2004). The behavioural and neural processes involved in reward anticipation are now well-established (e.g. Galván, 2010; Knutson, Westdorp, Kaiser & Hommer, 2000) but this understanding is largely based on work with monetary rewards only. Whilst monetary rewards are a powerful form of reward, with monetary reward defined as the pursuit and obtaining of monetary incentives, the anticipation of other rewards, like social rewards, may also have an important and under-estimated influence on behaviour (Fulford, Campellone & Gard, 2018).

Social reward is defined as the feeling of warmth and pleasure that healthy individuals typically extract from social interaction (Eisenberg, Eggum, & Di Giunta, 2010; Grelotti, Gauthier, & Schultz, 2002; Zahn-Waxler & Smith, 1992). According to Foulkes, Viding, McCrory and Neumann (2014), social reward comprises six subcomponents, including admiration (receiving flattery and positive attention), prosocial behaviour (mutual kind relationships), passivity (letting others have control of a social interaction), sociability (being part of social situations), sexual relationships (frequent sexual experiences), and negative social potency (enjoyment of witnessing or causing cruelty to others). Although qualitatively distinct, 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.

Most work has focused on developing our understanding of social reward anticipation by comparing social reward anticipation mechanisms to the behavioural and neural processes

that are involved in the anticipation of non-social rewards. Reviewing the neural processes involved in monetary reward anticipation, Oldham et al. (2018) concluded that the monetary reward anticipation system encompasses the striatum, insula, amygdala and thalamus. Furthermore, they reported that orbitofrontal and ventromedial prefrontal regions are recruited during reward consumption and evaluation of outcome. It may be that this monetary reward system translates to social rewards also. For example, Spreckelmeyer et al. (2009) used a reward anticipation paradigm to show that monetary rewards elicit greater activation within the left putamen and are associated with faster reaction times (RTs) than social rewards. This finding is mirrored in other research (e.g. Izuma et al., 2008; Lin, Adolphs & Rangel, 2012; Rademacher et al., 2010) which posits that monetary rewards have a more dramatic behavioural and neurobiological impact than social rewards, but that there is some overlap in the brain areas activated during their anticipation (Gu et al., 2019; Sescousse, Redoute & Dreher, 2010). Together, this work highlights the converging neural and behavioural mechanisms that may be involved in the anticipation of non-social and social rewards.

SOCIAL REWARD ANTICIPATION AND PSYCHOPATHOLOGY

There is evidence to suggest that reward anticipation may be interrupted within a range of psychopathologies (e.g. Barkus & Badcock, 2019; Hägele et al., 2015). Indeed, Dichter, Damiano and Allen (2012) showed that atypical reward anticipation is somewhat transdiagnostic, with individuals with schizophrenia (Gard, Kring, Gard, Horan & Green, 2007), or autism spectrum conditions (Kohls et al., 2010), or mood disorders (Olinio et al., 2014) demonstrating reduced anticipation (hypoanticipation) of monetary rewards at behavioural and neural levels. 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, Hyde, Neumann, Viding & Hariri, 2013) – suggesting that hyperanticipation of monetary rewards may be linked to some elements of externalising symptomatology (Kohls, Peltzer, Herpertz-Dahlmann & Konrad, 2009).

This raises questions whether, as with non-social rewards, social reward anticipation is adjusted across psychiatric conditions. Atypical social reward anticipation may account for some of the maladaptive or atypical social behaviours that characterise a range of psychopathologies (Ethridge & Weinberg, 2018). Indeed, changes in social behaviour are described as an important marker of illness onset and progression (Cornblatt et al., 2011) and so understanding how atypical social reward anticipation may influence these changes is important. Indeed, the Responsiveness, Emotional Attention, and Learning (REAL) (Dadds & Frick, 2019) and Sensitivity to Threat and Affiliative Reward (STAR) (Waller & Wagner, 2019) models have recently highlighted how socioemotional learning, including the development of social reward networks and social reward sensitivity, influences current or future psychopathology. For example, adolescence is associated with a heightening and intensifying of social reward sensitivity (Jarcho et al., 2012; Galván., 2013; Silverman, Jedd & Luciana, 2015) and so it is possible that this change in sensitivity to social rewards could, in-part, give rise to the onset of psychiatric symptoms related to psychosocial functioning during adolescence (Costello, Copeland & Angold, 2011).

As highlighted, 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 sensitivity 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.

Objectives

This review has three objectives.

- 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.
- Compare social reward anticipation across clinical groups and clarify whether atypical social reward anticipation is a transdiagnostic marker of psychopathology.
- Consider the implications of atypical social reward anticipation for clinical practice and identify potential directions for future research.

Methods

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 towards 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 supplemental material (Appendix A). 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 our search is given in the search strategy section of the supplemental material (Appendix A).

To be eligible for inclusion in this review, articles had to be focused on social reward anticipation, defined as wanting or seeking opportunities to obtain social rewards. Self-report, computerised, and neuroimaging methods were all eligible for inclusion provided that social reward anticipation was included as a primary outcome measure. The incentive delay task paradigm (Knutson, Westdorp, Kaiser & Hommer, 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 supplemental material (Appendix B).

Other experimental paradigms were eligible for inclusion if they had a defined reward anticipation period. We were mindful of including more complex social reward paradigms, such as trust or decision-making paradigms, if they did not have an anticipation component. 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 types described by Foulkes 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 1.

[Insert Figure 1 about here]

Figure 1. Flowchart of study selection process

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 (The Cochrane Collaboration, 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, we compared clinical and healthy control groups on behavioural anticipatory reaction times towards social rewards. Second, we compared the two groups on anticipatory response accuracy towards social rewards. Included studies were coded and rated by two authors independently (see supplemental material, Appendix C). 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, Smith, Schneider & Minder, 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 .

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 Appendix D of the supplemental material. Full information on psychotropic medication use in the reviewed studies is given in Appendix E of the supplemental material.

The results are presented per diagnostic category. The forest plots of the between-group meta-analyses are presented in Figures 2 and 3. The correlation coefficients for the self-report data are plotted in the supplemental material (Appendix F) 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 $p > .05$).

[Insert Figure 2 about here]

Figure 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.

[Insert Figure 3 about here]

Figure 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.

NEURODEVELOPMENTAL DISORDERS

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, Roeyers, Baeyens & Sonuga-Barke, 2011; Demurie, Roeyers, Wiersema & Sonuga-Barke, 2016; Kohls, Herpertz-Dahlmann, & Konrad, 2009; Kohls et al., 2014) investigating social reward anticipation in ADHD were reviewed. Three of them (Demurie et al., 2011; Kohls et al., 2009; Kohls et al., 2014) 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., 2009; Kohls et al., 2014) prior to participating.

Meta-analysis: 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 $g = 0.56$, $df = 2$, $p = 0.001$, $CI = [0.22, 0.90]$, $I^2 = 0\%$, $p = 0.74$). This reaction time difference was not meaningfully reflected in the response accuracy data, perhaps due to large heterogeneity within the data ($I^2 = 77\%$, $p = 0.01$)

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, Kohls, Troiani, Brodtkin & Schultz, 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., 2015; Cox et al., 2015; Delmonte et al., 2012; Demurie et al., 2011; Demurie et al., 2016; Dichter, Richey, Rittenberg, Sabatino & Bodfish, 2012; Foulkes, Bird, Gökçen, McCrory & Viding, 2015; Han, Tomarken & Gotham, 2019; Kohls et al., 2011; Kohls et al., 2012; Pankert, Pankert, Herpertz-Dahlmann, Konrad & Kohls, 2014; Richey et al., 2014; Ruta et al., 2017; Scott-Van Zeeland, Dapretto, Ghahremani, Poldrack & Bookheimer, 2010; Stavropoulos & Carver, 2018). Of these, 7 were eligible for inclusion in the meta-analyses.

Two studies employed self-report measures of social reward anticipation. Foulkes et al. (2015) showed that autism quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) scores significantly predicted reduced anticipation of social rewards involving opportunities for admiration, prosocial interaction, sexual relationships and sociability. Scores also positively predicted increased anticipation 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 social reward hypoanticipation in ASD in comparison to healthy individuals (see Appendix D).

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 (Bennaroch, 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, Kelley, Pornpattananangkul, Mittal & Nusslock, 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 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 Zeeland 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 E.

Meta-analysis of experimental behavioural data: ASD participants showed significantly slower RTs when anticipating social rewards than typically developing individuals, with a small-medium effect size (Hedge's $g = 0.38$, $df = 5$, $p = 0.006$, $CI = [0.11, 0.65]$, $I^2 = 10\%$, $p = 0.35$). They also showed significantly lower response accuracy, with a medium effect size (Hedge's $g = -0.45$, $df = 4$, $p = 0.002$, $CI = [-0.73, -0.17]$, $I^2 = 0\%$, $p = 0.43$).

Conduct Disorder: Conduct Disorder is described as a neurodevelopmental condition that significantly increases the chances of an individual developing antisocial personality disorder in later life (Schaeffer, Petras, Ialongo, Poduska & Kellam, 2003). Children and adolescents with conduct disorder often show high levels of callous-unemotional traits and can demonstrate a persistent defiance of authority and disregard for social convention (Frick & Ellis, 1999). They can also demonstrate minimal motivation for affiliative or close interpersonal relationships (Waller & Wagner, 2019). Only one study on conduct disorder and social reward anticipation was available for review (Foulkes, Neumann, Roberts, McCrory & Viding, 2017). Taking a self-report approach within a normative sample, this study showed that individuals with higher levels of conduct disorder traits (as assessed by

Callous-Unemotional Scale of Antisocial Process Screening Device; Frick & Hare, 2001) self-report anticipating greater feelings of social reward from social interactions that involve opportunities for cruelty to others. There was also a negative correlation between conduct disorder traits and self-reported anticipation of enjoyment from prosocial interactions, admiration, and social passivity. Together, these self-report data suggest that conduct disorder individuals may be less motivated to pursue social rewards that are prosocial in nature but may hyperanticipate rewards than include opportunities for cruelty to others. Meta-analysis: Foulkes et al. (2017) employed a self-report approach and therefore the data are not included in the meta-analysis.

SCHIZOPHRENIA SPECTRUM CONDITIONS

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 also manifests in atypical social behaviour, including a lack of engagement with social norms and reduced motivation to be part of the social environment (Barch, Yodkovik, Sypher-Locke, & Hanewinkel, 2008). Three studies on social reward anticipation in schizophrenia spectrum conditions were eligible for inclusion in this review (Hanewald et al., 2017; 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 reaction time 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 E). They suggested that this 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.

Meta-analysis: 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 $g=0.72$, $df=2$, $p = 0.00001$, $CI=[0.46, 0.99]$, $I^2 = 0\%$, $p = 0.82$). This suggests that individuals with schizophrenia spectrum conditions demonstrate hypoanticipation of social rewards. However, this was not significantly reflected in the

response accuracy comparison (Hedge's $g = -0.02$, $df=2$, $p = 0.89$, $CI = [-0.28, 0.24]$, $I^2 = 0\%$, $p = 0.89$).

MOOD DISORDERS

Alexithymia: Alexithymia is a psychopathological personality dimension associated with dysfunction in emotional and reward processes (Fantini-Hauwel, Luminet & Vermeulen, 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 self-report assessments of social reward anticipation, whilst Goerlich et al. (2017) used an incentive delay paradigm. Foulkes et al. (2015) found that alexithymia scores significantly predicted self-reported hypoanticipation 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. Meta-analysis: Neither study was eligible for inclusion in the meta-analysis because both used a correlation design with alexithymia assessed as a dimensional trait.

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, Cunningham, Kober & Gruber, 2015; Dutra, Man, Kober, Cunningham & Gruber, 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 (Appendix E) and all described effects remained when antipsychotic medication use was included as a covariate. Meta-analysis: Neither study was eligible for inclusion in the meta-analysis as behavioural data were not reported.

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 (Han et al., 2019; He, Zhang, Muhlert & Elliott, 2019; Oumeziane, Jones & Foti, 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 task performance. Similarly, relative to healthy controls, He et al. (2019) found no significant evidence of neural social reward hypoanticipation in the clinical group. 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 self-report measures of experience of social reward, 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 above) and found no significant group differences in self-reported social reward anticipation by ASD and MDD individuals. Both He et al. (2019) and 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. Meta-analysis: None of the studies reviewed were eligible for inclusion in the meta-analysis: He et al. (2019) did not report behavioural data, 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.

Post-Traumatic Stress Disorder: Post-traumatic stress disorder (PTSD) is a debilitating psychiatric mood disorder that emerges following a traumatic event. Like some other mood disorders, individuals with PTSD often present with elevated levels of anhedonia (Carmassi et al., 2014) and those feelings of anhedonia can have a marked negative impact on treatment engagement and chronicity of illness (Hassija, Jakupcak & Gray, 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. Meta-analysis: 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.

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, Coplan & Gorman, 2001). Richey et al. (2014), Richey et al. (2017), and Cremers, Veer, Spinhoven, Rombouts, and Roelofs (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. Meta-analysis: 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 $g = 0.20$, $df = 1$, $p = 0.65$, $CI = [-0.67, 1.07]$), perhaps due to heterogeneity within the data ($I^2 = 74\%$, $p = 0.05$).

EATING AND FEEDING DISORDERS

Eating 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, Tchanturia, Rabe-Hesketh, Collier & Treasure, 2009) and comorbidity with social anxiety is also common (Godart et al., 2006). Whilst a distinct subtype of eating disorder, individuals with bingeing/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, Luebbe and Smith (2018) studied social reward anticipation in eating disorders via self-report measures within a normative sample. They found that restricting and bingeing/purging types of eating disorders were associated with increased anticipation of social rewards, and so indicate that hyperanticipation of social rewards may be a characteristic of eating disorders of different types. Meta-analysis: Both studies used self-report measures only and therefore were not eligible for inclusion in the meta-analysis.

PERSONALITY DISORDERS

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, Milner, Akhtar & De Fruyt, 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. Meta-analysis: Doell et al. (2020) provided reaction time data and so the data are included in the overall meta-analysis.

Psychopathy: Psychopathy is a personality dimension encompassing a constellation of traits, including impulsivity, lack of empathy, pathological lying, manipulateness, superficial charm and grandiosity (Hare, 2006). Individuals elevated in the interpersonal dimension of psychopathy are likely to be high in self-esteem (e.g. Cale & Lilienfeld, 2006) and thus may over-see, or hyperanticipate, 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, Neumann and Viding (2014) ran two studies with two separate normative participant samples that were included in one manuscript. In

their first study, Foulkes et al. (2014) correlated self-reported psychopathic traits with self-reported social reward anticipation and found significant positive correlations between psychopathic traits (total score and facets [interpersonal, affective, lifestyle, antisocial]) and anticipation of opportunities for cruelty to others. They also reported positive correlations between the interpersonal facet of psychopathy and anticipation of social rewards involving admiration. In contrast, they found that all aspects of psychopathy negatively correlated with increased anticipation of opportunities for prosocial behaviour (Foulkes et al., 2014). In their second study, they again investigated the correlations between psychopathic traits and self-reported experience 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 anticipatory responses towards social and non-social rewards. However, they found no significant relationships between psychopathic traits and task performance for either social or non-social rewards.

Meta-analysis: As Foulkes 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.

SUBSTANCE-RELATED AND ADDICTIVE DISORDERS

Pathological Gambling: Pathological gambling disorder describes a level of gambling behaviour that interferes with the individuals' occupational, emotional, or social wellbeing. Sescousse, Barbalat, Domenech and Dreher (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. Meta-analysis: This study did not meet the inclusion criteria for meta-analysis as the behavioural data were not reported.

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. Meta-analysis: 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.

NEUROCOGNITIVE DISORDERS

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, Sturm, Wood, Miller and Kramer (2015) studied social reward anticipation in bvftD and this was the only study eligible for review in this 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. Meta-analysis: Perry et al. (2015) did not include behavioural data scores and so were not eligible for inclusion in the meta-analysis.

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 hypoanticipation of social rewards. As intimated earlier and illustrated in Figure 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.

Overall meta-analysis: With the limited number of studies eligible for meta-analysis, we found some evidence of atypical social reward anticipation as a transdiagnostic characteristic. When pooling data from participants with ADHD, ASD, schizophrenia spectrum conditions, social anxiety, and borderline personality disorder, we found that 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 $g = -0.19$, $df = 11$, $p = 0.08$, $CI = [-0.39, 0.02]$, $I^2 = 40\%$, $p = 0.08$).

[Insert Figure 4 about here]

Figure 4. Figure illustrating findings from this review on axes of behavioural and neural anticipation.

Discussion

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

Firstly, our meta-analytic findings showed that ADHD, ASD and schizophrenia spectrum conditions 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 2). Furthermore, our 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, we found 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 self-report, neuroimaging, and meta-analytically ineligible behavioural data supported our 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 anticipation in alexithymia were also reviewed and increased feelings of alexithymia were significantly linked to self-reported hypoanticipation 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, borderline personality disorder, 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 hyperanticipate opportunities for cruelty to others or 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, our meta-analysis and systematic review highlights that hypoanticipation (evidenced by slower RTs) is common across ADHD, ASD and schizophrenia 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.

CRITICAL EVALUATION OF METHODOLOGY AND DIRECTIONS FOR FUTURE RESEARCH

Emotion decoding deficits in psychopathology: Most studies reviewed here included emotional faces as social rewards. However, the psychopathologies reviewed are associated with a range of emotion decoding difficulties (e.g. Guyer et al., 2007; Hoernagl & 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 decoding (Chevallier et al., 2012), and so future research should include a test of emotion decoding when also using emotional stimuli as social rewards.

Defining types of social reward: Foulkes et al. (2014) argue that social reward is a multi-dimensional construct that includes several subcomponents. Indeed, whilst emotional facial stimuli may be indicative of positive social interaction, and thereby socially motivating, they

may not fit precisely into one of the social reward subcomponents listed earlier. Instead, emotional faces might cross-over several subcomponents of social reward as described by Foulkes et al. (2014) (e.g. admiration, prosocial behaviour, sociability). Given the issues related to facial emotion decoding described above, and the lack of specificity of emotional faces to social reward subcomponents, 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 subcomponents in other ways (e.g. use of animations or virtual reality; Fulford et al., 2018; Kim, Geiger, Herr & Rosenthal, 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 relations are included as a social reward in the Foulkes et al. (2014) definition, we felt justified in including these studies within our review while acknowledging that their results may be less comparable to the other studies included in this review because of the valence and arousal differences between the two stimuli types. Having said that, the inclusion of erotic stimuli as a type 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 et al. (2014) subcomponents within social reward anticipation paradigms may then discover more nuanced links between symptomatology and anticipation of certain types of social reward.

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, Halari, Cubillo & Taylor, 2009; Schlagenhauf et al., 2008) which could have influenced the participants' anticipation of social and non-social rewards. Acute withdrawal effects (for example, dopamine supersensitivity 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).

Gender effects in social reward anticipation: 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, Chapman & Raulin.,

1976; Khesht-Masjedi, Shokrgozar, Abdollahi, Golshahi, & Sharif-Ghaziani., 2017; Goldstein & Link, 1988; Ring et al., 1991). This review has highlighted that higher levels of 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 anticipation in psychopathology should be considered.

The effect of cognitive deficits on reward anticipation: It is likely that general dysfunction in cognitive ability will affect metrics of reward anticipation, 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.

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.

Implications for clinical practice: This review found evidence for atypical social reward anticipation as a transdiagnostic characteristic of psychopathology. Following our results, and if these effects are borne out in future studies, atypical social reward anticipation may have implications for how we incentivise and engage individuals with mental health difficulties 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 practising interpersonal skills. Conversely, clinical groups that demonstrate social reward hyperanticipation (particularly towards opportunities for admiration or cruelty to others) may be more difficult to manage within group-therapy activities, such as the tendency towards bullying and taking control that we see in group work with highly psychopathic individuals (Harris & Rice, 2006; McGauley, Adshead, Sarkar, Felthouse, & Sass, 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 subcomponents of social reward more than others. Future therapies could then look to take these different social reward components into account and develop more bespoke group psychotherapeutic approaches.

LIMITATIONS

Whilst this review has been a comprehensive synthesis of social reward anticipation in psychopathology, there are a few important points that have not been covered here. First, we were strict in the type of paradigms that were eligible for inclusion in this review (justification given in methods section). However, this meant that some of the data in the reviewed articles were not evaluated. For example, Kohls et al. (2009; 2011; 2012; 2014) used an incentivised go/no-go task but we could only include 'go trials' 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 anticipation in psychopathology. Second, whilst we have provided meta-analytic and narrative evidence for specific hypoanticipation of social rewards across psychopathologies, it is possible that general psychomotor slowing associated with clinical illness (e.g. Morrens, Hulstijn, & Sabbe, 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, we decided to focus on visual stimuli here 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 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. Relatedly, the small amount of data available for review on this topic limits confidence in some of our findings until they are confirmed and supported by future research.

CONCLUSIONS

This review investigated atypical social reward anticipation across different psychopathologies. Its findings revealed i) meta-analytic and descriptive evidence of social reward hypoanticipation (reflected in slower anticipatory RTs towards social reward stimuli) in ADHD, ASD, and schizophrenia spectrum conditions when comparing clinical and healthy groups on behavioural measures of social reward anticipation, ii) correlational evidence for self-reported social reward hypoanticipation 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 reward-circuit activity during social reward anticipation in comparison to non-social rewards. Further research is needed to

confirm these findings, while taking gender and medication into account, and the clinical implications of the results should be tested further.

Data Access Statement.

All data supporting the meta-analysis reported in this article are available from Brunel University London research repository at [10.17633/rd.brunel.13158104](https://doi.org/10.17633/rd.brunel.13158104)

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