

**Experimental Investigation of the Impact of Goal-Oriented Mental Imagery on Reward
Perception**

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DClinPsy Thesis (Volume 1), 2021

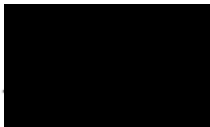
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Thesis Declaration Form

I confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signature:



Name: Joseph Flynn

Date: 02.08.2021

Overview

This thesis examines whether mental imagery of goal attainment can bias the perception of reward value.

Part One: Literature Review. Part one is a systematic review of the efficacy of psychotherapeutic interventions using positive mental imagery on mood or anxiety problems.

Part Two: Empirical Paper. Part two is a quantitative, empirical study examining whether mental imagery influencing motivation can bias the perception of reward value during learning. It also explored whether these effects are stronger in those more prone to mental imagery and higher levels of mood symptoms. Analyses quantified the impact of visualising goal-attainment versus goal-failure; first, on mood and motivation during a reinforcement learning task, and secondly whether this manipulation differentially biased preference for stimuli encountered under the imagery conditions. The manipulation was highly effective in modulating changes in mood and motivation. Preferences for stimuli encountered when visualising goal-attainment were modulated by changes in momentary motivation and depression symptoms.

Part Three: Critical Appraisal. Part three is a critical appraisal of the process of undertaking the systematic review and empirical project described in parts one and two. It includes reflections on the research process, consideration of broader questions and issues encountered during this process, and also the field of study and the methodologies employed in studying these kinds of phenomena.

Impact Statement

Mood and anxiety disorders are highly prevalent and often occur comorbidly, with it being reported that around 50-60% of individuals with a clinical diagnosis of major depressive disorder (MDD) also have a history of one more anxiety disorder (Kaufman & Charney, 2000; Fava et al, 2000; Kessler et al, 1996). Mental imagery has been found to play an important role in generating and maintaining symptoms in mood and anxiety problems and has been referred to as an 'emotional amplifier' (Holmes et al, 2009). However, in much psychotherapeutic practice, interventions assessing and challenging negative verbal cognitions often take precedence and the role of mental imagery, especially in promoting positive cognitions, is often neglected.

The systematic review conducted in Part One identified 18 studies using psychotherapeutic interventions aimed at increasing positive imagery in individuals experiencing clinical mood and anxiety problems. Six out of 12 studies that measured depression symptoms found improvements following intervention versus controls (50%), and six of nine studies measuring anxiety symptoms (66%). Although proffering generally mixed efficacy on general measures of mood and anxiety symptoms, these outcomes were still taken to infer good efficacy of mental imagery in providing a vehicle through which to therapeutically impact symptoms of anxiety and depression. An overall preponderance of computerised interventions using imagery CBM was observed. This suggests that the wider use of computerised interventions using imagery-based cognitive bias modification (CBM) and other similar interventions may provide an efficient mode of delivering effective interventions. However, future research should first further explore the efficacy of interventions aimed at promoting positive mental imagery, as well as how these imagery-based interventions compare to more commonly used verbally oriented interventions in terms of efficiency and acceptability.

Mood disorders are diverse: for example, in depression, individuals could be viewed as being more disposed to sad mood which thus reduces their drive with respect to reward (Clark et al, 2018). In mania, on the other hand, individuals show overall increased activity and energy levels, paired with either euphory or irritability, and often overconfidence, leading to increased impulsivity and risk-taking (Berrios, 2004). In this sense, imagery can be viewed to have a pivotal role in maintenance of mood disorders. These phenotypic observations highlight motivational drive and pursuit of goals (or rewarding outcomes) as potentially important processes within mood disorders. This raises the question as to what extent changes in mood and motivation might bias reward perception, and also whether understanding the factors modulating these effects may inform interventions towards mitigating the recursive and escalating cycle of mood and behaviour changes observed in depression and mania.

The empirical experiment in Part Two recruited 50 healthy participants to complete a brief, online-based manipulation in which they generated mental images related to goal-attainment and goal-failure with a view to increasing and decreasing motivation, respectively. Having confirmed the efficacy of the manipulation on mood and motivation, we then quantified the impact of imagery on two blocks of learning of stimuli with identical reward probability. Preferences for stimuli encountered when visualising goal-attainment were modulated by changes in momentary motivation and depression symptoms. Although there was some evidence of an overall “negative bias” towards preferring stimuli encountered when visualising goal-failure, this bias was offset when accounting for individual proneness to mental imagery and three factors representing “negative valence,” “arousal” and “anxiety.”

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Acknowledgements

Thank you to my research supervisor Dr Liam Mason for his consistent and thoughtful guidance throughout this project. Your expertise and assistance has been invaluable, and it has been a privilege and a pleasure working with you.

I would also like to thank my course tutor, Dr Kate Sherratt, for her extensive support of my personal and professional development over the last three years. All of the kindness and insights you have provided are greatly appreciated.

Finally, I would like to thank my partner Maya for her unwavering compassion and warmth, and for always being there when I needed her.

Part One: Literature Review

**A Systematic Review of the Efficacy of Positive-Imagery Interventions for Mood and
Anxiety Disorders**

Abstract

Background: In psychotherapeutic practice, the role of mental imagery in promoting positive cognitions is often neglected in lieu of assessing and challenging negative verbal cognitions. Mental imagery has been found to play an important role in generating and maintaining symptoms in mood and anxiety problems and has been referred to as an ‘emotional amplifier.’ This study therefore reviewed psychotherapeutic interventions aimed at increasing positive imagery in individuals experiencing clinical mood and anxiety problems.

Methods: Searches were undertaken of PsycINFO, MEDLINE and EMBASE, as well as reference lists of primary studies and review articles identified. Searches were done in December 2020. **Selection Criteria.** i) psychotherapeutic interventions aimed at increasing positive imagery, ii) studies with individuals above 16 years old, and iii) use of at least one clinically relevant measure of mood or anxiety symptoms. Only published studies were included. **Study Appraisal and Synthesis.** Given the variability of outcome measures and interventions used in the studies, the results are discussed narratively rather than meta-analytically. Studies were rated for risk of bias using the Cochrane Risk of Bias tool.

Results: Our search found 18 relevant studies. Six out of 12 studies that measured depression symptoms found improvements following intervention versus controls (50%), and six of nine studies measuring anxiety symptoms (66%). An overall preponderance of computerised interventions using imagery-enhanced cognitive bias modification (CBM) was observed.

Conclusions: The current study highlights the importance of mental imagery in providing a vehicle through which to therapeutically impact negative cognitive biases underlying symptoms of anxiety and depression. Furthermore, the wider use of computerised interventions using imagery CBM-I and other similar interventions may provide an efficient mode of delivering effective interventions. However, future research should first further explore efficiency and acceptability compared to verbally oriented interventions.

1. Introduction

Imagery-based psychological therapies promoting positive imagery are a relatively new mode of intervention and are not yet widely available. To date there are very few reviews examining their efficacy.

1.1. Clinical Mood and Anxiety Disorders

Mood and anxiety disorders are highly prevalent and often occur comorbidly, with it being reported that around 50-60% of individuals with a clinical diagnosis of major depressive disorder (MDD) also have a history of one more anxiety disorder (Kaufman & Charney, 2000; Fava et al, 2000; Kessler et al, 1996). Although this co-occurrence is frequently thought to reflect an empirical overlap between diagnostic constructs that are otherwise considered clinically distinct, there is also enough of a degree of heterogeneity between presentations to warrant separation into diagnostic subtypes (Watson, 2005). This raises the question as to what extent overlapping phenomena characterising mood and anxiety disorders may be taken as indication of common mechanisms for intervention or should be treated as diverse.

Both depression and anxiety disorders are commonly associated with verbal processing (Holmes et al, 2009). Theories considering clinical features of depression and anxiety disorders tend to converge on the understanding that although verbal processing reduces negative affect in the short term, continued abstract processing in this manner can also be maladaptive. In this respect, Holmes and colleagues (2009) refer to the interacting cognitive sub-systems model (Teasdale & Barnard, 1993) as demonstrating the impact of abstract/verbal thinking over implicational processes in depression, and also the reduced concreteness theory (Stober & Borkovec, 2007) as exemplifying how verbal worries can often serve to distract from distressing mental imagery. Indeed, Blackwell (2019) notes that

problems characterised by mental imagery are observed across many areas of psychopathology. These can include disorders with distressing mental imagery, such as intrusive or dissociative memories (or ‘flashbacks’) in post-traumatic stress disorder (PTSD; Ehlers et al, 2004), distorted images of oneself (e.g., blushing “bright red”) in social anxiety (Hirsch et al, 2003), or future-oriented imagery (“flash forwards”) characterising suicidal plans in depression (Hales et al, 2011). However, such future-oriented mental imagery can also be experienced as pleasant or motivating, such as the imagining of particularly positive or favourable events characteristic of mania in bipolar disorder (Ivin et al, 2014), or images of self-harm being experienced as providing comfort or relief from emotional distress (Weßlau et al, 2015).

While these examples serve to illustrate the presence of dysfunctional mental imagery across mood and anxiety disorders, depression, in particular, can also be characterised by a lack (or impoverishment) of positive mental imagery, with depressed individuals often experiencing difficulty with imagining positive future events (Holmes et al, 2016). In turn, individuals experiencing anxiety problems are known to often distract away from distressing imagery via processes of worry and cognitive avoidance (Stober & Borkovec, 2007). Moreover, negative imagery can also often lead to behavioural avoidance— for example, individuals with PTSD commonly avoid people and locations that trigger intrusive memories of trauma (Blackwell, 2019). Interventions promoting more positive mental imagery may therefore serve to ameliorate symptoms of depressed mood and have transdiagnostic benefits for anxiety problems.

1.2 Phenomenology of Mental Imagery

Mental imagery has been described as that which occurs when perceptual information is accessed from memory, giving rise to the experience of “seeing with the mind’s eye” or

“hearing with the mind’s ear” (Kosslyn et al, 2001). Holmes and Mathews (2005) propose that emotional processing in the brain is particularly sensitive to imagery (rather than verbal thought). They also posit that processes involved in mental imagery overlap with those in perception and therefore imagined events may be responded to “as if” real. In this sense, imagery is now appreciated to be a critical cognitive component in amplifying experience and exacerbating states of normal and abnormal emotion.

As Blackwell (2019) suggests, experiences of mental imagery are common for many people and feature as a normal part of their daily lives—for example, mental imagery can be employed to assist with decision making or problem solving (e.g., planning a travel route) or with emotional regulation (e.g., imagining a comforting scene or recalling positive memories). In this sense, positive mental imagery is typically characterised by mental images visualised within the ‘mind’s eye’ that relate to positive (or favourable) past events or potential future outcomes (e.g., Holmes et al, 2008; Blackwell et al, 2013; Blackwell & Holmes, 2017). Holmes et al (2009) have shown that mental imagery can have a strong emotional impact on healthy volunteers when compared to verbal processing. They also demonstrated that participants who had previously imagined scenarios as resolving positively also showed a greater propensity towards positively interpreting the outcome of subsequent ambiguous scenarios, and thus demonstrating that mental imagery can have a strong influence on both emotional valence and other related cognitive appraisal processes.

In recent work summarising and recontextualising Peter Lang’s (1977, 1979) bio-informational theory of mental imagery, Ji and colleagues (2016) explore insights from this theory with respect to enhancing emotional mental imagery training. The authors point towards Lang’s theory as having “opened an experimental window” onto what he referred to as “the mind’s emotional eye,” and suggest that his method of emotional imagery response training could be useful to enhance and reinforce emotional responding to mental imagery “as

if' it was real. Experimental studies suggest that following repeated rehearsal the realness of mental imagery may be increased to an extent where it is perceived as more plausible (Szpunar & Schacter, 2013), and also that repeatedly imagining positive future outcomes can lead to more optimistic appraisals of future events (Holmes et al, 2009; Meevissen et al, 2011). Given these factors, it is perhaps not surprising that mental imagery has also been shown to have an influence on behaviour and behavioural outcomes. While early studies showed that participants instructed to imagine the benefits of owning cable TV were more likely to subscribe (Gregory et al., 1982), other more recent studies have also shown associations between visualising positive outcomes and health-related behaviour such as physical exercise (Chan & Cameron, 2012) and dietary choices (Knäuper et al, 2011).

1.3 Imagery-Based Psychotherapeutic Interventions

Psychotherapeutic intervention (or 'psychotherapy') is broadly defined within the field of psychology as "a skilled and intentional treatment process whereby the thoughts, feelings, and behaviour of a person are modified with the intention of facilitating increased functioning and life adjustment" (Lambert et al., 1994, p. 709). There are already various imagery-based psychotherapeutic techniques that are either well-established or emerging in the field, including imaginal exposure, imagery rescripting, generation of compassionate imagery, and memory focused imagery techniques such as those commonly use in treatment for PTSD (Blackwell, 2019). Holmes and colleagues (2009) suggest that some clinicians view use of imagery in their practice less favourably, or perhaps feel deterred by a perceived lack of evidence, and therefore tend to focus predominantly on assessing and working with verbal cognitions in their sessions rather than images. They note that in the original conception of cognitive behaviour therapy, Aaron T. Beck (1976) emphasised the importance of assessing not only patients verbal thoughts, but also their images, and suggest that this emphasis seems to have become somewhat neglected more recently within clinical practice.

Imagery-based techniques more commonly used in CBT, such as imagery rescripting, have demonstrated good efficacy for treating a range of clinical mood and anxiety related difficulties, including PTSD and social anxiety disorder (Antz, 2012). Imagery-rescripting interventions provide an example of how therapists can make use of mental imagery to effect emotion and cognition and ameliorate distress. Using imagery rescripting, an existing memory or image can be brought to mind and then be reappraised so that it is perceived as less distressing and the negative affect that it evokes is decreased by incorporating alternative mental images into a “rescripted” appraisal (Holmes et al, 2007). Indeed, studies using a computerised approach called cognitive bias modification (CBM) have shown that incorporating imagery-based reappraisals can bring about greater changes in affect than developing reappraisals in a verbal form (e.g., Holmes et al, 2009). Studies within an experimental paradigm in which mental images were generated in response to word or picture cues have also found similar results (e.g., Gorgen et al, 2015; Mathews et al, 2013). However, studies attempting to replicate findings in individuals with depression did not find a similar result, suggesting that people with depression may have more difficulty in generating positive mental imagery, and may therefore require additional guidance in order to more consistently generate vivid and affective mental imagery (Holmes et al, 2016).

With respect to psychotherapeutic interventions specifically aimed at increasing positive mental imagery in order to impact mood and anxiety symptoms, there are few approaches which have achieved this to date. Those more common psychotherapeutic approaches (such as cognitive behaviour therapy [CBT]) that do utilise aspects of mental imagery tend to focus on rescripting or challenging negative cognitions in a manner that typically serves to neutralise emotional affect and related cognitions and images, rather than actively promote more positive ones. As depressed individuals have been shown to have particular difficulty in generating positive mental imagery, this could be an important target

for intervention. To this end, recent clinical studies have used imagery-enhanced CBM, typically delivered via a computerised interface, in an attempt to train a more positive interpretation style amongst individuals currently experiencing symptoms of depression, with some promising findings in reducing negative interpretations via the training of imagery relating to more positive outcomes (e.g., Pictet et al, 2016). This has opened up an exciting prospect for further trial and development of this computerised approach in individuals experiencing mood and anxiety problems.

1.4 Previous Reviews

Searches indicated no previous systematic reviews of psychotherapeutic interventions specifically aimed at increasing positive mental imagery in adults experiencing clinical mood and anxiety disorders. In terms of imagery-based interventions more broadly (i.e., not focussed on those promoting positive mental imagery), one systematic review was found on the use of mental imagery in CBT for PTSD (Lindern et al, 2014). Several narrative articles were also found reviewing the emerging literature for the use of mental imagery-based interventions for depression (Browning et al, 2013; Holmes, 2016), bipolar disorder (Holmes & Geddes, 2008; Ng et al, 2016), in CBT interventions (Holmes, 2007; Antz, 2012) and application of mental imagery-based techniques more generally across psychotherapeutic approaches (Blackwell, 2019; Holmes & Matthews, 2010; Pearson et al, 2015). However, these narrative reviews do not set minimum quality criteria or specify their search strategy and are therefore at risk of selection bias.

1.5 Aims

The primary aims of this review are to assist in providing insights towards the efficacy of specific modes of intervention promoting positive imagery in ameliorating mood and anxiety symptoms, including gaining understanding towards the factors typically modulating

such efficacy. It is therefore hoped to inform future research and development of imagery-based clinical interventions by:

(i) reviewing evidence in relation to the efficacy of psychotherapeutic interventions aimed at increasing positive imagery in individuals experiencing clinical mood or anxiety disorders;

(ii) establishing which factors have previously been observed to modulate effectiveness of these interventions.

2. Methods

2.1 Eligibility Criteria

The current review focused on studies evaluating psychotherapeutic interventions aimed at increasing positive mental imagery in adults experiencing clinical mood or anxiety problems. Studies were assessed for inclusion in terms of research design, population characteristics, intervention, outcome measures used, and publication status.

2.1.1 Research Design

The current review only included studies with at least one between-subjects comparison or control group.

2.1.2 Population

This review focused on studies evaluating interventions for individuals (aged ≥ 16 years) assessed using relevant measures for symptoms characteristic of clinical mood and anxiety disorders as outlined in the fifth edition of the American Psychiatric Association's (APA; 2013) Diagnostic and Statistical Manual of Mental Disorders (DSM-5). In addition to clinical samples, we therefore allowed for inclusion of studies using interventions aimed at increasing positive mental imagery in samples of otherwise 'healthy' participants in which clinically relevant outcome measures had been used to distinguish individual levels of mood or anxiety symptoms.

2.1.3 Intervention

For this purpose, we used a broad definition of psychotherapeutic interventions that included both typical 'talking therapies' (Bolsover, 2007) and also computer-assisted therapies—that is, "the use of computers to deliver some aspects of psychotherapy or behavioural treatment directly to patients via interaction with a computer program or

delivered via the Internet” (Carrol & Rounsaville, 2010, p. 2). The review therefore excluded studies that did not fit this definition of psychotherapeutic intervention or were deemed to use methodology predominantly for the purpose of experimental manipulation, rather than clinical intervention per se. Our inclusion criteria focused on interventions aimed at increasing positive mental imagery—i.e., mental images giving rise to the experience of “seeing with the mind’s eye” or “hearing with the mind’s ear” (Kosslyn et al, 2001). We therefore excluded psychotherapeutic interventions involving multi-component treatments that were not methodologically dismantled to an extent to which the efficacy of specific components promoting positive imagery could be independently assessed. For this reason, studies evaluating multi-component interventions using CBT or ‘third wave’ therapies (e.g., compassion focused therapy) were excluded unless the imagery-based aspect of the intervention was assessed aside from other treatment components. Those studies that focused predominantly on interventions in sports or educational settings, motor or neurological rehabilitation, physical pain, traumatic brain injury or weight loss, rather than more specifically on increasing positive mental imagery with a view to alleviating symptoms attributable to mood or anxiety disorders, were also excluded.

2.1.4 Outcomes

Studies not using outcome measures relevant to assessing symptoms of clinical mood or anxiety disorders were excluded.

2.1.5 Publication

Studies were restricted to published full-text journal articles written in English. No date limits were set.

2.2. Literature Search and Study Selection

Literature searches were completed in December 2020 via the Ovid Interface and spanned three electronic databases—Embase, MEDLINE, and PsychINFO. These three databases incorporate literature from fields of healthcare, biomedical sciences, social sciences, and humanities. The search strategy combined synonymous terms relating to two key concepts of “psychotherapeutic intervention” and “positive imagery” (Appendix A), which were informed by keywords from literature included in several recent narrative reviews relevant to the use of mental imagery in psychotherapeutic interventions (Blackwell, 2019; Ng et al, 2016; Holmes et al, 2016; Holmes et al, 2007). Terms relating to these two key concepts were searched in titles, abstracts, and keywords in the three electronic databases. A third set of terms relating specifically to the key concept of “mood and anxiety disorders” were considered but not included to ensure that initial search results were inclusive of all psychotherapeutic interventions encompassing aspects of positive mental imagery, regardless of their primary target. A second reviewer (a psychology masters student conducting meta-analysis using a smaller sample of the reviewed articles; see section 2.4) completed the same search independently and screened results using the same eligibility criteria. Discussion was had to resolve any disagreements and ensure high reliability for study selection.

2.3 Quality Assessment

The methodological quality of the studies included in this review was assessed using criteria outlined in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al, 2011). The Cochrane criteria are primarily devised to assess risk of bias. Risk of bias relates to factors consistent with a study’s internal validity - that is, the extent to which a study employs measures to prevent or minimise factors that may bias or distort the true result (Ryan et al, 2013). Assessment of risk of bias therefore includes evaluation of elements across

the following domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data and attrition, selective outcome reporting, and other biases. A second reviewer (see section 2.2) independently assessed risk of bias for each study and discussion was had to resolve any disagreements. Our research supervisor (LM) was available for a third opinion if required.

A grading of ‘high,’ ‘low,’ or ‘unclear’ was given to each potential source of bias. Either relevant quotations from the reviewed papers or authors’ justifications for each judgement are provided in each bias domain and are presented in the risk of bias table for each study (see Appendix B). For any judgements where risk of bias was rated as ‘unclear,’ the study authors were emailed where their contact details were provided in the papers, and any responses received were subsequently accounted for in our judgements.

2.4 Analyses

Given the variability of outcome measures and interventions used in the studies, the results are discussed narratively here rather than assessed quantitatively with meta-analyses. A smaller sub-sample of eight of the included studies using the Beck Depression Inventory-II (BDI-II; Beck et al., 1996) as a common outcome measure were assessed separately using meta-analyses within the scope of the research supervisor’s research programme. This separate meta-analysis is not reported or discussed here but is intended to be synthesised with the current narrative review prior to submission for formal publication.

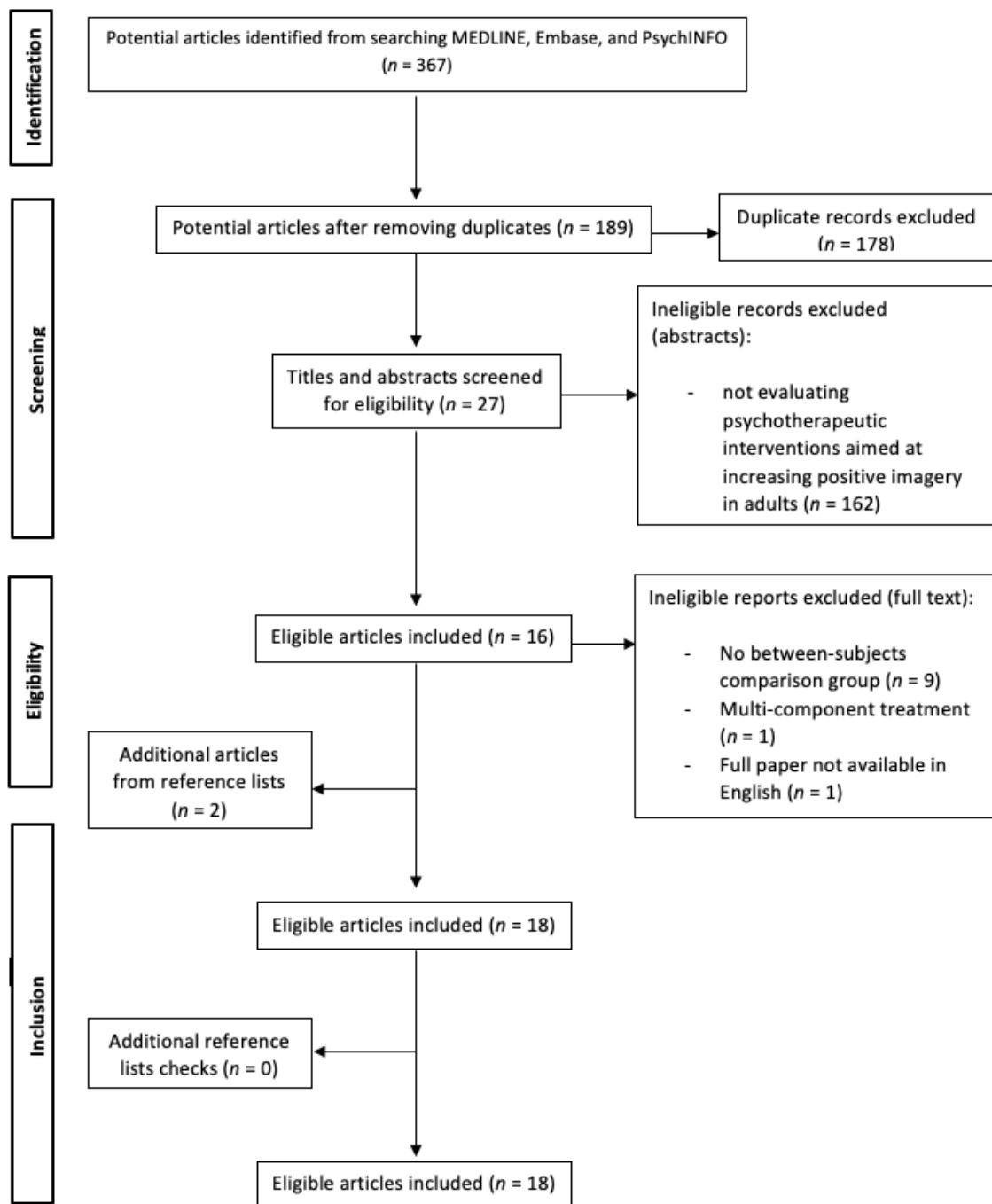
3. Results

3.1 Results of the Search

Using the described search strategy (see section 2.3), a total of 129 prospective results were obtained from Embase, 104 from MEDLINE, and 134 from PsychINFO, yielding a total of 367 results exported from Ovid to Endnote. Duplicate search results were deleted using Endnote (version X9.3.3). The titles and abstracts of 189 remaining papers were then screened to identify reports to review, leaving 27 papers evaluating psychotherapeutic interventions aimed at increasing positive mental imagery in adults. Following more detailed examination, a further 11 papers were omitted based on our selection criteria, leaving 16 eligible articles. Having examined reference lists of these eligible reports for additional articles meeting our selection criteria, two additional articles were identified. This yielded a final total of 18 articles included within this review (see Figure 1).

Figure 1

Prisma Flow Diagram of Systematic Selection Process (Adapted from Moher et al., 2009)



3.2 Included Studies

Eighteen studies met the inclusion criteria for the review. Seventeen studies were RCTs and one study included only a non-randomised control group (Sit et al, 2014). Publication dates for the included studies ranged between 2006 and 2020, and population size varied from 25 to 166 (mean: 82). Twelve studies were conducted by researchers with affiliation to the Department of Psychiatry, University of Oxford, UK, and the Medical Research Council Cognition and Brain Sciences Unit, University of Cambridge, UK (Blackwell et al, 2015; Di Simplicio et al, 2020; Holmes et al, 2009; Holmes et al, 2006; Ji et al, 2018; Lang et al, 2012; Murphy et al; 2015; Renner et al, 2017; Rohbacher et al, 2014; Torkan et al, 2014; Williams et al, 2015). Other studies were conducted in affiliation with the Department of Psychology, University of Austin, Texas, USA (Dainer-Best et al, 2018), Kings College London, Institute of Psychiatry, Psychology and Neuroscience, UK (Hirsch et al, 2020; Feng et al, 2020), Johannes-Gutenberg University of Mainz, Germany (Linke & Wessa, 2017), Department of Psychology and Educational Sciences, University of Geneva, Switzerland (Pictet et al, 2016) and the School of Psychiatry, University of New South Wales, Australia (Williams et al, 2013).

Three of the studies were secondary analyses conducted to explore additional mood and anxiety related outcomes within the same population as other included studies. Two studies follow-up Blackwell and colleagues (2015), one exploring effects on vividness of prospective imagery and optimism between treatment conditions (Ji et al, 2018), and another examining effects of treatment on behavioural activation (Renner et al, 2014), within the same sample. One other paper (Feng et al, 2020) comprised of two studies explores worry related outcomes (Study 1), and effects on interpretation bias (Study 2; with a unique sample of participants), in response to the same intervention reported by Hirsch et al (2020).

The key characteristics and main findings of each study are shown in Table 1. Effect sizes (partial eta-squared or Cohen's *d*) were not reported in many studies but appear in Table 1 if available. The statistical procedures used varied considerably between studies and therefore the statistics for the main findings are not presented.

Table 1*Included Studies: Key Characteristics and Main Findings*

Study and Country	N	Population ^a	Clinical Problem	Groups (N Starters/ Completers)	Description of Interventions/ Comparators	Intervention Modality	Length	Measures ^b	Main Findings
Blackwell et al. (2015); UK	150	68.5% female 35.5 years (SD = 13.9)	Major Depressive Episode (DSM-IV; SCID-I)	IE-CBM-I (62/76) CBM-I (74/62)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control: Cognitive Bias Modification of Interpretation	Computerised (web-based) with face-to-face screening assessment	12 sessions over 4 weeks	1, 9, 19 PT, FU (1-, 3-, and 6-months) 11, 18 (pre-training only)	No advantage of imagery enhanced CBM-I over non-enhanced CBM-I on depression symptoms (primary outcome), negative interpretive bias, or vividness of positive future imagery. Exploratory analysis showed imagery enhanced CBM-I group showed a greater improvement on anhedonia subscale of the BDI-II.
Dainer-Best et al. (2018); USA	87	75% female 26.8 years (SD = 7)	Depression Symptoms (scores >13 on CES-D)	PSRT (124/43) AC (140/43)	Active: Positive Self-Reference Training Active control: focus on present locations that were generic and neutral	Computerised (web-based)	7 sessions completed over 2 weeks	2, 10 MT, PT	PSRT group showed a greater increase in positive self-referent processing than control. Negative self-referent processing and symptoms of depression declined comparably in both groups. Increase in positive and decrease in negative self-referent processing was associated with a greater reduction in depression in both groups.

Di Simplicio et al. (2020); UK	38	81.6% female 16-25 years	Self-harm (at least two episodes reported in the last 3 months)	FIT (19/10) Delayed/TAU (19/14)	Active: Functional Imagery Training Control: TAU and then FIT (delayed by 3 months)	Face-to-face with phone support	Two face-to-face sessions (90 mins each) and five phone support calls (15-30 mins each) completed over 8 weeks	16, 17, 19, 22, 27, 28 PT, FU (3-months)	FIT produced moderate reductions in self-harm frequency at 3 months after immediate ($d = 0.65$) and delayed delivery. The Immediate FIT group maintained improvements from 3 to 6 months. Participants receiving usual care also reduced self-harm.
Feng et al. (2020); UK	Study 1: 178 Study 2: 66	Study 1: 82% female 29.2 years (SD = 10.7) Study 2: 87% female 27.1 years (SD = 7.9)	Study 1: High levels of worry or rumination (scores >55 on PSWQ; scores >63 on RSS) Study 2: High levels of worry (scores >55 on PSWQ)	Study 1: IE-CBM-I (62/59) CBM-I (61/55) AC (55/52) Study 2: IE-CBM (36/35) AC (30/30)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Active control groups: 1) Cognitive Bias Modification of Interpretation (Study 1 only); and 2) ambiguous scenarios without interpretation correction.	Study 1: Computerised (web-based) training with pre- and post-visits to clinic. Study 2: Computerised training in clinic with EEG fitted.	Study 1: 10 sessions completed over 3 weeks Study 2: Single session	Study 1: 3, 5, 12, 13, 18, 23 PT, FU (1 month) Study 2: 3, 12, 13, 15, 23, 30	Study 1: Pre-post PSWQ showed significant difference between CBM-I with imagery and control group. Study 2: CBM-I with imagery resulted in the highest levels of positive interpretation bias using an offline test of interpretation bias (i.e., when individuals have time to reflect).

Hirsch et al. (2020); UK	178	82% female 29.2 years (SD = 10.7)	High levels of worry or rumination (scores >55 on PSWQ; scores >63 on RSS)	IE-CBM-I (62/59) CBM-I (61/55) AC (55/52)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Active control groups: 1) Cognitive Bias Modification of Interpretation; and 2) ambiguous scenarios without interpretation correction.	Computerised (web-based) training with pre- and post-visits to clinic.	10 sessions completed over 3 weeks	3, 5, 6, 9, 12, 13, 14, 18, 23 PT, FU (1 month)	Both forms of CBM-I (vs. control) facilitated more positive interpretations and reduced negative intrusions during a worry task. At 1-month follow-up, anxiety, depression, RNT, and worry in the past week were lower in the CBM-I than control conditions, but not rumination or trait worry. Compared with standard CBM-I, the enhanced form facilitated more positive interpretations, reduced negative intrusions after training, and reduced trait rumination at 1-month follow-up, but it did not augment effects on trait worry, anxiety or depression.
Holmes et al. (2006); UK	26	65% female 38.9 years (SD =15.64)	Healthy Adults (various mood and anxiety related outcomes)	IE-CBM-I (20/20) CBM-I (20/20)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control: Cognitive Bias Modification of Interpretation (verbal)	Computerised (attended in-person)	Single session	11, 17 PT 18 (pre-training only)	The imagery condition reported greater increases in positive affect and rated new descriptions as being more positive than did those in the verbal condition.

Holmes et al. (2009); UK	Study 1: 40 Study 2: 60	Study 1: 55% female 31 years (SD = 11.31) Study 2: 66.6% female 24.3 years (SD = 7.49)	Healthy Adults (various mood and anxiety related outcomes)	Study 1: IE-CBM-I (20/20) CBM-I (20/20) Study 2: IE-CBM-I (20/20) CBM-I (20/20) CBM-RV (20/20)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control: 1) Cognitive Bias Modification of Interpretation (verbal); CBM with reduced verbal comparisons (Study 2 only)	Computerised (attended in-person)	Single session	11, 17 PT 1, 9, 18 (pre-training only) No Scrambled Sentences Task in Study 2.	Study 1: Replicated key benefits of imagery compared with verbal CBM-I. Imagery condition demonstrated significant improvements in mood (positive affect and state anxiety). Verbal CBM-I led to an increase in anxiety from baseline. Study 2: Reduced verbal comparisons ameliorated negative impact.
Ji et al (2018); UK	150	68.5% female 35.5 years (SD = 13.9)	Major Depressive Episode (DSM-IV; SCID-I)	IE-CBM-I (62/76) CBM-I (74/62)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control: Cognitive Bias Modification of Interpretation	Computerised (web-based) with face-to-face screening assessment	12 sessions completed over 4 weeks	1, 9, 21, 30 PT, FU (1-, 3-, and 6-months) 11, 18 (pre-training only)	Vividness of positive prospective imagery (PIT) was significantly associated with both current optimism levels at baseline and future (seven months later) optimism levels, including when controlling for potential confounds. Even when depressed, individuals with higher PIT scores were more optimistic (LOT-R).
Lang et al. (2012); UK	28	77.5% female 28.6 years (SD = 8.85)	Major Depressive Episode (DSM-IV; SCID-I)	IE-CBM-I (14/13) AC (14/13)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Active control: ambiguous scenarios without interpretation correction (imagery)	Computerised (web-based) with face-to-face screening assessment	7 sessions completed over 1 week	1, 4, 6, 9, 11, 18, 21, 22, 26 PT, FU (1 week)	Individuals in the IE-CBM-I demonstrated significant improvements from pre-treatment to post-treatment in measures of depressive symptoms, cognitive bias and intrusive symptoms compared with the control condition. Improvements in depressive symptoms at two-week follow-up were at trend level.

Linke & Wessa (2017); Germany	30	70% female 23.8 years (SD = 3.75)	Healthy Adults (pre-selected for low reward sensitivity; mood related outcomes)	MIT (15/15) WL (15/15)	Active: Mental Imagery Training Control: waitlist	Computerised (web-based) with online and telephone screening assessment	8 sessions (15 minutes each) completed over 2 weeks	17 (pre-post each session) 1, 31, 32, 33 PT	The intervention led to an increase in wanting and reward sensitivity ($d = 0.55-1.06$) Further, the training group displayed faster approach toward positive edibles and activities and reductions in depressive symptoms.
Murphy et al. (2015); UK	81	57.1% female 67.2 years (SD = 5.9)	Healthy (Older) Adults (various mood and anxiety related outcomes)	IE-CBM-I (40/36) AC (41/41)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Active control: no imagery - ambiguous scenarios without interpretation correction.	Computerised (attended in-person)	12 sessions completed over 4 weeks	1, 11, 17, 18, 19, 29 PT, FU (4 weeks)	Both groups reported decreased negative affect and trait anxiety, and increased optimism across the three assessments. Imagery cognitive bias modification significantly increased the vividness of positive prospective imagery post-training (PIT), compared with the control training ($d = 0.65$). No difference between the training groups in negative interpretation bias (SST).
Pictet et al. (2016); Switzerland	101	79.2% female 26.7 years (9.06)	Depression Symptoms (scores >13 on BDI-II)	IE-CBM-I (34/33) CBM-I (34/32) WL (33/32)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control groups: 1) Cognitive Bias Modification of Interpretation; and 2) waitlist	Computerised (web-based)	4 sessions completed over 6 days	1, 7, 25, 34 PT 11, 18 (pre-training only)	Imagery CBM led to greater improvements in depressive symptoms ($d = 1.17$), interpretation bias and anhedonia when compared to closely matched control group and waitlist ($d = 0.86$).

Renner et al. (2017); UK	150	68.5% female 35.5 years (SD = 13.9)	Major Depressive Episode (DSM-IV; SCID-I)	IE-CBM-I (62/76) CBM-I (74/62)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control: Cognitive Bias Modification of Interpretation	Computerised (web-based) with face-to-face screening assessment	12 sessions completed over 4 weeks	8 PT, FU (1-, 3-, and 6-months)	BADS scores increased over time in both groups (CBM: $d = 0.97$; AC: $d = 0.96$), but there was an initial greater increase in the imagery CBM-I group to the control group at post-treatment (CBM: $d = 0.89$; AC: $d = 0.71$), 1-month (CBM: $d = 0.81$; AC: $d = 0.60$) and 3-months (CBM: $d = 1.01$; AC: $d = 0.38$).
Rohrbacher et al. (2014); UK	54	75.9% female 22 years (SD = 2.9)	Healthy Adults (various mood and anxiety related outcomes)	IE-CBM-I (18/18) CBM-I (18/18) AC (18/18)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Active control groups: 1) Cognitive Bias Modification of Interpretation; and 2) scenarios without interpretation correction.	Computerised (attended in-person)	Single session	17, 25 PT 1, 11 (pre-training only)	Both CBM-I group showed significantly increased the tendency to interpret fresh ambiguous material in an optimistic manner (AST). However, only the standardized imagery CBM-I paradigm positively influenced mood.
Sit et al. (2020); China	41	70.6 % female 22.3 years (SD = 2.85)	Depression Symptoms (mean score on BDI-II = 15.4)	IE-CBM-I (30/22) WL (21/19)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Control: waitlist	Computerised (attended in-person)	12 sessions completed over 4 weeks	1, 5, 17 PT, FU (4 weeks)	Depressive symptoms, positive and negative affect, and rumination within the intervention group demonstrated better outcomes than controls across time.

Torkan et al. (2014); Iran	39	64.3% female 27.6 years (SD = 8.76)	Major Depressive Episode (DSM-IV; SCID-I)	IE-CBM-I (13/8) CBM-I (13/8) NTC (13/8)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation Active control groups: 1) Cognitive Bias Modification of Interpretation; and 2) no treatment control.	Computerised (web-based) with face-to-face screening assessment and follow-up	7 sessions completed over 1 week	1, 5, 9, 11, 18, 20 PT, FU (2 weeks)	Imagery CBM led to greater improvements in depressive symptoms, interpretive bias, and imagery vividness than either control condition at post-treatment and improvements were maintained at follow-up.
Williams et al. (2013); Australia	69	76.2 % female 44.76 years (SD = 12.05)	Major Depressive Episode (DSM-IV; MINI)	IE-CBM-I (38/26) followed by iCBT (26/20) AC (31/27) followed by iCBT (27/22)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation followed by internet-based Cognitive Behavioural Therapy Active control: matched to active CBM condition but with 50% of scenarios not positively resolved (i.e., no interpretation correction) followed by internet-based Cognitive Behavioural Therapy	Computerised (web-based) with pre-screening via telephone	7 sessions IE-CBM-I completed over 1 week (or waitlist); followed by 6 sessions of iCBT for depression.	1, 3, 6, 11, 25, 35, 36 PT, FU (3 months)	Significant reductions observed in primary measures of depressive symptoms and distress ($d = 0.62-2.40$) following CBM-I and the combined (CBM-I + iCBT) intervention. Change in interpretation bias at least partially mediated the reduction in depression symptoms following CBM. CBM showed superiority over WLC on all outcome measures at both time points. Significant reductions observed following the combined intervention on secondary measures: disability, anxiety, and repetitive negative thinking. Twenty-seven percent of patients evidenced clinically significant change following CBM-I, and this proportion increased to 65% following the combined intervention.

Williams et al. (2015); Australia	121	73.3% female 41.8 years (SD = 11.39)	Major Depressive Episode (DSM-IV; MINI)	IE-CBM-I (60/26) followed by iCBT (26/20) WL (60/27) followed by iCBT (27/22)	Active: Imagery Enhanced Cognitive Bias Modification of Interpretation followed by internet-based CBT Control: waitlist followed by internet-based CBT	Computerised (web-based) with pre-screening via telephone	7 sessions IE-CBM-I completed over 1 week (or waitlist); followed by 6 sessions of iCBT for depression.	1, 3, 11, 25, 35, 36 PT	Both conditions showed reductions in primary measures of depression and interpretation bias (PHQ9, BDI-II, AST-D; $d = .57-1.58$). Reductions were observed for secondary measures of distress, disability, anxiety, and repetitive negative thinking (K10, WHODAS, STAI, RTQ; $d = .81-1.32$). CBM-I showed increased improvement over control group on depression symptoms (PHQ9, BDI-II) and psychological distress (K10) following CBM and following iCBT (PHQ9, K10).
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^a Treatment type, Percentage male, mean age. Where age (mean/SD) was reported per group, a formula was used to compute an average for whole sample.

^b Outcome measures are listed in Table 3.

MT – Mid-treatment

PT – Post-treatment

FU – Follow-up

WL – Waitlist

TAU – Treatment-as-usual

AC – Active control

3.3 Participants

Participants recruited to the studies varied in their diagnostic status with respect to mood and anxiety problems. Seven studies included only participants who currently met Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; DSM-IV-TR; APA, 2000) criteria for major depressive episode. Five of these studies (Blackwell et al, 2015; Ji et al, 2018; Lang et al, 2012; Renner et al, 2017; Torkan et al, 2014) pre-screened participant symptoms using the Structured Clinical Interview for DSM-IV-TR Axis I Disorders (SCID-I; First et al, 2002) and two (Williams et al, 2015, 2013) using the Mini International Neuropsychiatric Interview Version 5.0.0 (MINI; Sheehan et al, 1998). Two studies included only participants meeting clinically significant threshold for at least mild depression symptoms on the BDI-II (Pictet et al, 2016) or Centre for Epidemiologic Studies-Depression Scale (CES-D; Radloff, 1977; Dainer-Best et al, 2018), and another (Sit et al, 2020) found average baseline scores on the BDI-II (mean = 15.4) to be above the clinically significant threshold (i.e., scores >13).

With respect to comorbid anxiety problems, two studies (both using the same sample of participants; Feng et al, 2020; Hirsh et al, 2020) pre-screened for individuals with high levels of worry or rumination above respective clinically significant cut-offs on either the Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990) or Ruminative Response Scale (Nolen-Hoeksema & Morrow, 1991). One other study (Di Simplicio et al, 2020) measured mood and anxiety related outcomes but included only participants (aged 16-25 years) with at least two recent instances of self-harm. The other included studies used clinically relevant outcomes measures to distinguish levels of depression or anxiety symptoms within samples of otherwise 'healthy' adult participants.

The majority of studies recruited participants via sources including local media (e.g., newspapers, radio), websites (e.g., Google, Facebook), and community, university, and health settings. One study conducted recruitment through a combination of self-referral from the community (via posters and social media), as well as direct referral from primary care services (general practitioners, psychology), secondary mental health care services, or university/school counsellors (Di Simplicio et al, 2020), and another via outpatient psychiatry clinics (Torkan et al, 2014).

The mean age of the randomised populations was calculated as ranging from 22 to 44.76 years for all except two studies: one in which only younger participants were included, aged from 16-25 years (no mean age reported; Di Simplicio et al, 2020), and another that included only older participants aged from 60-80 years (mean age: 67.2 years; Murphy et al, 2015). Most studies excluded participants who met criteria for a current psychotic or substance-abuse disorder, had a history of mania or hypomania, had recently started or changed dose of antidepressant medication, were currently receiving psychological therapy, or were involved in other current treatment trials.

3.4 Interventions

Based on our eligibility criteria (see section 2.1.3), the studies included within this review were found to predominantly use computerised, imagery-enhanced cognitive bias modification (CBM) techniques that target *interpretation* of ambiguous scenarios (CBM-I) in attempt to modify *negative interpretation bias* (i.e., the tendency to interpret ambiguous stimuli more negatively; Butler & Matthews, 1983). While earlier experimental work within the CBM paradigm used verbal instructions to modify interpretation bias (Matthews & Mackintosh, 2000), more recently, Holmes and colleagues (2006; Holmes & Matthews, 2005) have suggested an advantage of mental imagery (i.e., over verbal instructions) in positively

impacting emotion (decreasing anxiety and increasing positive affect) and reducing negative interpretation bias. This review therefore comprises the initial RCT using imagery-enhanced CBM-I conducted by Holmes et al (2006), as well as 14 subsequent RCTs testing the efficacy of this approach versus various comparison groups (see section 3.5). The three other studies included in this review used alternative psychotherapeutic approaches aimed at increasing positive imagery in adults experiencing clinical mood or anxiety problems (with two of these being computerised interventions).

Typically based on protocol used by Holmes et al (2006), a single computerised CBM-I session involves participants listening to auditory descriptions of different situations with a positive emotional outcome. Half of the recorded descriptions they used began by implying a potentially negative situation that then resolves in the final word(s) to have a benign or positive outcome (e.g., “You have the impression that you heard a frightening noise and *then realize with relief that it was your partner returning home*” [resolution in italics]). The remaining descriptions began with a benign situation that then ends even more positively (e.g., “It’s your birthday, and your partner reaches over to you with a present. You open it and *feel incredibly happy*” [resolution in italics]; examples from Holmes et al, 2006, p. 239). The scenarios used were randomised and all had more than one possible outcome, with the primary aim being to train participants to generate positive resolutions of situations that could have developed in other potentially negative or less desirable ways. A simple distinction was made in the imagery-enhanced CBM-I protocol (i.e., compared to verbal protocol) whereby participants were instructed to *imagine* positive events “as if actively involved, seeing them through [their] own eyes,” as opposed to thinking about the verbal meaning.

Three of the studies used only a single session of imagery-enhanced CBM-I (Holmes et al, 2006; 2009; Rohrbacher et al, 2014), while the other twelve studies varied between four to twelve computerised sessions delivered over a period from six days to four weeks. Five

studies followed CBM-I protocol as per Blackwell et al (2015; Ji et al, 2018; Murphy et al, 2015; Renner et al, 2017; Sit et al, 2020). This comprised 12 sessions (each with 64 training stimuli) completed over a 4-week period (one session per day in the first week, and two sessions per week in each of the three subsequent weeks), with six sessions using audio descriptions as per previous studies (Holmes et al, 2006; Blackwell & Holmes, 2010) and the other six sessions requiring participants to generate mental images for stimuli presented in a picture-word format (Holmes et al, 2008). Two studies, one (Torkan et al, 2014) requiring participants to complete seven sessions over 1-week (one a day), and another (Pictet et al, 2016) with four sessions completed over six days, both used imagery enhanced CBM-I interventions comprised solely of audio descriptions (Blackwell & Holmes, 2010; Holmes et al, 2006). Another study (Lang et al, 2012) was also of one week duration, but used several various imagery-enhanced CBM techniques: days 2, 5 and 7 used audio descriptions (Blackwell & Holmes, 2010), days 3 and 6 used picture-word stimuli (Holmes et al, 2008), day 4 used a novel CBM of appraisals session (Lang et al, 2009), and the first session (day 1) comprised all three CBM components. Two studies (Feng et al, 2020; Hirsch et al, 2020) involved 10 sessions of imagery-enhanced CBM-I, using audio descriptions of 40 worry- or rumination-related scenarios (Hirsch et al, 2018), completed over a period of three weeks. Feng and colleagues (2020) also completed a second single session study (reported in the same paper) using this protocol.

Two studies (Williams et al, 2013; 2015) tested a combined intervention on participants diagnosed with major depressive episode. Both studies first asked participants to complete seven 20-minute sessions of imagery-enhanced CBM-I using audio descriptions (Blackwell & Holmes, 2010), then followed by six sessions of internet-based cognitive behaviour therapy (iCBT) based on the Sadness Program (Titov et al, 2010). Post-treatment outcome measures taken following the CBM-I interventions in these studies (i.e., prior to

beginning the iCBT component) allowing mental imagery-related components to be evaluated both separately and (with the inclusion of a waitlist-iCBT control group; i.e., no prior CBM-I) in relation to the potential effects on the subsequent iCBT interventions.

Two other studies used alternative computerised psychotherapeutic approaches to CBM-I (Dainer-Best et al, 2018; Linke & Wessa, 2017). Dainer-Best and colleagues (2018) developed and used a novel computerised CBM intervention called positive self-reference training (PSRT), which focused on enhancing self-referent processing by encouraging participants to imagine themselves and their future more positively via cued descriptions of positive scenarios (e.g., going to a café or receiving a gift) and then audio record key aspects of these images. Linke and Wessa (2017) designed a computerised “mental imagery training” program to be used by participants to promote positive emotions, affirmative thoughts, and pleasurable sensations associated with food stimuli and activities, with a view to increasing behavioural activation and reducing depression symptoms.

Only one study (Di Simplicio et al, 2020) used a non-computerised, face-to-face intervention with the aim of promoting positive imagery. This study used an approach called Functional Imagery Training (FIT) with a standard protocol (Kavanagh, Connolly, Andrade, & May, 2016) involving four key elements: (1) formulation of personal motives for addressing target behaviours (in this instance, self-harm); (2) motivational interviewing combined with mental imagery to enhance motivation to change; (3) refinement of goals for change and strategies to achieve them (including imagery-based emotion regulation); and (4) practice of functional imagery to support goal-achievement (as outlined by Di Simplicio et al, 2020, p. 728). The two face-to-face sessions were also supported by use of a smartphone app which included audios to assist participants with imagining adaptive activities.

3.5 Outcome Measures

All studies measured depression or anxiety related outcomes. Fifteen of the eighteen studies included at least one general measure of depression symptoms, while the three remaining studies included either a combined measure of anxiety and depression symptoms (Di Simplicio et al, 2020), a measure of positive and negative affect (Rohrbacher et al, 2014), or a related measure of behavioural activation (Renner et al, 2017). Four studies included additional specific measures of rumination (Feng et al, 2020; Hirsch et al, 2020; Lang et al, 2012; Sit et al, 2020), one of anhedonia (Pictet et al, 2016), and six of schema-related processing as relevant to depressive symptomatology (Blackwell et al, 2015; Dainer-Best et al, 2018; Hirsch et al, 2020; Ji et al, 2018; Lang et al, 2012; Torkan et al, 2014). Nine studies included a general outcome measure of anxiety symptoms (Holmes et al, 2006; Holmes et al, 2009; Lang et al, 2012; Murphy et al, 2015; Torkan et al, 2014; Williams et al, 2013; Williams et al, 2015) and two of these studies also measured outcomes related more specifically to worry (Feng et al, 2020; Hirsch et al, 2020).

Other measures related to aspects of physical and psychological wellbeing or generation of mental imagery as relevant to directly affecting or modulating the efficacy of interventions. The Positive and Negative Affect Schedule (PANAS; Watson & Clark, 1988) was used in seven studies to provide a broader measure of both positive and negative affect across two respective subscales (Di Simplicio et al, 2020; Holmes et al, 2009; Holmes et al; Linke & Wessa, 2017; Murphy et al, 2015; Rohrbacher et al, 2014; Sit et al, 2020). Six studies employed specific measures of interpretation bias (Feng et al, 2020; Hirsch et al, 2020; Pictet et al, 2016; Rohrbacher et al, 2014; Williams et al, 2013; Williams et al, 2015), and eight measured factors relevant to mental imagery (Blackwell et al, 2015; Di Simplicio et al, 2020; Feng et al, 2020; Hirsch et al, 2020; Ji et al, 2018; Lang et al, 2012; Murphy et al, 2015; Pictet et al, 2016) including generation of prospective mental imagery and individual

ability (or propensity) to mental imagery. Other measures pertained to self-harm (Di Simplicio et al, 2020), neuroticism (Murphy et al, 2015), optimism (Feng et al, 2020; Ji et al, 2018), reward sensitivity (Linke & Wessa, 2017; Pictet et al, 2016), distress (Williams et al, 2013; 2015), and disability (Williams et al, 2013; 2015). The number key in Table 2 corresponds to the outcome measures listed by study in Table 1.

Table 2*Outcome Measures*

- Depression**
1. Beck Depression Inventory-II (Beck et al., 1996)
 2. Centre for Epidemiologic Studies-Depression Scale (Radloff, 1977)
 3. Patient Health Questionnaire (Kroenke & Spitzer, 2002)
 4. Hamilton Rating Scale for Depression (Hamilton, 1960)
- Rumination
5. Ruminative Response Scale (Nolen-Hoeksema & Morrow, 1991)
 6. Repetitive Thinking Questionnaire (McEvoy et al., 2014)
- Anhedonia
7. The Snaith-Hamilton Pleasure Scale (Snaith et al., 1995)
- Behavioural Activation
8. Behavioural Activation for Depression Scale (Kanter et al., 2007)
- Schema-Related Processing
9. Scrambled Sentences Task (Rude et al, 2002)
 10. Self-Referent Encoding Task (Derry & Kuiper, 1981)
- Anxiety**
11. State Trait Anxiety Inventory (Spielberger et al., 1983)
 12. Generalised Anxiety Disorder Scale-7 (Spitzer et al, 2006)
- Worry
13. Penn State Worry Questionnaire (Meyer et al., 1990)
 14. Penn State Worry Questionnaire-Past Week (Stöber & Bittencourt, 1998)
 15. Breathing Focus Task (Eagleson et al., 2016)
- Combined (Mood and Anxiety)**
16. Depression Anxiety and Stress Scales-21 (Henry & Crawford, 2005)
- Positive and Negative Affect**
17. Positive and Negative Affective Schedule (Watson & Clark, 1988)
- Mental Imagery**
- Imagery Propensity/Ability
18. Spontaneous Use of Imagery Scale (Reisberg et al., 2003)
 19. Plymouth Sensory Imagery Questionnaire (Andrade et al, 2014)
 20. Vividness of Visual Imagery Questionnaire (Marks, 1973)
- Prospective Imagery
21. Prospective Imagery Task (Stöber, 2000)
 22. Impact of Future Events Scale (Deepröse & Holmes, 2010)
- Interpretation Bias**
23. Recognition Task (Hirsch et al., 2018; Matthews and Mackintosh, 2000)
 24. Lexical Decision Task (Hirsch & Matthews, 1997; 2000)
 25. The Ambiguous Scenarios Test for depression-related bias (Rohrbacher & Reinecke, 2014)
 26. Response to Intrusions Questionnaire (Clohessy & Ehlers, 1999)
- Self-harm**
27. Self-harm Imagery Interview (Hales et al., 2011)
 28. Craving Experience Questionnaire for Self-Harm (May et al., 2014)
- Neuroticism**
29. Eysenck Personality Questionnaire Neuroticism sub-scale (Eysenck et al., 1985)
- Optimism**
30. The Life Orientation Test-Revisited (Scheier et al., 1994)
- Reward Sensitivity**
31. Approach Avoidance Task (Rinck & Becker, 2007; Wiers et al., 2010)
 32. Probabilistic Reward Task (Pizzagalli et al., 2005)
 33. Reward Responsiveness Scale (Van den Berg et al., 2010)
 34. Temporal Experience of Pleasure Scale (French version; Favrod, Giuliani, & Bonsack, 2009)
- Distress**
35. Kessler Psychological Distress Scale (Kessler et al., 2002)
- Disability**
36. World Health Organization Disability Assessment Schedule-II (Ustün et al., 2010)

3.6 Risk of Bias in Included Studies

A summary of the risk of bias across studies is presented in Figure 2.

Figure 2

Risk of Bias Summary

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Blackwell et al. (2015)	+	+	+	+	+	+	?
Dainer-et al. (2018)	+	+	+	+	+	?	+
Di Simplico et al. (2020)	+	+	-	+	-	-	+
Feng et al. (2020)	+	+	-	-	+	?	+
Hirsch et al. (2020)	+	+	-	-	+	?	+
Holmes et al. (2009)	?	?	-	?	+	?	+
Holmes et al. (2006)	?	?	?	?	+	?	+
Ji, Holmes, Blackwell (2018)	+	+	+	+	+	+	?
Lang et al. (2012)	+	+	-	?	+	?	+
Linke & Wessa (2017)	?	?	+	+	+	?	+
Murphy et al. (2015)	+	+	-	?	+	?	+
Pictet et al. (2016)	+	+	+	+	+	?	+
Renner et al. (2017)	+	+	+	+	+	+	?
Rohrbacher et al. (2014)	?	?	?	?	+	?	+
Sit et al. (2020)	-	-	-	-	+	?	+
Torkan et al. (2014)	?	?	?	?	-	?	+
Williams et al. (2013)	+	+	+	+	-	+	+
Williams et al. (2015)	+	+	+	+	-	+	+

- High risk of bias
 ? Unclear risk of bias
 + Low risk of bias

3.6.1 Allocation

Twelve studies (Blackwell et al, 2015; Dainer et al, 2018; Di Simplicio et al, 2020; Feng et al, 2020; Hirsch et al, 2020; Ji et al, 2018; Lang et al, 2012; Murphy et al, 2015; Pictet et al, 2016; Renner et al, 2017; Williams et al, 2013; Williams et al, 2015) were deemed to be at low risk of bias for random sequence generation. This judgement was based on appropriate randomisation methods being reported (namely use of web-based randomisation, a computerised random number generator, randomisation codes being prepared independently of researchers, or use of sealed envelopes). Five studies were rated as having an unclear risk of bias, as they were described as “randomised” but were lacking in sufficient details on which to judge to potential bias (Holmes et al, 2006, Holmes et al, 2009; Linke & Wessa, 2017; Rohrbacher et al, 2014; Torkan et al, 2014). Sit et al (2020) openly acknowledged non-random allocation and were therefore considered at high risk of bias for both random sequence generation and allocation concealment.

Given that the computerised and web-based methods of randomisation used also concealed allocation prior to assignment, ratings of low risk of bias for allocation concealment also corresponded with those given for random sequence generation. Those studies with inadequate detail of random sequence generation were also found to have an unclear risk of bias on the basis of not providing sufficient details of allocation concealment.

3.6.2 Blinding

Eight studies (Blackwell et al, 2015; Dainer et al, 2018; Ji et al, 2018; Linke & Wessa, 2017; Pictet et al, 2016; Renner et al, 2017; Williams et al, 2013; Williams et al, 2015) were considered to be at low risk of bias for blinding of participants and personnel. The interventions within these studies were completed entirely online and therefore enabled personnel to remain

blind. This was also the case for blinding of outcome assessments within these studies, and also for one study conducted in-person which clearly reported that their outcome assessors were blind to allocation (Di Simplicio et al, 2020). Three studies (Holmes et al, 2006; Rohrbacher et al, 2014; Torkan et al, 2014) were rated as having unclear risk of bias with respect to blinding of participants and personnel due to insufficient detail being reported, and seven studies (Di Simplicio et al, 2020; Feng et al, 2020; Hirsch et al, 2020; Holmes et al, 2009; Lang et al, 2012; Murphy et al, 2015; Sit et al, 2020) were deemed at high risk as they clearly noted personnel to have had an awareness of participant assignment due to higher levels of personnel-participant contact/guidance. These unclear and high risk ratings were congruent for bias relating to blinding of outcome assessments with the exception of three studies (Holmes et al, 2009; Lang et al, 2012; Murphy et al, 2015) which were rated as high risk for blinding of participant and personnel but as unclear risk for blinding of outcome assessment because insufficient detail was reported.

3.6.3 Incomplete Outcome Data

Four studies were deemed as high risk for attrition bias. Both studies by Williams and colleagues (2013; 2015) had high rates of attrition (>20%) from allocation to completion of CBM-I treatment, and Torkan and colleagues (2014) and Di Simplicio and colleagues (2020) both reported high levels of attrition (>30%) at 2-week and 6-month follow-up, respectively. Although Di Simplicio and colleagues (2020) reported a 24% attrition rate for their primary outcome at 3-month follow-up, their sample size at allocation was relatively small ($n= 38$) and rates of attrition (three months) varied significantly between groups (immediate treatment: 36.8%; delayed treatment: 10.5%). None of these four studies included dropouts in their analyses and nor did they report imputation to account for missing data. The other 14 studies were considered to be at low risk for attrition. This is either because they had low rates of

attrition (<20%) which were balanced across groups, or because they used appropriate methods of imputation to account for missing data.

3.6.4 Selective Reporting

Five studies were deemed to be at low risk of bias for selective reporting. Blackwell and colleagues (2015) and two affiliated papers (Ji et al, 2018; Renner et al, 2017) pre-registered protocol for the methods and combined outcomes measured in the single sample population included in their reports. All pre-registered primary and secondary outcomes are reported across these three papers and therefore they were deemed at low risk of bias. Similarly, the two separate studies conducted by Williams and colleagues (2013; 2015) were considered low risk of selective reporting as both pre-registered methods and outcomes which were appropriately followed-up and reported. Although Di Simplicio and colleagues (2020) diligently pre-registered their study, they were rated as high risk of selective reporting as they did not report planned analyses for outcome measures taken at 3- and 6-month follow-up due to high attrition. The other 13 included studies did not pre-register their studies and intended outcomes and were therefore rated as unclear for risk of bias attributable to selective reporting.

3.6.5 Other Sources of Bias

Blackwell and colleagues (2015) and two affiliated papers (Ji et al, 2018; Renner et al, 2017) were deemed to have an unclear risk of other bias as control participants scored significantly higher at baseline on vividness of negative future imagery than did those in the intervention group on the Prospective Imagery Task (PIT). As this measure is associated with enhanced imagery of future negative events, and also higher levels of anxiety (Stöber, 2000), it is possible that the control group would have been less likely to show improvements on this measure regardless of intervention. No other sources of bias (such as baseline imbalances) were

identified in the other 17 studies, and they were all therefore rated as low risk for other sources of bias.

3.6.6 Summary of Risk of Bias

While none of the included studies were rated as having a low risk of bias on all assessed criteria, there were four studies that scored as low risk on all criteria except for unclear ratings on either ‘selective reporting’ due to the study not being reported as pre-registered (Dainer et al, 2018; Pictet et al, 2016) or ‘other bias’ attributable to significant differences on baseline measures (Blackwell et al, 2015; Ji et al, 2018; Renner et al, 2017). Two studies by Williams and colleagues (2013, 2015) were rated as having a low risk of bias on all criteria except for ‘incomplete outcome data’ which was rated as high risk of bias due to high rates of participant attrition at follow-up in both studies. A further four studies were also rated as high risk for one of the criteria (Holmes et al, 2009; Lang et al, 2012; Murphy et al, 2015; Torkan et al, 2014), two studies for two of the criteria (Feng et al, 2020; Hirsch et al, 2020), and two studies for three or more criteria (Di Simplicio et al, 2020; Sit et al, 2020; see Figure 2). Seven studies were rated as having an unclear risk of bias on two or more of the assessed criteria (Holmes et al, 2006, Holmes et al, 2009; Lang et al, 2012; Linke & Wessa, 2017; Murphy et al, 2015; Rohrbacher et al, 2014; Torkan et al, 2014).

3.7 Efficacy of Interventions

The study findings were considered by outcomes relevant to efficacy of interventions on mood and anxiety problems, and also factors modulating clinical efficacy. For convenience and clarity, these were classified under headings of: efficacy on depression, efficacy on anxiety, and other additional factors modulating clinical efficacy.

3.7.1 Efficacy on Depression

Of the 12 studies that measured outcomes related to general depression symptoms, six studies (50%) reported a significant improvement in depression symptoms (at least on the BDI-II, if not also on other depression measures) following intervention over that observed in control groups. Five of these studies used imagery enhanced CBM-I within their treatment condition, with two studies showing superiority of imagery enhanced CBM-I over standard (verbal) CBM-I (Pictet et al, 2016; Torkan et al, 2014), two over control conditions using imagery and audio descriptions without bias modification (Lang et al, 2012; Torkan et al, 2014), and three over waitlist control groups (Pictet et al, 2016; Sit et al, 2020; Williams et al, 2015). Williams and colleagues (2015) also showed that completing CBM-I prior to iCBT showed a greater improvement in depression symptoms following the combined intervention when compared to waitlist followed by iCBT alone. Linke & Wessa (2017) found a significant improvement in depression symptoms on the BDI-II for individuals receiving a mental imagery training intervention when compared to waitlist control.

In terms of other outcomes considered by us to represent symptoms relevant to depression (i.e., based on DSM-5 criteria), imagery enhanced CBM-I was found to have superior efficacy over control groups in improving symptoms of rumination in three studies (Hirsch et al, 2020; Sit et al, 2020; Williams et al, 2013), anhedonia in two studies (including on the anhedonia subscale of the BDI-II; Blackwell et al, 2015; Pictet et al, 2016), negative affect in three (PANAS; Holmes et al, 2009; Rohrbacher et al, 2014; Sit et al, 2020) and schema-related processing in two studies (Holmes et al, 2009; Lang et al, 2012), as well as increasing behavioural activation in one study (Renner et al, 2017). Linke and Wessa (2017) also found a significantly greater improvement in anhedonia in response to their mental imagery training, and Dainer and colleagues (2018) in schema-related processing in response to

PSRT (which they note as correlated with depression change in their study), when compared to respective waitlist and active control groups.

3.7.2 Efficacy on Anxiety

Of the nine studies that included outcomes measures relating to symptoms of anxiety (including worry), six studies (66%) reported a significant improvement on at least one of these measures following intervention when compared to controls. All six of these studies used imagery enhanced CBM-I and compared efficacy with various control groups comprising of either standard (verbal) CBM-I (Feng et al, 2020; Hirsch et al, 2020; Holmes et al, 2006; Holmes et al, 2009; Torkan et al, 2014), audio descriptions of ambiguous scenarios (Feng et al, 2020; Hirsch et al, 2020; Torkan et al, 2014), or waitlist followed by iCBT (Williams et al, 2015).

As four of these studies (Feng et al, 2020; Hirsch et al, 2020; Holmes et al, 2006; Holmes et al, 2009) were deemed to be at high risk for bias relating to at least one area of blinding, it is difficult to rule out the possibility of demand effects in these studies. High risk of bias due to incomplete outcome data (i.e., attributable to high rates of attrition) may also have affected outcomes in the two other studies finding significant between group effects for imagery enhanced CBM-I in reducing anxiety symptoms (Torkan et al, 2014; Williams et al, 2015).

3.7.3 Additional Factors Modulating Clinical Efficacy

3.7.3.1 Factors Modulating Efficacy on Mood. Various factors measured in the included studies were found to modulate effects on measures of depression symptoms. Four studies, all using imagery enhanced CBM-I, found effects of various mental imagery measures in addition to mood related factors being impacted by their interventions. Lang et al (2012) found that responders to their intervention—that is, those participants who demonstrated

decreases in depression symptoms (BDI-II) and cognitive bias (based on the Scrambled Sentences Task [SST] and the Response to Intrusions Questionnaire [RIQ])— also had higher scores on measures of mental imagery propensity (Spontaneous Use of Imagery Scale [SUIS]) and prospective mental imagery (PIT). In addition to finding significant improvements in depression symptoms (BDI-II) and cognitive bias (SST), Torkan et al (2014) also report increased scores on measures of imagery vividness (Vividness of Visual Imagery Questionnaire [VVIQ]) following their intervention, but not on the SUIS which can be considered a more trait-based measure of imagery propensity. Increases in vividness (VVIQ) over time in response to imagery enhanced CBM-I were also reported by Renner and colleagues (2017) in addition to increases in behavioural activation on the BADS, as well as by Murphy and colleagues (2015) who found improvements in depression symptoms in both their treatment and control groups. Additionally, in two affiliated studies using the same population sample, Blackwell and colleagues (2015) reported observing an improvement in depression symptoms only in those participants with fewer than five episode of depression who engaged to a threshold level of imagery, while Ji and colleagues (2018) found that increased vividness of prospective mental imagery (PIT) predicted optimism post-treatment and at seven-month follow-up.

Sit and colleagues (2020) found increases in positive affect and decreases in negative affect on relative subscales of the PANAS in addition to improvements in depression symptoms (BDI-II) in response to their intervention, including reduced rumination (Ruminative Response Scale). Although Rohrbacher and colleagues (2014) only measured depression symptoms (BDI-II) at baseline (with no significant differences found between groups prior to intervention), they also found changes on the PANAS comparable to Sit and Colleagues (2020) in response imagery enhanced CBM-I. Furthermore, Rohrbacher and colleagues (2014) also

observed improvements on an additional measure of interpretation bias (AST; not measured by Sit et al, 2020) following imagery-enhanced CBM-I. With additional respect to modulating effects of interpretation bias on efficacy, it is notable that Williams and colleagues (2015) observed reductions in interpretation bias in response to imagery enhanced CBM-I in addition to improved BDI-I scores, and also that Lang and colleagues (2012) were able to observe reductions on two similar (schema-related) measures of cognitive bias (SST and RIQ) in addition to decreases in depression symptoms.

Several findings in relation to factors modulating efficacy were also of note in studies using alternative intervention approaches to CBM-I. Linke and Wessa (2017) found that those individuals that showed a reduction in depression symptoms (BDI-II) in response to their mental imagery training intervention (versus waitlist control) also demonstrated faster approach towards positive food stimuli and activities on the Approach Avoidance Task (AAT). They also found that change in reward sensitivity (based on AAT responses) significantly predicted improvement in post-training BDI-II scores. Additionally, Di Simplicio and colleagues (2020), found that those individuals that showed a greater reduction in frequency of self-harm following FIT intervention showed higher scores on negative affect items (PANAS) relating to ‘nervousness’ and ‘jitteriness’ following episodes of self-harm (as measured over the course of treatment), as well as higher baseline psychopathology (MINI) and higher scores for negative intrusive imagery on the Impact of Future Events Scale.

3.7.3.2 Factors Modulating Efficacy on Anxiety. Of the six studies finding an improvement in anxiety symptoms in response to imagery enhanced CBM-I (i.e., when compared to control), one study also found a significant increase in positive mental imagery (Torkan et al, 2014) and two reported a reduction in measures of either schema-related cognitive bias (SST; Holmes et al, 2009) or interpretation bias (Recognition Task; Hirsch et al,

2020). Interestingly, Holmes and colleagues (2009) found that CBM-I with *verbal* instructions (as opposed to *imagery*) led not only to a lack of mood improvement, but also to an increase in anxiety within this condition over the course of their single session intervention. This result was taken to largely confirm previous findings of a reduction in positive mood (PANAS) following verbal CBM-I found by Holmes and colleagues (2006). They hypothesised that this increase in anxiety in the verbal condition could be attributable to participants making “unfavourable personal comparisons with the highly positive material.” A second study within their paper tested this hypothesis by adding in an additional condition of CBM-I with reduced verbal comparisons and found that the anxiety levels were ameliorated in this group—thus, providing empirical weight to their explanation for the original adverse effect on anxiety symptoms. Furthermore, Lang et al (2012) found that both imagery enhanced CBM-I and a control condition that involved visualising mental imagery (without correcting biases) both had a significant effect in reducing anxiety symptoms over time (with only a trend level effect [$p = .09$] of CBM-I over the control group). They suggest that a common attentional component across groups— i.e., involving disengaging from distracting thoughts and focussing on imagery—could have contributed to the significant decrease in anxiety found in both conditions.

Murphy et al (2015) found a similar improvement in both their imagery-enhanced CBM-I condition and a control condition *without* an imagery component on various mood and anxiety related outcomes measures. The authors suggest it is likely that non-specific factors, such as the enjoyment of taking part in a research study, increased social interaction, cognitive stimulation, or expectation of training effects, may have broadly impacted these outcomes across both groups in their sample of older adults. However, they do also suggest it as noteworthy that other studies in younger adults finding a comparably larger improvement on

outcome measures following imagery enhanced CBM-I have tended to have a shorter timescale for intervention (i.e., a single session or sessions completed within a one-week period; e.g., Holmes et al, 2009; Torkan et al, 2014), whereas studies using a longer four-week schedule did not find a predicted difference between groups (e.g., Blackwell et al, 2015).

4. Discussion

4.1. Summary of Main Results

This study reviewed psychotherapeutic interventions aimed at increasing positive imagery in individuals with clinical mood and anxiety problems evaluated across 18 randomised control trials, with a view to understanding whether the interventions led to improvement in symptoms. The review highlights the preponderance of computerised interventions, most notably CBM-I, promoting mental imagery as a means to reduce negative cognitive bias, with a view to improving mood and anxiety related outcomes. It also explores the role of a number of relevant cognitive factors in potentially modulating clinical efficacy of these interventions. Having synthesised results narratively across mood and anxiety related outcomes, overall findings show variable efficacy for interventions aimed at increasing positive mental imagery on clinical outcomes specific to depression and anxiety.

Findings with respect to efficacy of interventions on depression symptoms were inconsistent between studies but showed some promise when considering effects on specific facets of depression symptoms and cognitive factors linked to the intervention. While 12 of the included studies employed outcomes to measure the effect of interventions on general levels of depression symptoms (e.g., BDI-II, PHQ-9), only six of these studies (50%) found a significant improvement on these measures in the intervention group versus controls. Previous narrative reviews report that imagery-based interventions are highly effective (Blackwell, 2019; Holmes & Matthews, 2010; Pearson et al, 2015), but they did not limit their findings to studies with a comparison group as we did. It is also notable that all but one of the included studies reports allocation as being randomised. While two of these studies (Pictet et al, 2020; Linke & Wessa, 2017) were considered to have no clear risk of bias in our assessment, findings relating to

effects of CBM-I on depression symptoms for the other four studies should be interpreted with caution given that they were deemed to be at high risk of bias in at least one of five areas due to issues pertaining to allocation, blinding or attrition. However, a further 10 studies (eight using imagery enhanced CBM-I, and two using alternative imagery-based approaches) demonstrated superior efficacy within the intervention group on at least one peripheral or process-specific measure of depression symptoms, including rumination, anhedonia, positive/negative affect, behavioural (de)activation, and negative schema-related processing. The effectiveness of interventions on more general measures of depression symptoms can therefore be considered somewhat variable.

When considering both general depression symptoms (i.e., BDI-II, PHQ-9, CES-D, HRSD) and closely related peripheral factors (i.e., rumination, anhedonia, negative affect, behavioural activation, negative schema-related processing), of the 13 studies measuring at least one of these outcomes, all of them (100%) observed an improvement on at least one measure of depression and/or related symptoms within the treatment group when compared to controls. The remaining three studies also demonstrated some efficacy for imagery-based interventions on constructs and processes related to mood. Ji and colleagues (2020) demonstrated an increase in optimism in the intervention group, and Murphy and colleagues (2015) a decrease in negative mood, depression, and neuroticism, and an increase in optimism, with no significant differences in response between the imagery-enhanced CBM-I condition and the active control group. Di Simplicio and colleagues (2020) observed significant behavioural reductions in self-harm in response to FIT within their sample but did not report measures of depression symptoms due to high attrition at follow-up. This study was also deemed to be at high risk of bias on criteria pertaining blinding, missing outcome data, and selective reporting. This suggests that the interventions were found to be more effective when

specific facets of depression symptoms and cognitive factors linked to the interventions were taken into consideration.

Although there is some evidence that the included interventions have efficacy in modulating key facets of depression that align with the intervention, including vividness of mental imagery and reduction in negative cognitive bias, evidence for more global benefits on depression (vis-a-vis overturning "caseness" or remitting depression as a "disorder") is less compelling. Furthermore, as many of the studies test multiple effects on various outcomes measures, the likelihood of false positives on certain measures is high; especially for those studies measuring peripheral factors (e.g., rumination, anhedonia) overlapping with broader clinical measures of depression symptoms. Although the three studies reporting efficacy of CBM-I on anhedonia and behavioural activation were considered to have no clear risk of bias in our assessment, it is also notable that the four studies reporting efficacy on rumination and schema-related processing were found to have inadequate blinding (and one study also for allocation; Sit et al, 2020), which may have affected their outcomes.

The overall evidence for efficacy on anxiety symptoms was comparable to depression but more congruent with a broader anxiety construct (when including state- and trait-based measures, as well as those pertaining to worry). All nine of the studies measuring anxiety outcomes used imagery-enhanced CBM-I, with six of these studies (66%) reporting a significant improvement following intervention when compared to non-imagery controls (Feng et al, 2020; Hirsch et al, 2020; Holmes et al, 2006; Holmes et al, 2009; Torkan et al, 2014; Williams et al, 2015). Two other studies observed significant improvements in anxiety symptoms in both intervention and control groups (Lang et al, 2012; Murphy et al, 2015). Williams and colleagues (2013) only measured anxiety symptoms following a combined intervention (i.e., post-treatment, following both CBM and iCBT), but did observe an overall

improvement. The effectiveness of the interventions on anxiety symptoms can therefore be considered comparable to depression symptoms, but the measures used related to a broader construct of anxiety rather than specific facets or symptoms.

The utility on anxiety found for imagery-enhanced CBM-I in this review is perhaps unsurprising given the earlier findings of Holmes and colleagues (2006, 2009) with respect to the advantage of imagery-based CBM-I interventions in reducing anxiety symptoms when compared to verbal CBM-I (which was found to increase anxiety symptoms in previous interventions). Given this prior evidence, it is likely that common therapeutic factors (e.g., enjoyment, social interaction, cognitive stimulation) account for the comparable efficacy on anxiety found by Murphy and colleagues (2015) in their verbal control condition. Similarly, the improvement in anxiety observed by Lang and colleagues (2012) in their imagery-based control may be attributed to a common attentional factor (engaged when visualising mental imagery) which served to distract away from anxious thoughts. Although this raises a question as to the added benefits of the bias modification component of CBM-I on anxiety symptoms, Holmes and colleagues (2009) did find that reducing verbal comparisons in verbal CBM-I ameliorated adverse effects on anxiety and reduced differences in efficacy when compared to imagery-enhanced CBM-I.

Taken on balance, the factors inferring efficacy of imagery-based interventions on depression symptoms could point more specifically towards reductions in anhedonia (i.e., a lack of emotional affect often characterising depression). In this sense, the increase in positive affect observed in some studies in response to visualising positive mental imagery may serve to reduce symptoms of anhedonia. Indeed, the BDI-II does include a subscale measuring symptoms of anhedonia which was not analysed by the majority of the studies but may at least partially account for effects of the interventions in reducing symptoms on this measure.

Furthermore, the only study in this review to measure both increases in positive affect (PANAS), as well as finding a significant change on the BDI-II, reported observing a respective increase in positive affect and decrease in symptoms in the imagery CBM group when compared to controls (Sit et al, 2020). It is in this vein that Blackwell and colleagues (2015) note anhedonia to be “an important but often neglected clinical target in its own right.” All studies included in this review used interventions that promoted the use of vivid mental imagery to visualise more positive outcomes. Most notably, as well as modulating positive changes in interpretation bias in several studies, increased vividness of mental imagery was also observed to be a key modulating factor for improvement in depression symptoms in at least six of the studies reviewed.

4.2. Overall Completeness and Applicability of Evidence

The inclusion of multiple outcome measures, as well as the broad narrative comparisons made in relation to efficacy of interventions on symptoms of both anxiety and depression, allowed for inclusion of relevant findings from a larger number of studies with respect to establishing estimates of effectiveness on each of these key clinical outcomes. As our eligibility criteria allowed for inclusion of participants with clinical diagnoses in addition to samples of generally healthy participants (showing various degrees of mood and anxiety symptoms on clinically relevant outcome measures), the findings of this review can be considered more broadly generalisable to a range of clinical and non-clinical populations. Only half of the included studies had follow-up assessments (ranging between one-week to six-months) and where measured longer-term outcomes tended to be variable with respect to sustained efficacy.

4.3. Quality of the Evidence

The risk of bias for each study and across bias domains has been reported in detail previously and summarised in Figure 2. Power calculations were conducted and reported in all but eight studies (Di Simplicio et al, 2020; Holmes et al, 2006; Holmes et al, 2009; Ji et al, 2018; Lang et al, 2012; Murphy et al; 2015; Renner et al, 2017; Rohrbacher et al, 2014). However, some studies with smaller sample sizes that did not report power calculations may have missed real effects. Seven studies had small samples under 65 participants (Di Simplicio et al, 2020; Holmes et al, 2006; Holmes et al, 2009; Lang et al, 2012; Linke & Wessa, 2017; Rohrbacher et al, 2014; Torkan et al, 2014). Seven studies had large samples of over 100 participants (Blackwell et al, 2015 [$N = 150$]; Feng et al, 2020 [$N = 178$]; Hirsch et al, 2020 [$N = 178$]; Ji et al, 2018 [$N = 150$]; Pictet et al, 2016 [$N = 101$]; Renner et al, 2017 [$N = 150$]; Williams et al, 2015 [$N = 121$]). Four of these trials had no significant high risk biases identified (although several judgements were unclear due to poor reporting) and therefore perhaps more weight should be given to these studies (Blackwell et al, 2015; Ji et al, 2015; Pictet et al, 2016; Renner et al, 2017). Three of these studies reported outcomes in response to a single set of interventions conducted within the same sample of participants and found efficacy for imagery enhanced CBM-I in improving symptoms of anhedonia, as well as in increasing optimism and behavioural activation (Blackwell et al, 2015; Ji et al, 2015; Renner et al, 2017). They also found evidence that efficacy on all of these outcomes was modulated by increased vividness of mental imagery. Additionally, Pictet et al (2016) found efficacy of imagery CBM-I over control in improving symptoms on measures of both anhedonia and depression symptoms more broadly, which their analyses showed to be mediated by trained change in interpretation bias.

4.4 Potential Biases and Limitations

Some potential biases and limitations within the review process should be considered when interpreting the findings.

Outcome measures were categorised under various domains for convenience and ease of interpretation. It is acknowledged that some of these domains likely overlap with one another and represent similar constructs. For example, measures of generalised anxiety likely include items pertaining to worry, and measures of schema-related processing relate closely to those labelled as measuring interpretation bias. Although findings are discussed broadly across related measures, these crude categorisations may affect inferences drawn with respect to efficacy based on these outcomes.

Although all but one of the included studies used computerised interventions, there was significant heterogeneity between settings. For example, while some interventions were conducted in-person with high levels of guidance from personnel, others were conducted entirely remotely. Populations also varied to a large extent on factors such as age, country, and degree of symptom severity and baseline impairment. While many of the included studies controlled for some baseline factors, it is still possible that such heterogeneity will have affected the degree to which participants were able to benefit from interventions.

Three literature databases were used to conduct the searches for this review. Although searches were repeated by an independent reviewer to provide assurance that no relevant articles were missed, “grey literature” was not included, which may have led to an overestimate in efficacy, because of the potential for publication bias (i.e., with null findings being less likely to be published).

4.5 Conclusions

The studies reviewed indicate variable efficacy for interventions promoting positive mental imagery in alleviating symptoms of depression and anxiety, with only six out of 12 studies (50%) measuring general depression symptoms finding an improvement following treatment over controls, and six out of nine studies (66%) measuring symptoms of anxiety or worry. All but one of the studies employed computerised interventions, and only two of these used approaches other than imagery enhanced CBM-I. Efficacy of imagery-based interventions for depression reached 100% when allowing for improvement on at least one of all depression related outcomes (i.e., including specific measures of rumination, anhedonia, negative affect, behavioural activation, and negative schema-related processing) measured across 13 studies. However, these broader outcomes are considered to represent a wide range of constructs being evaluated and variability in measures used, and therefore may not be a particularly reliable indicator of more general efficacy for depression. Furthermore, it is also likely that the inclusion of multiple related clinical outcomes in the majority studies will have inflated the likelihood of a false positive effect on these measures.

Although changes in interpretation bias were found to modulate improvements in depression and anxiety across studies, the vividness of positive mental imagery elicited via the interventions was also found to be an important factor in modulating efficacy on clinical symptoms. Anhedonia in particular may be a target for interventions aimed at using positive mental imagery as a mechanism to increase positive affect. Three studies trialling various alternative interventions promoting positive mental imagery found efficacy for reducing self-harm, increasing approach to positive stimuli and activities, and in reducing negative schema-related processing and depression symptoms.

There are still however questions in relation to how these relatively brief imagery-based, computerised interventions compare with more traditional verbal-based cognitive behavioural therapies. There is a growing weight of evidence that positive mental imagery is effective in impacting factors relevant to CBM (i.e., imagery vividness and interpretation biases) which then seem to modulate effects on depression and anxiety symptoms, but what has not yet been thoroughly explored is how well computerised, imagery-based interventions fares against mainstream interventions such as CBT. Specifically, it is important to establish whether imagery-based CBM interventions are more efficient (i.e., showing comparable efficacy over fewer sessions) or may be more effective for specific individuals—for example, those individuals with fewer baseline symptoms or more trait propensity to mental imagery.

4.6 Implications for Practice

The current study highlights the importance of mental imagery in providing a mechanism through which to therapeutically impact negative cognitive biases underlying symptoms of anxiety and depression. Furthermore, the wider use of computerised interventions using imagery CBM-I and other similar interventions may provide an easily accessible and affordable mode of delivering effective intervention to individuals experiencing distress due to mood and anxiety problems. Promoting positive mental imagery as a mechanism for ameliorating such distress should also be considered a common adjunct to more typical face-to-face therapies, including in augmentation of CBT practices, which all too often focus on verbal cognitions at the expense of adequately assessing and utilising imagery.

4.7 Implications for Research

Future research should seek to further explore the efficacy of interventions aimed at promoting positive mental imagery in impacting emotional states more broadly, as well as

efficiency and acceptability compared to more commonly used verbally oriented interventions. It is also important to understand the extent to which factors such as imagery vividness and individual proneness to mental imagery may modulate the extent to which mental imagery positively or negatively impacts on various mood states. Interestingly, only one study with a smaller sample size ($N = 28$; Lang et al, 2012) found an association between efficacy on depression symptoms and scores on a more trait-based measure of imagery propensity (SUIS). It would therefore be important to elucidate the extent to which baseline mental imagery ability (or propensity) modulates effectiveness of imagery-based interventions on clinical outcomes; especially given that depressed individuals demonstrate deficits in generating positive imagery (Holmes et al, 2016). The role of mental imagery in altering cognitive bias and perception of events (or stimuli) would also be a useful avenue for future investigations.

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Part Two: Empirical Paper

Experimental Investigation of the Impact of Goal-Oriented Mental Imagery on Reward Perception

Abstract

Aims: Recent studies have shown that mood can bias perceived reward value, with this effect being strongest in individuals with more mood instability. Spontaneous use of mental imagery has been highlighted as an important feature in generating and maintaining mood symptoms in bipolar disorder. We examined whether mental imagery influencing motivation biases perceived reward value during learning, and to what extent effects are modulated by mood symptoms.

Method: 50 healthy participants completed a brief, online-based manipulation in which they generated mental images related to goal-attainment and goal-failure with a view to increasing and decreasing motivation, respectively. We quantified the efficacy of this manipulation on mood and motivation, as well as on the perception of reward stimuli encountered in two learning blocks. Participants performed each block under one of the two types of imagery, thus using a within-participants design. To test for bias in perceived reward value, participants were subsequently asked to indicate their preference in pairwise choices between all stimuli encountered. Trait mood instability (HPS), propensity towards imagery (SUIS), and depression symptoms (PHQ-9) were included in analyses to test for modulatory effects on biased preference.

Results: Goal-oriented mental imagery effectively impacted subjective motivation, with higher ratings in the goal-attainment imagery block, compared to goal-failure. Depression symptoms, but not mood instability, were observed to have a modulating effect on change in motivational state. The degree to which momentary motivation was impacted by imagery was positively associated with bias in perceived reward value, and further modulated by depression symptoms.

Conclusions: Our findings indicate that goal-oriented mental imagery is effective in impacting motivational state in healthy individuals reporting more depression symptoms, and that motivational state in turn modulates reward perception. Insights are offered to aid development of interventions using mental imagery as an emotional and motivational “amplifier” to improve depressed mood.

1. Introduction

1.1 Background

1.1.1 Mood and Reward Perception

Mood disorders are diverse: for example, in depression, individuals could be viewed as being more disposed to sad mood which thus reduces their drive with respect to reward (Clark et al, 2018). In mania, on the other hand, individuals show overall increased activity and energy levels, paired with either euphoria or irritability, and often overconfidence, leading to increased impulsivity and risk-taking (Berríos, 2004). These common phenotypic observations outline clear differences in terms of motivational drive and pursuit of goals (or rewarding outcomes) within mood disorders. This raises the question as to what extent changes in mood and motivation might bias reward perception, and also whether understanding the factors modulating these effects may inform interventions towards mitigating the often debilitating changes in mood and behaviour brought about by depression and mania.

A “mood as information” theory (Schwarz & Clore, 1983; 2003) argues that mood is adaptive for human beings, because moods have information value about the changing environment around us. By this view, positive mood signals that the environment is safe and rich in rewards, whereas negative mood signals that the environment is problematic, or lacking in rewards (Eldar et al, 2016; Schwarz & Clore, 2003). Although mood can affect how we perceive events, we likely vary in the extent that our moods bias our perception. When we are in a positive mood, we are likely to experience events and stimuli more positively and therefore attribute them with a higher reward value. Conversely, when we are in a negative mood, we are likely to perceive the environment more negatively and consequently attribute events and stimuli with a lower reward value. Having a moderate level of mood bias may be adaptive

when an environment is changing, either for better or for worse. In contrast, if a person's mood very strongly biases how they perceive rewards in the environment this cycle can then cause mood, expectations, and behaviour to escalate to extremes. The result may then precipitate a recursive cycle where events are perceived as being better than they are, leading to unrealistically high expectations about reward and eventually negative surprises that then worsen mood in a similar recursive cycle (Mason et al, 2017).

Eldar and Niv (2015) tested whether inducing changes in mood can change how individuals perceive the value of subsequently encountered stimuli. Participants completed a task in which they chose between pairs of stimuli: one of which was rewarded often and the other infrequently. Through trial and error, they learned the reward value of each option. Participants performed this task before mood induction, and then again afterwards, with a new set of options (i.e., different stimuli). Crucially, the stimuli presented before and after the mood induction had the same objective rate and magnitude of reward. At the end of the task participants were asked to choose between different pairs of all of the stimuli they had encountered, allowing the researchers to test whether changes in emotional state feed back onto how the subsequently encountered options are perceived. As predicted, they observed a *bi-directional* relationship between mood and reward perception: participants in a positive mood were biased towards perceiving the value of those options encountered after the mood induction as higher than those encountered before the mood induction, whereas those participants who received a negative mood induction perceived the value of subsequent rewards as lower. This work showed that changes in mood can bias the valuation of subsequent outcomes. Interestingly, this tendency was also higher in people with higher levels of hypomanic personality traits (a marker for risk of developing bipolar disorder; Kwapil et al, 2000). Furthermore, reward-related brain activity in the striatum was increased when in a

positive mood compared to negative mood, and these effects were stronger in those at with higher hypomanic traits. Overall, they used a computational model of participants' choice behaviour to infer the subjective reward value of options and to quantify how much this was biased away from their objective value by current mood (Eldar & Niv, 2015; Rutledge et al., 2017). This model allowed for the prediction and quantification of the extent that mood biases the perception of reward and provides a valuable marker by which to evaluate experimental manipulation of mood bias on reward perception.

Mood is a multifaceted construct, likely comprising both emotional valence and arousal. Indeed, the circumplex model of affect (Russell, 1980), which accounts systematically for a range of interrelated hedonic and motivational factors in influencing emotion (e.g., pleasure, excitement, arousal, distress, displeasure, depression, sleepiness, and relaxation), is now thought to be more consistent with many recent findings from behavioural, cognitive neuroscience, neuroimaging, and developmental studies of affect than other less nuanced models of emotion (Posner et al, 2005). In this sense, combining constructs that capture both valence (or 'hedonic tone') and state of arousal— as perhaps inferred by asking individuals to make separate, subjective ratings related to states of both 'happiness' and 'motivation'— would serve to produce a richer and more conducive representation of emotional state than would measuring either of these factors alone. Furthermore, motivational state is proposed to be mediated by endogenous fluctuations in dopamine response (Hamid et al, 2016; Niv et al, 2007), which have in turn been linked to risky decision-making (Chew et al, 2019). This suggests that changes in momentary mood and motivation may ramp up dopamine responses in the midbrain that then impact on decision making, and possibly also on reward perception.

One lesser explored aspect is whether higher levels of depression symptoms or mood instability bias perception of rewards. A depressed mood has been associated with a reduction

in reward learning (Drombrowski et al, 2013; Vrieze et al, 2013). However, other findings suggest that this association is more likely attributable to a reduction in valuation of rewards in depressed individuals rather than impaired learning (Huys et al, 2013). Moreover, it is notable that within clinical populations there is a preponderance of depressive symptoms (i.e., versus mania). In this sense, Eldar et al (2016) suggest that more frequent generation of negative moods might be due to a stronger biasing effect, which in turn reflects an evolutionary need to rapidly react to “negative changes in momentum.” This raises the question as to whether there are dissociable effects of depressed and hypomanic mood, possibly interacting between one another, and also to what extent changes in emotion and motivational state drive these effects. In this respect, while it is well established that cognitive factors (including both verbal cognition and mental images) have a key role in modulating changes in emotion and behaviour (e.g., Beck, 1976), more recent findings have shown that mental imagery, in particular, may be heightened in individuals disposed to unipolar and bipolar depression (Di Simplicio et al, 2016; Holmes and Mathews, 2005).

1.1.2 Mental Imagery

Mental imagery has been described as that which occurs when perceptual information is accessed from memory, giving rise to the experience of “seeing with the mind’s eye” or “hearing with the mind’s ear” (Kosslyn et al, 2001). Prospective or “future-focused” mental imagery is also common in the general population and known to have some role in various mood and anxiety disorders, including in both unipolar and bipolar depression (Di Simplicio et al, 2016). Holmes and Mathews (2005) propose that emotional processing in the brain is particularly sensitive to imagery and can act as an “emotional amplifier.” They also posit that processes involved in mental imagery overlap with those in perception and therefore imagined events may be responded to “as if” real. In this sense, imagery is now appreciated to be a

critical cognitive component in amplifying experience and exacerbating states of normal and abnormal emotion. It has thus been suggested that bipolar disorder patients may be particularly imagery-prone, and that the catalytic effect of mechanisms of mental imagery on emotion may precipitate the extremes of mood intensity and rapid changes in mood commonly observed in this clinical group (Holmes et al., 2008). Holmes et al (2011) tested the prediction that patients with bipolar disorder would score more highly on mental imagery measures. Their findings show mental imagery may be heightened in these individuals (Holmes et al., 2008) and are consistent with a fundamental phenomenology of intrusive imagery in bipolar disorder (Gregory et al, 2010; Mansell & Hodson, 2009; Mansell & Lam, 2004). This poses the question as to whether this form of imagery can be a target for intervention (Hackmann et al, 2011; Holmes et al, 2007), and, indeed, emerging evidence already suggests efficacy for interventions targeting mental imagery in a range of mood and anxiety disorders (see Part One), including a growing evidence-base relating to bipolar disorder (e.g., Holmes et al, 2008, 2011; Deepröse et al 2011; Ivins et al, 2014; Di Simplicio et al, 2016; O'Donnell et al, 2018).

1.1.3 Reward-Based Learning and Decision-Making

The decisions we make day-to-day are influenced by a range of factors. One factor appears to be our mood at that moment, which can influence how we perceive events that happen and available courses of action (Paul & Pourtois, 2017; Hägele et al, 2015). When in a better mood, we are likely to experience events (and in experimental context, *stimuli*) as being better than they actually are, i.e., positive mood signals that the environment is favourable, whereas negative mood signals that the environment is problematic (Eldar et al, 2016; Schwarz & Clore, 2003; see section 1.1.1). It has been shown experimentally in healthy participants that there is individual difference in the degree of this tendency for normal mood changes to bias the perception of stimuli when their reward value is learned by trial-and-error (Eldar & Niv,

2015). However, the factors that modulate this bias are poorly understood. For example, contextual factors such as how certain the person is about the options available (e.g., how well known the probability, magnitude and variance of reward are) may play a role. Similarly, personality traits related to extraversion and openness, as well as dispositional mindfulness (e.g., awareness of internal states), may also likely play a role (Smillie et al, 2019; Fisher et al, 2017). What is not known is how much this effect is driven by positive affect (happiness at that moment) per se, and how much it is driven by concomitant changes in motivational drive.

There is evidence that motivational state relates to endogenous levels of dopamine in the brain's reward system, which is known to fluctuate moment-by-moment, and these fluctuations predict reward-based decision-making in healthy participants (Chew et al, 2019). Various fMRI studies to-date have demonstrated increased dopamine and activation of the brain's reward system in response to real and imagined rewarding events, including when imagining rewarding scenes (Sulzer et al, 2013) or utilising other cognitive strategies aimed at increasing motivation (MacInnes et al, 2016). Indeed, many people purposefully modulate their own motivational states for example when preparing for job interviews, when playing sports, and other performance-focused activities (Holmes & Collins, 2001). A common method is to use visual imagery; for example, of achieving the goal of scoring a goal in game of football (Ramsey et al, 2010) or a successful putt in a round of golf (Smith et al, 2008). However, it has not been shown whether these states also influence perception of reward value (putatively via endogenous fluctuations in dopamine), in a similar way to being in a better mood.

The behavioural approach system (BAS) dysregulation theory (Depue & Collins, 1999) provides a model that integrates understanding of biological and psychosocial aspects of bipolar disorder, and specifically demonstrates how appraisal of external events culminates in neurobiological responses that drive changes in mood, motivation, and decision making.

Moreover, the model demonstrates how level of approach motivation serves to organise a diverse array of symptoms (e.g., motor, affective, cognitive, vegetative) which account for both poles (i.e., depression and hypomania/mania) of bipolar disorder. As such, the BAS model has since been expanded to provide more specificity in relation to how appraisal processes (i.e., related to reward perception), and dopaminergic response to rewards, feature within a causal chain leading to depression and mania (Urošević et al, 2008). According to this expanded model, individuals demonstrating more activation in the BAS system can orchestrate or pursue the very events that trigger an opposite state of deactivation; whereby, for example, in a state of increased activation (or dysregulation), an individual who is more prone to dysregulation of the BAS system may overestimate their abilities, thus setting unrealistic goals, and, in turn, setting themselves up for a failure through which an opposite state of deactivation can occur that then sets in motion processes leading to depression. Given the understanding provided by the BAS model, and the interaction this theory suggests between cognitive appraisal processes and activation of the BAS, a question is posed as to whether targeting cognitive processes involved in such reward based appraisals (e.g., goal-oriented or motivational mental imagery) may serve to regulate problematic states of over activation or deactivation of this system which are otherwise suggested to precipitate symptoms of unipolar and bipolar depression.

1.2 Current Investigation

Based on the literature reviewed so far, it is proposed that elucidating the role of mental imagery in affecting momentary changes in mood and motivational state could shed light on potential mechanisms that contribute to the aetiology and maintenance of mood disorders. It is also important to understand whether changes induced by mental imagery serve to bias perception of reward value in a similar manner to previous investigations which used a monetary outcome to induce mood (Eldar & Niv, 2015). Furthermore, as motivational state

relates to changes in endogenous dopamine levels known to impact reward learning and decision making (MacInnes et al, 2016; Urošević et al, 2008), and the extent of this can be regulated via use of mental imagery (Sulzer et al, 2013), understanding the link between mental imagery, motivation and reward perception could help towards the development of psychological interventions. Indeed, Holmes (2018) argues that more experimental and neurobiological work is needed to understand how best interventions can target mechanisms thought to contribute to mood disorders, including the rapid fluctuations in mood and motivational state observed in bipolar disorder. To this end, elucidating to what extent any changes we observe in motivation are modulated by individual differences attributable to trait mood instability, current depression symptoms, and individual proneness to mental imagery may provide an important contribution to understanding mechanisms relevant to refinement of targeted psychological interventions.

1.2.1 Aims and Hypotheses

The current investigation broadly aimed to explore the impact of mental imagery (in particular, goal-oriented mental imagery) on momentary mood and motivation, and in turn to what extent changes in mood and motivation influence perception of the reward value of learned stimuli of matched reward probabilities.

Two specific aims were formulated for this purpose. Firstly, we aimed to examine the impact of goal-oriented mental imagery on momentary mood and motivation; whilst also accounting for individual differences measures of trait mood instability, proneness to mental imagery, and depression symptoms (Aim 1). This was accomplished by using a brief, online-based manipulation in which participants are prompted to formulate meaningful goals and then utilise mental imagery (related to goal-attainment or -failure) with a view to impacting mood

and motivation at several time points, and also by testing for modulating effects of relevant traits and symptoms. Secondly, we aimed to explore whether goal-oriented mental imagery influencing momentary motivation and happiness also influences the perception of rewards during learning; whilst again accounting for trait mood instability, proneness to mental imagery, and depressive symptoms (Aim 2). This was achieved by measuring the impact of the mental imagery manipulation on perceived reward value during a reward learning game and testing for modulating effects of momentary motivation and happiness during the experiment, over-and-above individual trait and symptom differences. The following hypotheses were derived from these aims:

H1: Positive affect will be increased following visualisation of mental imagery related to goal-attainment and decreased following visualisation of mental imagery related to goal-failure (H1a), whereas negative affect will be decreased following visualization of mental imagery related to goal-attainment and increased following visualisation of mental imagery related to goal-failure (H1b).

H2: Motivation will be increased by visualising goal-attainment and decreased following visualisation of goal-failure (H2a). Effects on motivation will be modulated by factors of trait mood instability (H2b), current depression symptoms (H2c), and trait proneness to mental imagery (H2d), with those who have higher trait and symptom scores showing a larger increase in momentary motivation in response to imagery relating to goal-attainment and a larger decrease in momentary motivation in response to imagery relating to goal-failure.

H3: Participants will demonstrate a bias for preferring stimuli encountered when visualising mental imagery relating to goal-attainment when compared to stimuli encountered when visualising goal-failure (H3a), with individuals with higher reported levels of trait mood

instability and current depression symptoms (H3b), and also higher trait proneness to mental imagery (H3c), demonstrating a stronger bias for preferring stimuli encountered when visualising goal-attainment.

H4: Preference for stimuli encountered when visualising goal-attainment will be modulated by change in motivation (H4).

2. Method

2.1 Pilot

The goal formulation, mental imagery and reward learning aspects of the experiment were piloted and refined over several iterations, first with peers within the research team, and then in a small sample of participants ($n=19$) recruited via SONA and Prolific online research participation platforms. The goal formulation aspect of the experiment was initially guided by the SMART goal framework, and subsequently refined to focus on eliciting goals that were specific enough to be visualised in particular detail (see section 2.2.3 for final protocol). Prompts to elicit goal-oriented mental imagery were guided by the PETTLEP acronym (Holmes & Collins, 2001) and also protocol outlined by Holmes and colleagues (2019) aimed at evoking affective mental imagery (see section 2.2.4 for final protocol). The reward learning game and subsequent test block were based on a design used previously by Eldar and Niv (2015). We utilised functionality within Gorilla (online experiment builder) to create a similar scenario, in which participants were presented with pairs of stimuli with yoked high- and low- reward probabilities that they learned before then completing a subsequent test block (see sections 2.2.6 and 2.2.7 for final protocol).

Participants completed a short survey following the experiment and were also contacted by telephone for qualitative feedback. Overall, participants reported few issues, with generally high acceptability and clarity of procedures, but some refinements were made to the experiment based on their feedback. To minimise unnecessary repetition of audio prompts to elicit mental imagery and reduce average completion time for the reward learning task, we systematically reduced and refined the prompts used in the goal formulation and mental imagery sections of the experiment whilst ensuring minimal impact on reported levels of excitement and disappointment

in relation to goals, as well as on reported vividness of mental imagery. Although longer completion times were recorded for participants who took extended breaks during the experiment, all participants reported being able to complete the experiment within 60 minutes and without excessive fatigue to experimental procedures. Initial analysis of learning for this pilot sample showed that participants were able to identify the stimuli that gave the higher likelihood of reward. It was therefore decided that reducing the number of trials from 42 to 36 in each learning block would allow participants to conserve effort that may increase engagement with and effects of the imagery-based manipulation.

2.2 Main Experiment

2.2.1 Participants

Sixty-two participants were recruited via the online research participation platform Prolific and completed the experiment. Power analysis was informed by prior work by Eldar and Niv (2015). In this study the authors measured the effect of mood induction on mood and bias for stimuli of different reward probabilities in healthy participants from the general population and found a between-groups effect size of Cohen's $d=0.79$ (medium-to-large). Using G*Power, the minimum sample size at 80% power was estimated at $N=52$ (26 per group). Participants received reimbursement at a base-rate of £6.25 per hour spent on the experiment and an additional performance-dependent bonus of £1.25 per hour was paid for completing the experiment, making a total payment of £7.50 per hour. All payments were made via Prolific following completion of the experiment. Basic inclusion criteria required that participants self-reported fluency in English, were aged between 18-65, had access to a computer or smart tablet on which to access and complete the online experiment, and demonstrated above chance learning of reward probabilities on the reward learning game. Twelve participants who completed the

experiment were found to have performed below chance for identifying the high probability stimuli in the reward learning game and were not included, therefore leaving a final sample of $N=50$ (mean age: 28, age range: 18-62, 18 females) who met our inclusion criteria.

2.2.2 Procedure

Participants were directed from Prolific via URL to REDCap, where they were informed of details of the experiment, provided consent, and completed basic demographic information (age and gender), before being redirected to the online experiment builder Gorilla (Anwyl-Irvine et al., 2019) which was used to build and run the experiment as described in this section. The experiment involved participants first formulating personal motivational goals and then creating relevant motivational imagery. They were then prompted to utilise mental imagery in relation to achieving (goal-attainment) and not achieving (goal-failure) their goal during a reward learning game in which they experienced paired stimuli of yoked high- and low-reward probabilities. Preference for stimuli of matched reward probability was then subsequently tested to explore any bias in preference exhibited between imagery conditions.

2.2.3 Goal Formulation

Prior to generating mental imagery, participants were first asked to identify an “important personal goal [that they wanted] to achieve in the next year or so” within two goal areas: 1) *attainment* and 2) *personal life*. Instructions were given that each goal should “feel amazing if you were to achieve it” and “be disappointing if you were to not achieve it” and also that each goal should be specific. Using the SMART goal framework (Doran, 1981), examples of suitable goals (e.g., “To find out that I graduated in the top one percent of my class”) and unsuitable goals (e.g., “To be a good student” is not specific or time-limited enough) were provided to assist participants with formulating specific enough goals in each

area, as well as an explanation for why example goals were deemed unsuitable (e.g., “The goal of being a good student is not specific enough [because] there should be a moment in your future when you envisage reaching a specific outcome”). Having identified a suitable goal in each of the two areas, participants were then prompted to type these in separate text boxes before proceeding with the experiment.

2.2.4 Mental Imagery

Participants were instructed to visualise mental imagery with a view to increasing or decreasing mood and motivation ratings prior to and during the reward learning game (see section 2.2.6). Holmes and Collins' (2001) PETTLEP acronym (Physical, Environment, Task, Timing, Learning, Emotion, Perspective) which is commonly used by sports athletes to visual goals, provided a framework which was used to guide participants use of imagery within the current study. Participants were instructed to turn on their audio or connect headphones for audio functionality and also advised on use of Gorilla's audio recording function to interact verbally with the task of creating relevant mental imagery. Audio recordings were only accessed during initial piloting to check functionality in a small sample of participants.

Based on previous findings (Holmes, 2008, 2011), it was anticipated that the employment of mental imagery relating to goal-attainment and goal-failure, as opposed to neutral mental imagery, would be most effective in impacting mood bias for the purpose of this investigation. In order to begin to visualise mental imagery in relation to goal-attainment and -failure, participants were first asked to visualise an image in their mind's eye of the moment when they either achieve (goal-attainment) or do not achieve (goal-failure) each of the two goals they identified. Specific prompts were provided to assist with visualising the environment

(e.g., “Where are you in the image?”), the task (e.g., “What are you doing?”) and basic sensory elements (e.g., “What can you see and hear?”) in the mind’s eye. These were given as verbal audio prompts with text also appearing on screen. Instructions were reiterated in text on subsequent pages with text entry boxes below in which participants were asked to type a description of mental imagery in relation to achieving their goal (e.g., “When I visualise achieving my goal, I imagine...”) and not achieving their goal (e.g., “When I visualise not achieving my goal, I imagine...”) for each of the identified *attainment* and *personal life* goals. Having provided a description of mental imagery, participants were then asked to rate relative feelings of excitement (in relation to achieving their goal) and disappointment (in relation to not achieving their goal) for each goal area on a scale from 0 to 10, with 0 being “not [excited / disappointed] at all” and 10 being “extremely [excited / disappointed].”

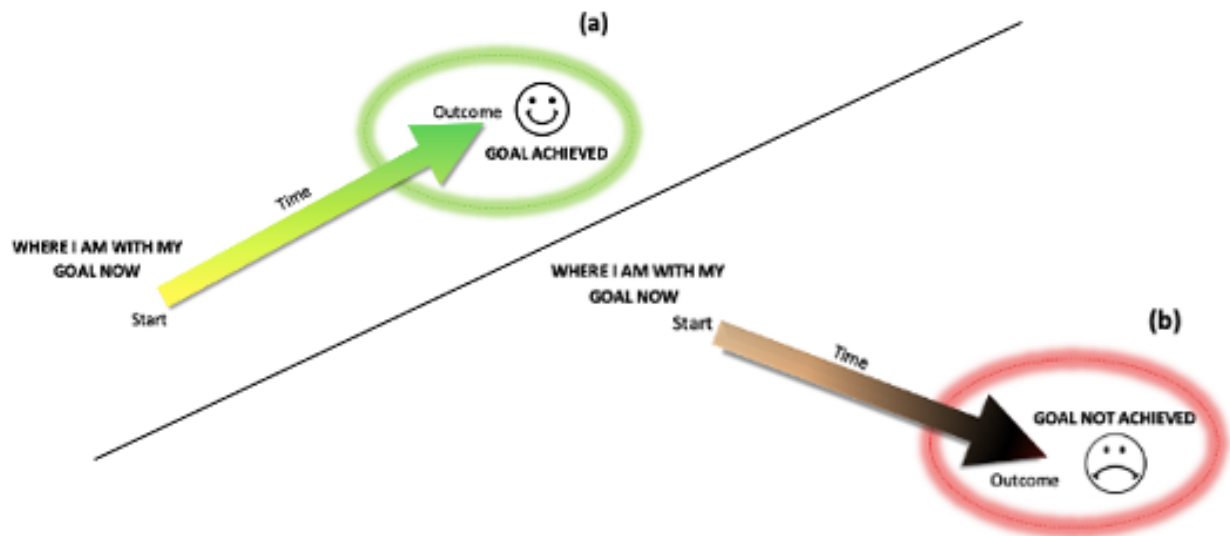
To enhance mental imagery prior to the reward learning game, participants were instructed to choose the goal that they had rated as most exciting or disappointing when they visualised the two outcomes to focus on and develop further. Additional verbal audio prompts were used within this part of the experiment in addition to functionality within Gorilla to enable participants to record verbal responses to each prompt. These aspects were intended to assist participants to engage interactively with the process of developing mental imagery by emulating basic features of the reciprocal interaction that would occur if developing imagery with an experimenter or therapist in-person. Visuals were also provided to assist participants with identifying and visualising the specific moment when they either achieve or do not achieve their goal (Figure 1). Two prompts were given for developing imagery in relation to each goal outcome at this stage in the experiment. For imagery relating to goal-attainment, the first of these prompts asked participants to specify their chosen goal, while the second instructed them to imagine in the first-person, present tense the steps they would take as they

achieve their goal and how their motivation builds at each step. The prompts for imagery relating to goal-failure followed on from this and first asked participants to describe the image elicited when they imagined not achieving their chosen goal, with the second prompt being parallel to that given for imagery relating to goal-attainment but instructing participants to imagine broadly how they “feel” at each step rather than specifying that they imagine feelings of motivation. Subjective ratings of excitement and disappointment were taken again in relation to relative goal outcomes, as well as ratings of imagery vividness for each outcome on a similar scale from 0 to 10, with 0 being “not vivid at all” and 10 being “extremely vivid.” These ratings provided an initial indication of effectiveness of the prompts in eliciting vivid and affective imagery (Supplementary Table 1).

A series of further mental imagery prompts were also provided immediately before each of the first two learning blocks in the reward learning game (Supplementary Table 2). One set of prompts focused on consolidating imagery relating to goal-attainment and was given just prior to participants being instructed to visualise this outcome during one block of the reward learning game, while another set of prompts consolidated imagery relating to goal-failure to be utilised in an alternate learning block. The order of these prompts was randomised so that one half of participants ($n=24$) consolidated and utilised imagery relating to goal-attainment in the first learning block then followed by imagery relating to goal-failure in the second learning block, with this order being reversed for the other half of participants ($n=26$). Participants were given text prompts intermittently throughout each of the learning blocks (occurring once every six trials) instructing them to close their eyes and visualise their image (i.e., either achieving or not achieving their goal) for 10 seconds “until you hear the tone.” The “bell chime” tone used was retrieved from www.freesound.org and lasted approximately two seconds in duration.

Figure 1

Visual Prompts to Assist Participants with Identifying and Visualising the Specific Moment When They Either (a) Achieve or (b) Do Not Achieve Their Goal.



2.2.5 Mood Ratings

To evaluate initial change in mood following the audio prompts given to consolidate mental imagery, participants were asked to complete a Mood Zoom (Tsanas et al., 2016) before the first and second learning blocks of the reward learning game, with momentary subjective ratings of six categories of affect: angry, anxious, happy, energetic, sad and irritable (Supplementary Figure 1). Participants were instructed to rate how much each of these words described their current mood using six sliders each on a continuous scale from 0, “not at all,” to 100, “very much.” Baseline Mood Zoom ratings were taken following a short break prior to completing the first set of audio prompts. Two further comparison Mood Zoom ratings were then taken immediately after each set of audio prompts before each of the learning blocks.

2.2.6 Reward Learning Game

In the reward learning game participants completed two learning blocks of 36 trials consisting of a binary choice between stimuli pairs of low (.33) and high (.66) reward probabilities. Although each block was referred to as a ‘round’ during the game to be more congruent with gaming lexis (e.g., Round 1), these are referred to as ‘blocks’ for the purpose of this report as this is more typical in empirical reporting. The two learning blocks were randomised between blocks to vary the order in which participants were prompted to visualise imagery relating to goal-attainment or -failure (see section 2.3.2).

Instructions were provided prior to the reward learning game informing participants that they would need to “collect coins by choosing between objects” and that they would “learn about these objects in pairs.” Participants were also advised that there would not always be a coin available and that their task in the game was to “earn as much money as possible by choosing the object that pays out most often.” For the purpose of encouraging maximum effort during the game, and also creating a sense of reward-based motivation, participants were told that each correct choice was worth £0.05 and that they would have the opportunity to earn up to £1.25 bonus for their choices in the game. Additional instructions outlined that “a pound coin” symbol would signal that £0.05 had been earned for a choice, whereas a horizontal line would signal that no bonus had been won. Participants were told that they would be informed of their earnings at the end of the experiment. The bonus was paid in addition to the base payment of £6.25 per hour, with all participants being informed upon completion of the experiment that they would be paid the maximum bonus of £1.25.

All stimuli were depicted in black on a white background. Pairs of stimuli within each block consisted of randomised combinations of six geometric shapes, with participants first

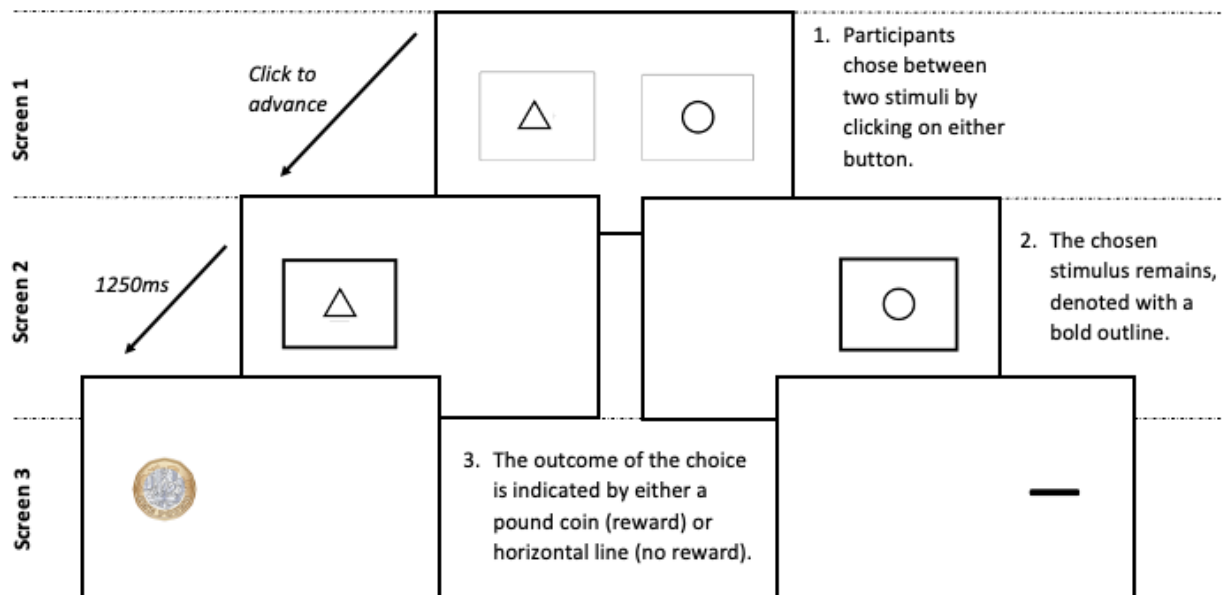
completing 12 practice trials which required them to choose between two novel stimuli (Supplementary Figure 2). Stimuli during the 12 practice trials were presented side-by-side on a white background, with text instructions given above the stimuli during trials to guide participants through the requirements of the game (Supplementary Figure 3). Participants were advised that although no monetary reward was available during the practice trials, a coin would still appear to indicate that they had made the correct choice. Three forced choices were also included in the 12 practice trials. In these trials only one of the two paired stimuli appeared in the centre of the screen and participants were forced to click on it to reveal the outcome.

For each trial within the reward learning game (Figure 2) participants were required to choose between stimuli pairs in the same manner as they had been prompted to in the practice trials. There were thirty binary choice trials (in which stimuli pairs appeared side by side) and six forced choice trials (in which each stimuli appeared alone in the middle of the screen). Participants were required to click on stimuli to make their choice. Following each choice, the unchosen stimulus disappeared, and the chosen stimulus remained on the screen with a boldened outline. The outcome was then shown on the same side of the screen subsequent to the chosen stimulus, denoted by either a pound coin (to indicate a reward) or a horizontal line (to indicate no reward), lasting for 1000ms duration before advancing to the next trial/screen.

In addition to Mood Zoom ratings (see section 2.2.5), separate ratings of momentary motivation and happiness were also taken throughout the reward learning game. For these ratings, participants were asked to rate “How [motivated / happy] do you feel right now?” on a continuous scale from “Not at all [motivated / happy]” to “Very [motivated / happy].” Individual ratings of motivation were taken following the 6th, 18th and 30th trial throughout each block, whereas ratings of happiness were taken less frequently, after the 24th and 36th trial, and served to supplement Mood Zoom ratings of ‘happy’ affect (Supplementary Figure 4).

Figure 2

Exemplary Process Diagram for One Trial of the Reward Learning Game.



Note. Screens 1-3 show the process involved in each trial of the reward learning game. Participants make a choice between two stimuli by clicking on one of them and then learn the reward outcome as denoted by a one pound coin (a reward was earned) or a horizontal line (no reward was earned). The two sides of the diagram show how choosing the shape on the left earns a reward, whereas choosing the shape on the right does not.

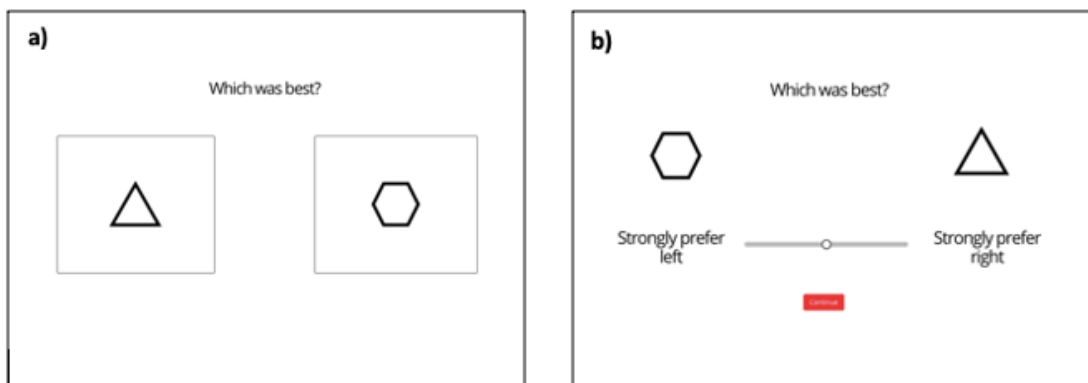
2.2.7 Test of Perceived Reward Value

A test block (or ‘bonus round’) was completed following the two learning blocks. This consisted of participants first being presented with all paired combinations of the four stimuli encountered in the learning blocks (six paired choices in total) and being asked to make a binary choice in response to the question “Which was best?” (Figure 3a). The chosen stimuli would then appear alone on the same side of the screen with a boldened outline for 1250ms before advancing to the next trial/screen. These choices were immediately followed by a further set of parallel comparisons in which participants repeated the six paired choices rating on a

slider scored from -1 (“strongly prefer left”) to 1 (“strongly prefer right”) in response to the same question and then clicking the ‘continue’ button to advance the next trial/screen (Figure 3b). This meant that participants were asked to rate each pairing twice (in order to increase power and reduce noise), which therefore generated a total of 12 comparisons within these two learning blocks. Participants were instructed in advance that these trials would “count for double the reward” and to “do your best and try not to rush.”

Figure 3

Exemplary Test Block Displays for (a) Binary Choices and (b) Continuous Preference Ratings.



Note. Each pairing of the stimuli encountered across block 1 and block 2 were presented twice in the test block, once as a binary choice and then again as a continuous preference rating. This yielded 12 comparisons.

2.2.8 Questionnaires

Two trait-based self-report questionnaires were completed by participants. The first of these questionnaires, the International Personality Item Pool (IPIP; Goldberg et al., 2006) version of the Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986), was a self-report measure of personality with 12-items enquiring about features of changeable mood,

specifically “an overactive, gregarious personality style with hyperthymic (especially positive) moods,” with a higher HPS score indicating less stable mood. This measure has been shown to correlate with frequency of good and bad moods (Meyer, 2002), as well as with risk of developing bipolar disorder (Kwapli et al., 2000). The second, the Spontaneous Use of Imagery Scale (SUIS; Reisberg et al., 2003), was a 12-item questionnaire designed to measure spontaneous use of imagery during daily life, using a five-point scale on which a person is asked to rate the degree to which each item is appropriate for them (from “never appropriate” to “always completely appropriate”), with higher scores indicating more proneness to mental imagery. A sample item is: “when I think about visiting a relative, I almost always have a clear mental picture of him or her.” A third self-report symptom-based questionnaire, the Personal Health Questionnaire-9 (PHQ-9; Spitzer et al., 1999), was used to measure depressive symptoms. The PHQ-9 scores each of the nine DSM-IV diagnostic criteria for depression based on frequency as “0” (not at all) to “3” (nearly every day) over a two-week period, with higher scores being indicative of more depressive symptomatology. Each of these questionnaires were completed by participants in the interval prior to the test of perceived reward value.

2.3 Ethics

Ethical approval for the study was granted by the UCL Psychology and Language Sciences Ethics Committee (Project ID CEHP/2020/580; Appendix C). Prior to completing the experiment, participants were first directed to REDcap and informed of the study objectives, their right to withdraw from the study and potential harms and benefits of taking part via the project information sheet (Appendix D) and provided informed consent online (Appendix E). Participants were given researcher contact details if they had any questions or concerns about any aspect of the study. The use of visual imagery had the potential to be emotionally arousing,

however we minimised the chances of this because 1) we did not prompt participants to imagine emotionally arousing memories; rather, participants were asked to visualise obtaining or not obtaining an imaginary goal, 2) we followed established procedures used extensively in studies in the positive psychology literature (e.g. PETTLEP used in sports psychology) and 3) participants decided which image they would like to focus on (and they had control over how much to engage with the image) and were instructed to only select non-distressing images. The use of mental health related questionnaires (i.e., HPS and PHQ-9) also had potential to raise concerns in relation to reported mental health symptoms and traits. Participants were provided with a list of sources of mental health support (Appendix F) at the end of the experiment and advised that if they had concerns about aspects of their mental health then the listed helplines and websites could offer expert support and advice.

2.4 Statistical Analyses

Data was downloaded from Gorilla and relevant variables were extracted using MATLAB R2020b before then being exported to IBM SPSS Statistics version 27 for statistical analysis. Some preliminary plots examining learning and experienced reward probabilities were produced in MATLAB. A range of general linear model (GLM) analyses were conducted to explore the outlined aims and related hypotheses. Tests of homogeneity of variance were conducted for all analyses and adjusted statistics were taken (and are subsequently reported) where this assumption was violated. All conducted analyses are described in detail in this section.

2.4.1 Intervention Efficacy

Two planned GLM analyses were conducted to examine the impact of mental imagery of positive and negative orientation on momentary mood and motivation (Aim 1). For the first

of these analyses, the Mood Zoom ratings for six mood states (energetic, angry, happy, irritable, anxious, and sad; dependent variables [DVs]) at three time points were entered as dependent measures within a repeated measures ANOVA with time of measurement as a within-subject factor and imagery orientation as a between-subjects factor (independent variables [IVs]). The dependent measure represented three time-points taken pre- and post-intervention for each of the two interventions separately eliciting imagery relating to goal-attainment or -failure, with the second time-point acting as a pre-manipulation measure for the second of the two imagery manipulations (i.e., prompts eliciting imagery relating to goal-attainment for those who visualised goal-failure in block 1 (B1), or vice-versa for those who visualised goal-attainment in B1). For the second analysis examining intervention efficacy, mean scores of motivation and happiness were calculated separately across B1 and block 2 (B2) and then z-scored (DVs). These scores were then entered as two dependent measures within a repeated measures ANOVA with time of measurement (B1, B2) as a within-subject factor and imagery orientation (the order in which participants were prompted to visualise imagery relating to goal-attainment and goal-failure across learning blocks) as a between-subjects factor (IVs).

A series of planned principal component analyses were conducted with the aim of reducing the six Mood Zoom states into three specific factors as recommended by Tsanas et al (2016). The Mood Zoom ratings for six emotional states were entered together into three separate principal component analyses for each of the three Mood Zooms taken throughout the experiment (see section 2.2.5). A Varimax orthogonal rotation with Kaiser normalisation was applied to maximize the variance shared among items so that results would more discretely represent how data correlate with each principal component (i.e., Allen, 2017). Three new factor variables were extracted in each of these analyses and the normalised eigenvalue

weightings on each Mood Zoom component were used to distinguish and label three specific emotional factors.

2.4.1.1 Differences in Intervention Efficacy Based on Trait Mood Instability, Depression Symptoms and Trait Proneness to Mental Imagery. Additional planned analyses were also conducted to test the separate modulating effects of trait mood instability, depression symptoms and trait proneness to mental imagery on intervention efficacy. In these analyses, measures of mood instability (HPS), depression symptoms (PHQ-9) and proneness to mental imagery (SUIS) were entered as covariates in the first of the two repeated measures analyses described in section 2.4.1. Separate parallel analyses were conducted for each of these covariates, with individual analyses testing for modulating effects on happiness and motivation with the interaction of each trait/symptom measure (i.e., by imagery orientation) included as a covariate.

2.4.2 Learning Performance and Test Accuracy

Initial checks were completed via analyses examining the ability of participants to accurately learn and distinguish between stimuli of different reward probabilities explored both the frequency with which participants were able to accurately distinguish and chose the high probability stimuli during the reward learning game (learning performance), and the proportion with which participants chose the high probability stimuli in the subsequent test of perceived reward probability (test accuracy).

2.4.2.1 Learning Performance. Paired sample t-tests were used to examine learning performance within B1 and B2. For each of two learning blocks, mean percentage accuracy for choosing the high probability stimuli was calculated separately for the first three and the last 27 trials binary choice trials (IVs). These variables were then compared within each learning block

(DVs), yielding two paired comparisons. To infer learning of reward probabilities, it was expected that there would be a significant difference (increase) in accuracy for choosing the high probability stimuli between the first three trials and the last 27 trials in each learning block.

2.4.2.2 Test Accuracy. Test accuracy was explored via two analyses using variables derived from test choices between pairs of high and low probability stimuli encountered in each learning block. The first of these analyses checked that the proportion of participants consistently choosing the high probability stimuli at test was above a designated threshold of .51. Continuous slider ratings were binarised for each paired comparison so that scores below zero were categorised as preferring the stimuli on the left-hand side of the screen and scores above zero as preferring the stimuli on the right-hand side of the screen. Binary variables were then created for each block with participants who consistently chose the high probability stimuli over the low probability stimuli (i.e., on both the binary and the binarised comparison) denoted from those participants who did not. These scores were then entered into a binomial test with the test proportion set to .51, to confirm whether participants were performing above chance level. A second analysis then used a repeated measures ANOVA to test whether there was a difference in test accuracy either within (univariate) or between (multivariate) learning blocks based on continuous slider ratings (DV) attributable to the order in which participants completed learning blocks prompting them to visualize mental imagery relating to either goal-attainment or goal-failure (IV); it was expected that there would be no significant differences in test accuracy between learning blocks based on imagery orientation.

2.4.3 Effects of Imagery Orientation on Perceived Reward Value

Various planned GLM analyses were used to examine whether mental imagery influencing momentary motivation and happiness also influenced the perception of rewards during learning whilst accounting for individual differences in trait mood instability, proneness to mental imagery, and depressive symptoms (Aim 2).

Preferences at test were quantified in two ways. Firstly, the four binary choices and four binarised slider choices comparing stimuli encountered between B1 and B2 were summed, with choices representing a preference for B1 scored as -1 and choices representing a preference for B2 scored as +1, thus yielding a score from -8 to +8 for each participant. Two further variables were also calculated from continuous preference ratings for evenly matched .66 and .33 probability stimuli in B1 and B2, with choices centred around zero so that for each participant scores from -1 to -50 (i.e., below zero) represented a preference for B1 and scores from 1 to 50 (i.e., above zero) represented a preference for B2. This yielded two variables scored from -50 to +50, one for evenly matched .33 stimuli pairs and one for .66 stimuli pairs. Binarised preferences and continuous preference ratings were then entered as dependent variables in separate analyses.

A MANOVA was conducted to examine whether imagery orientation biased preference at test. A single variable denoting all binary choices and two variables based on continuous preferences (i.e., ratings for evenly matched .33 and .66 reward probability stimuli) were entered as DVs, and imagery orientation was entered as the IV. Two MANCOVAs were then conducted to test for modulating effects on binary and continuous preferences. In the first of these analyses, the separate interactions of imagery orientation with measures of mood instability and depression symptoms were entered together as covariates. The second

MANCOVA repeated the first analysis but with the interaction of imagery orientation with trait proneness to mental imagery (SUIS) entered as a sole covariate.

2.4.3.2 Effects of Imagery Orientation on Perceived Reward Value When

Accounting for Differences in Motivation. The change in motivation between B1 and B2 was calculated for each participant by subtracting mean ratings taken in the first learning block from those in the second block. All ratings were z-scored before being calculated. A MANCOVA was then conducted to test for modulating effect of change in motivation between B1 and B2 (covariate) on binary and continuous preferences (DVs) based on imagery orientation (IV).

3. Results

3.1 Efficacy of the Imagery Manipulation

Analyses of imagery manipulation efficacy tested the effectiveness of visualising imagery relating to goal-attainment and -failure in impacting mood and motivation, separately.

3.1.1 Efficacy on Mood (H1)

We predicted that positive affect (i.e., feeling happy and energetic) would be increased following visualization of mental imagery related to goal-attainment and decreased following visualisation of mental imagery related to goal-failure (H1a), whereas negative affect (i.e., feeling sad, angry, irritable, and anxious) would show the opposite response (H1b).

A repeated measures ANOVA showed that there was a significant effect of Time (pre- vs post-imagery top-up) x Imagery Orientation for all Mood Zoom ratings ($F_{2,48} = 7.122, p < .001, Wilks' \Lambda = .302, \eta p^2 = .698$). There was also a significant effect of Time x Imagery Orientation for each mood state within the Mood Zoom: happy (higher in goal-attainment than -failure; $F_{2,48} = 63.16, p < .001$), energetic (higher in goal-attainment than -failure; $F_{2,48} = 46.67, p < .001$), sad (higher in goal-failure than -attainment; $F_{2,48} = 42.13, p < .001$), irritable (higher in goal-failure than -attainment; $F_{2,48} = 26.56, p < .001$), angry (higher in goal-failure than -attainment; $F_{2,48} = 18.46, p < .001$), anxious (higher in goal-failure than -attainment; $F_{2,48} = 19.4, p < .001$). No order effects were observed for visualising goal-attainment or goal-failure on any of the six emotional states. Subjective ratings of positive affect (i.e., feeling happy and energetic) were significantly increased when visualising goal-attainment compared to baseline or when visualising goal-failure, whereas ratings of negative affect (i.e., feeling sad, anxious, irritable, and angry) decreased. Opposite effects were observed when visualising goal-failure, with positive affect decreasing and negative affect increasing (Supplementary Figure 5).

Based on the Mood Zoom ratings taken at baseline (i.e., prior to the imagery manipulations), the principal component analysis revealed three emotional patterns: the factor loadings of each pattern after orthogonal rotation are shown in Table 1. The three factors explained 84% of the variation in Mood Zoom ratings. The three factors were labelled based on the emotional states that loaded highly as follows: Factor 1: Negative Valence (predominantly ‘angry’, ‘irritable’, and ‘sad’); Factor 2: Arousal (predominantly ‘happy’ and ‘energetic’); Factor 3: Anxiety (predominantly ‘anxiety’). These factors accounted for 54.8%, 17.5%, and 12.2% of the variation in Mood Zoom ratings, respectively.

Table 1

Factor Loadings of Each Pattern from Mood Zoom at Baseline After Orthogonal Rotation.

Emotional States	Components		
	1	2	3
Energetic	-.066	.937	.005
Happy	-.347	.803	-.268
Anxious	.213	-.125	.960
Sad	.602	-.501	.314
Irritable	.834	-.163	.207
Angry	.932	-.134	.093

Note. Three factors were extracted from the analysis. Factor 1: angry, irritable, and sad (labelled “Negative Valence”); Factor 2: happy and energetic (labelled “Arousal”); and Factor 3: anxious (labelled “Anxious”). Bold highlighted eigenvalues represent those meeting a .6 threshold for inclusion within each mood factor.

A second repeated measures ANOVA showed that there was a significant effect of Time (pre-B1 vs pre-B2) x Imagery Orientation for all Mood Zoom factors ($F_{2,48} = 27.934, p < .001, Wilks' \Lambda = .354, \eta p^2 = .646$). There was also a significant effect of Time x Imagery Orientation for each of three Mood Zoom factors: Negative Valence (higher in goal-failure than -attainment; $F_{2,48} = 5.956, p = .006$), Arousal (higher in goal-attainment than -failure; $F_{2,48} = 36.96, p < .001$), Anxious (higher in goal-failure than -attainment; $F_{2,48} = 5.2, p = .002$). Correlational analyses found a significant positive correlation between change in motivation and happiness (from B1 to B2) and Arousal (motivation: $r_{47} = .631, p < .001$; happiness: $r_{47} = .612, p < .001$), and a negative (inverse) correlation with Negative Valence (motivation: $r_{47} = -.292, p = .042$; happiness: $r_{47} = -.524, p < .001$). No correlation was found between Anxiety and change in motivation ($r_{47} = -.070, p = .634$) or happiness ($r_{47} = -.014, p = .923$).

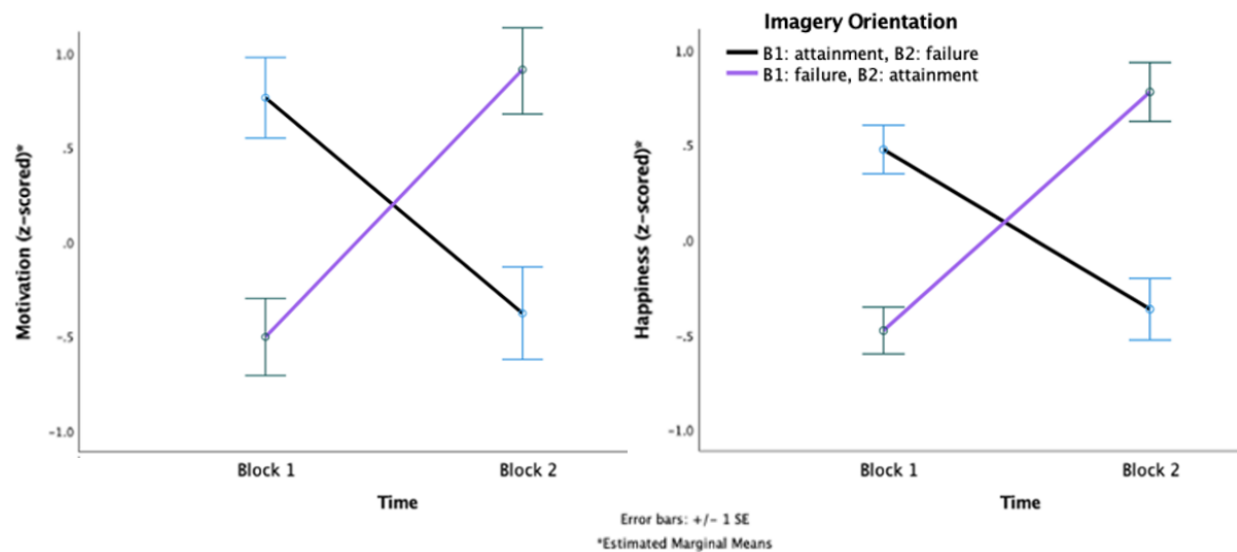
3.1.2 Efficacy on Motivation (H2)

It was also hypothesized that subjective ratings of motivation would increase following visualisation goal-attainment and decrease following visualisation of goal-failure (H2a), and that any effects on motivation would be modulated by factors of trait mood instability (H2b), current depression symptoms (H2c), and trait proneness to mental imagery (H2d).

A repeated measures ANOVA of average motivation in each block, showed a significant interaction effect of Time (Motivation) x Imagery Orientation ($F_{2,48} = 44.16, p < .001, \eta p^2 = .479$) and Time (Happiness) x Imagery Orientation ($F_{2,48} = 76.44, p < .001, \eta p^2 = .614$). As expected, the interaction plots (Figure 4) showed that both motivation and happiness increased from B1 to B2 for participants who visualized goal-failure imagery in the first block and decreased from the B1 to B2 for those who visualised goal-attainment.

Figure 4

Differences in Motivation and Happiness between Learning Blocks.



Note. Both motivation and happiness increased from B1 to B2 for participants who visualized goal-failure imagery in the first block and decreased from the B1 to B2 for those who visualised goal-attainment.

3.1.2.1 Differences in Intervention Efficacy Based on Trait Mood Instability,

Depression Symptoms and Trait Proneness to Mental Imagery. Initial correlational analyses found a significant correlation between PHQ-9 scores and HPS scores ($r_{47} = .320, p = .025$), but not with SUIS and PHQ-9 scores ($p = .826$), and nor with SUIS and HPS scores ($p = .764$). There were also no significant correlations found between trait/symptom measures (i.e., HPS, PHQ-9, SUIS) and motivation or happiness ratings (all $P_s \geq .332$). Analyses were conducted using the GLM to test whether the effects of imagery on motivation and happiness ratings were modulated by depression symptoms, trait mood instability and individual proneness to mental imagery (i.e., measured by scores from the PHQ-9, HPS and SUIS, respectively).

Depression symptoms: Interactions of Time x Imagery Orientation remained, although at trend level, when accounting for the interaction with depression symptoms (multivariate: $F_{1,46} = 2.535, p = .091, Wilks' \Lambda = .899, \eta p^2 = .101$), with a significant univariate effect on happiness ($F_{1,46} = 5.183, p = .028, \eta p^2 = .101$) but not on motivation ($F_{1,46} = 2.84, p = .099, \eta p^2 = .058$). The interaction of Time x Imagery Orientation x PHQ-9 was significant at the multivariate level ($F_{1,46} = 3.485, p = .011, Wilks' \Lambda = .750, \eta p^2 = .134$) and at the univariate level for both motivation and happiness (motivation: $F_{1,46} = 3.223, p = .049, \eta p^2 = .123$; happiness: $F_{1,46} = 7.390, p = .002, \eta p^2 = .243$). Post-hoc t-tests within the imagery condition in which participants visualised goal-attainment in the first block showed that PHQ-9 scores were significantly correlated with differences in motivation ($r_{22} = -.449, p = .028$) and happiness ($r_{22} = -.587, p = .003$), while parallel tests in the opposite imagery condition (i.e., visualising goal-failure in the first block) were not significant (motivation: $p = .236$; happiness: $p = .133$) (Figure 5a and 5b).

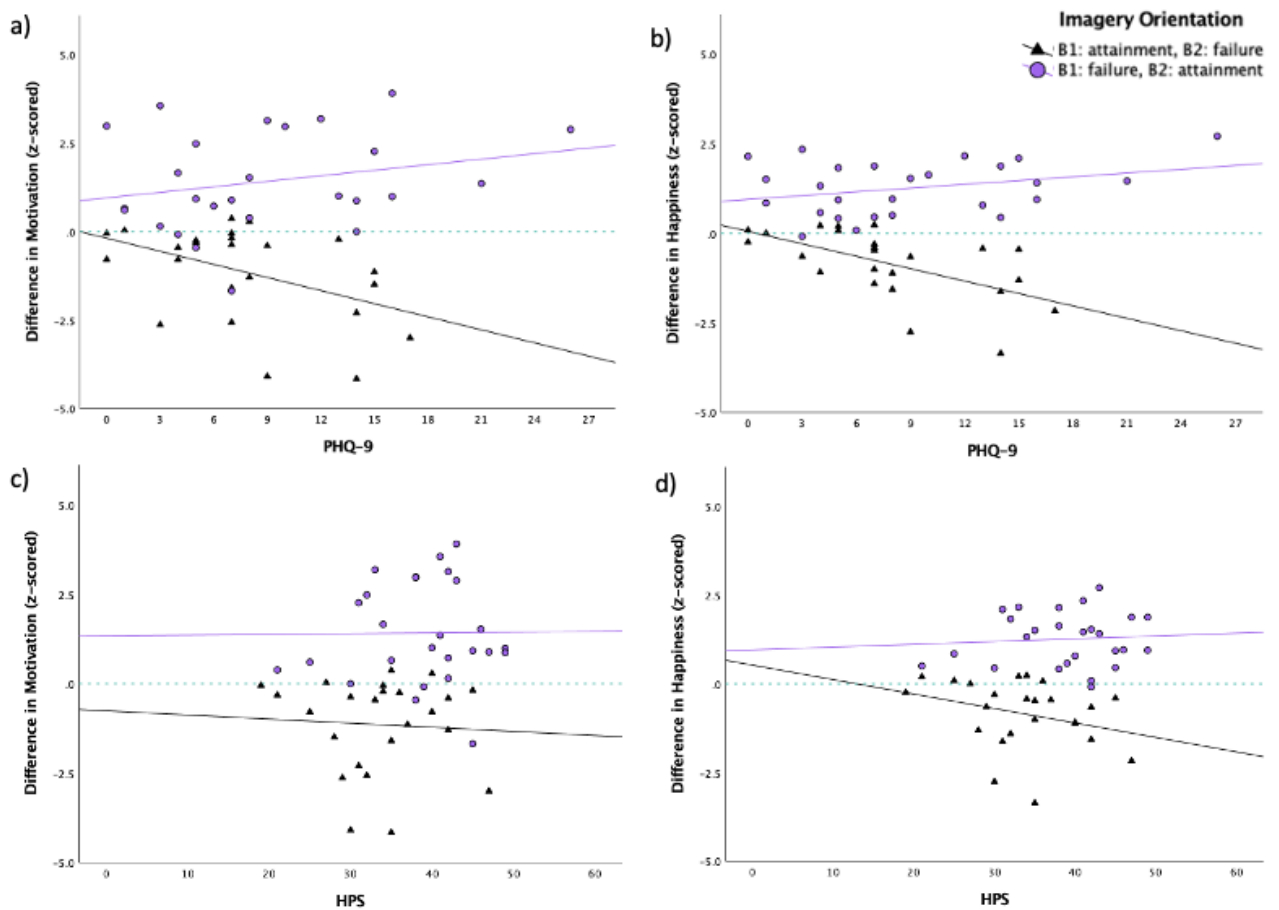
Trait mood instability: Interactions of Time x Imagery Orientation were no longer significant when accounting for the interaction with trait mood instability (multivariate: $F_{1,46} = 0.746, p = .480, Wilks' \Lambda = .968, \eta p^2 = .032$; motivation: $F_{1,46} = .994, p = .324, \eta p^2 = .021$; happiness: $F_{1,46} = .114, p = .737, \eta p^2 = .002$). The Time x Imagery Orientation x HPS interaction was also not significant (multivariate: $F_{1,46} = 1.312, p = .271$; motivation: $F_{1,46} = .040, p = .961$; happiness: $F_{1,46} = 1.375, p = .263$). Plots (Figure 5c and 5d) showed that mood instability had little interaction with difference in motivation between B1 and B2.

Trait proneness to mental imagery: The main effects of Time (Motivation) x Imagery Orientation ($F_{1,46} = 0.03, p = .863, \eta p^2 = .001$) and of Time (Happiness) x Imagery Orientation ($F_{1,46} = 1.188, p < .281, \eta p^2 = .025$) remained significant when accounting for interaction with proneness to mental imagery (multivariate: $F_{1,46} = 2.018, p = .145, Wilks' \Lambda = .918, \eta p^2 = .082$).

The Time x Imagery Orientation x SUIS interaction was not significant (multivariate: $F_{1,46} = 1.597, p = .182, Wilks' \Lambda = .872, \eta p^2 = .066$; motivation: $F_{1,46} = .008, p = .928$; happiness: $F_{1,46} = .443, p = .509$).

Figure 5

Scatterplots of Difference in Motivation and Happiness (B1 to B2) by Depression (PHQ-9) and Trait Mood Instability (HPS).



Note. A larger decrease in happiness and motivation is shown in response to visualising goal-failure for those who reported higher levels of depression symptoms (PHQ-9; **a-b**). Participants with more trait mood instability (HPS) demonstrated a larger decrease in happiness in response to visualising goal-failure (**d**), but not in motivation (**c**).

3.2 Learning Performance and Test Accuracy

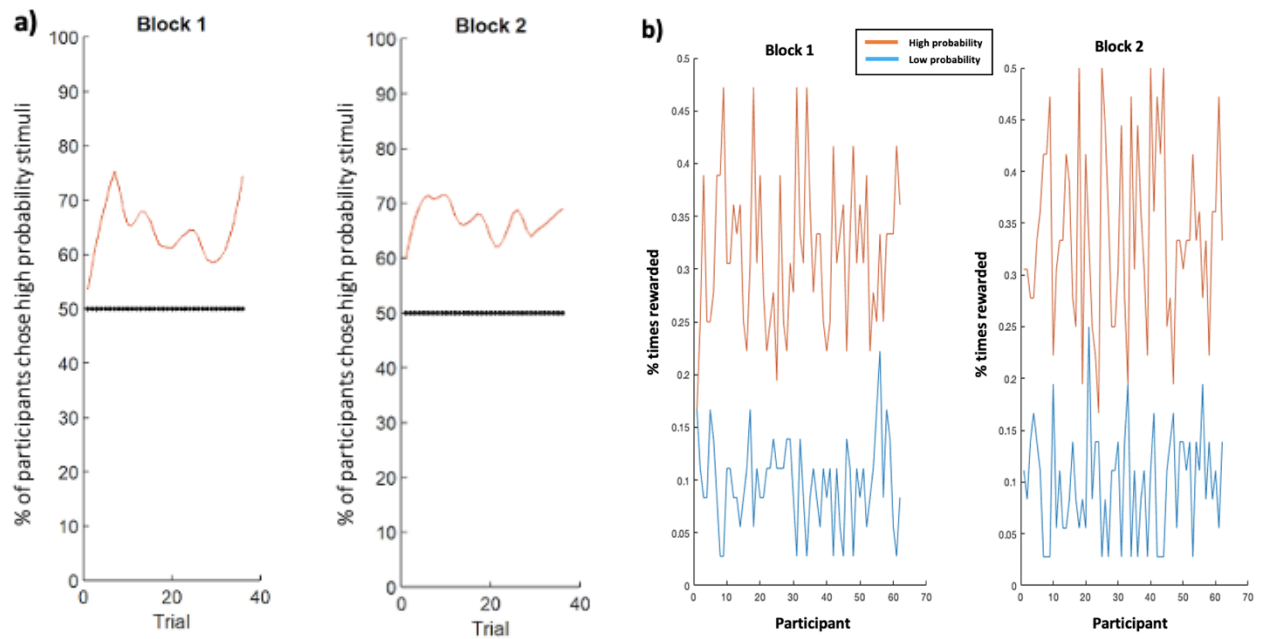
Analyses of learning performance and test accuracy tested the extent to which participants learned the value of stimuli and therefore accurately selected the higher .66 probability stimuli over the lower .33 probability within each learning block and also for these comparisons in the subsequent test block. We expected that participants would accurately distinguish between reward probabilities of stimuli in the reward learning game, with stimuli of a higher reward probability being chosen more frequently than stimuli of a lower reward probability, and also that participants would demonstrate a significant preference for stimuli of a higher reward probability at test when compared with stimuli of a lower reward probability.

3.2.1 Learning Performance

Paired-sample t-tests ($N = 50$) showed that there was a statistically significant increase in participant performance (number of times they chose the high probability option) between the first three trials and last 27 trials within B1 and B2 ($F_{1,49} = 12.009, p = .001$) with no significant difference in performance found between learning blocks ($F_{1,49} = .063, p = .804$; Block x Time interaction: $F_{1,49} = .349, p = .558$). Examination of the plots in Figure 6a showed a largely consistent pattern of learning across the two blocks whereby the remaining participants correctly chose the .66 probability stimuli most often between the first 3-10 trials and at the end of each block, with more fluctuation in performance observed through the middle of each block where participants may have been encouraged to explore because of the presence of forced choice trials.

Figure 6

Line-Graph Plots showing a) the Percentage of Participants who Chose the .66 Probability Stimuli in Each Trial in Blocks 1-2, and b) Participants Individual Experienced Reward Probabilities for High- and Low-Probability Stimuli in Block 1 and Block 2 of the Reward Learning Game.



Notes: a) A largely consistent pattern of learning is shown across the two blocks. A greater proportion of participants correctly chose the stimuli with a higher reward probability most often between the first 3-10 trials and at the end of each block. More fluctuation in performance is observed through the middle of each block where participants were encouraged to explore the reward probabilities of both stimuli via forced choice trials.

b) A variable pattern of experienced reward probabilities was seen across the two blocks. The large range of experienced probabilities likely meant that respective high and low probabilities were experienced as too similar for some participants to distinguish with confidence.

The high (.66) and low (.33) reward probabilities of stimuli were dependent on participants choosing stimuli consistently throughout each learning block. However, as participants were encouraged to explore and make variable choices to learn the reward probabilities of paired stimuli, the actual reward probabilities experienced were significantly lower than this. The post-hoc reward probabilities experienced by participants for high and low probability stimuli in B1 and B2 are shown in Table 2. A significant difference in experienced probabilities was found between blocks for stimuli of high reward probability ($t_{49} = -2.135, p = .038$), but not for stimuli of a low reward probability ($t_{49} = 0.074, p = .941$).

Table 2

Descriptive Statistics for Experienced Reward Probabilities for High- and Low-Probability Stimuli in Block 1 and Block 2 of the Reward Learning Game by Imagery Condition.

	Experienced Reward Probabilities					
	B1: Attainment, B2: Failure			B1: Failure, B2: Attainment		
	Range	Mean	SD	Range	Mean	SD
Block 1						
High reward probability	.22 to .47	.33	.07	.19 to .47	.33	.07
Low reward probability	.03 to .14	.08	.03	.03 to .17	.10	.04
Block 2						
High reward probability	.19 to .50	.37	.09	.19 to .50	.35	.08
Low reward probability	.03 to .17	.08	.04	.03 to .25	.10	.05

Examination of the plots in Figure 6b showed a variable pattern of experienced reward probabilities across the two blocks for both stimuli of high and low reward probabilities. The large range in experienced probabilities likely meant that for some participant respective high and low probabilities were too similar for participants to learn and distinguish. This therefore indicated a need to control for the potential confound of differences in experienced reward probabilities in subsequent analyses of the effects of imagery on perceived reward value.

3.2.2 Test Accuracy

A binomial test (one-tailed) confirmed that the proportion of participants consistently choosing the high probability stimuli on binarised preferences at test was significantly above the chance performance (50%) in B1 ($p < .001$) and B2 ($p < .001$). Analyses of continuous slider ratings also showed that there was not a significant difference in test accuracy based on imagery orientation for B1 ($F_{2,48} = .152$ $p = .7$) and B2 ($F_{2,48} = .49$ $p = .49$); and nor were there any significant differences in test accuracy between learning blocks.

3.3 Effects of Imagery on Perceived Reward Value (H3 and H4)

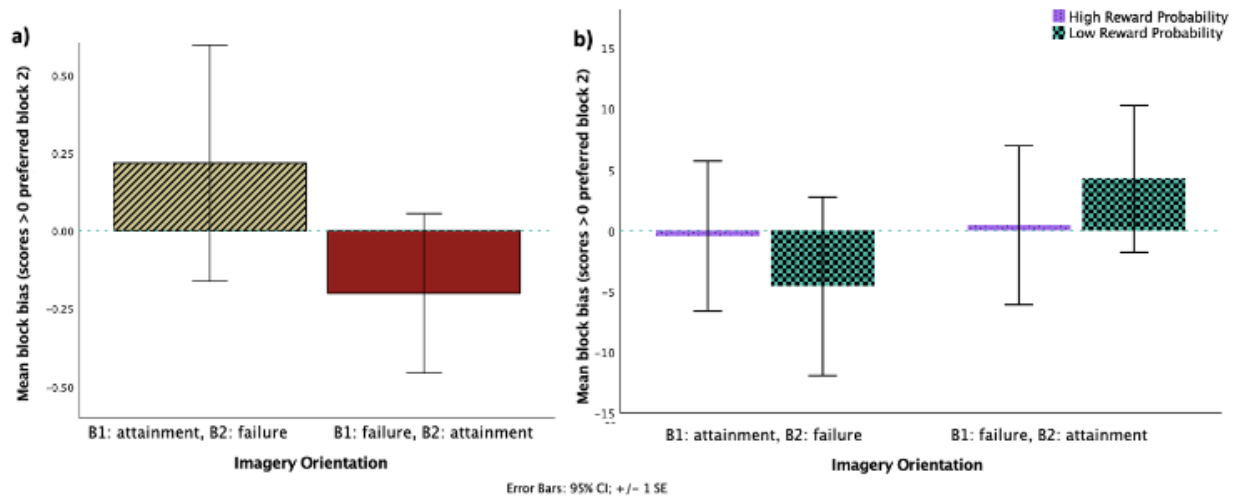
Given that the experienced probabilities of the reward stimuli varied across participants (Figure 6b), binary logistic regression was used to extract residuals for each of the binarised test choices after variance attributable to differences in the actual probabilities that participants experienced for each stimuli pair was regressed out. The residuals were then saved and summed again, as before, to give a measure of preference that now removes the differences in the actual probabilities of the stimuli. This variable was highly correlated with sum of raw binarised test preferences prior to accounting for variance ($r_{49} = .914$, $p < .001$). Analyses also examined differences in continuous preference ratings based on imagery orientation for evenly matched .66 and .33 probability stimuli in B1 and B2. The same extraction of residuals for

these continuous variables was completed using linear regression and these residuals were both highly correlated with raw preference ratings (high-probability: $r_{49} = .925$, $p < .001$, low-probability: $r_{49} = .988$, $p < .001$). All three adjusted-preference variables were entered as dependents in subsequent multivariate analyses of the effects of imagery on perceived reward value (for effects on the unadjusted preference variables, see Supplementary Tables 3a-e).

The GLM analyses of effects of imagery orientation on perceived reward value tested whether mental imagery (shown to influence momentary motivation and happiness by our previous analyses) also influences the perception of rewards during learning (H3a). Counter to our predictions, initial analyses found that imagery orientation did not bias preferences at test at the group level ($F_{1,48} = 2.427$, $p = .077$, *Wilks' Λ* = .863, $\eta p^2 = .137$), whether quantified as binary choices ($p = .358$; Figure 7a) or continuous preference ratings (high probability: $p = .922$; low probability: $p = .355$; Figure 7b). Examination of the plots (Figure 7) showed that although the multivariate effect of imagery orientation on block bias was at trend level, preferring stimuli learned in the negative block for both the positive-then-negative imagery order (Mean= .22, SD= 1.9) and for the negative-then-positive imagery order (Mean= -.20, SD= 1.3), the univariate effects for binarised choices and continuous preferences showed no significant bias towards preferring stimuli encountered when visualising either goal-attainment or goal-failure.

Figure 7

Bar Charts of Block Bias by Imagery Orientation for a) Binarised Preferences, and b) Continuous Preference Ratings of Evenly Matched .33 and .66 Reward Probabilities.



Note. The univariate effects for binarised choices and continuous preferences showed no significant bias towards preferring stimuli encountered when visualising either goal-attainment or goal-failure.

Subsequent GLM analyses tested whether preferences were additionally modulated by relevant trait and symptom measures. We hypothesised that individuals with higher reported levels of trait mood instability and depression symptoms (H3b), and more trait propensity to mental imagery (H3c), would show a stronger bias for preferring stimuli encountered when visualizing goal-attainment.

Trait and symptom measures (H3b): Individual differences measures of mood instability and depression symptoms had no effects or interactions with preferences based on imagery at the multivariate level ($p \geq .441$), or at the univariate level when quantified as binary choices ($p \geq .556$) or continuous preferences (high probability: $p \geq .470$; low probability: $p \geq .790$).

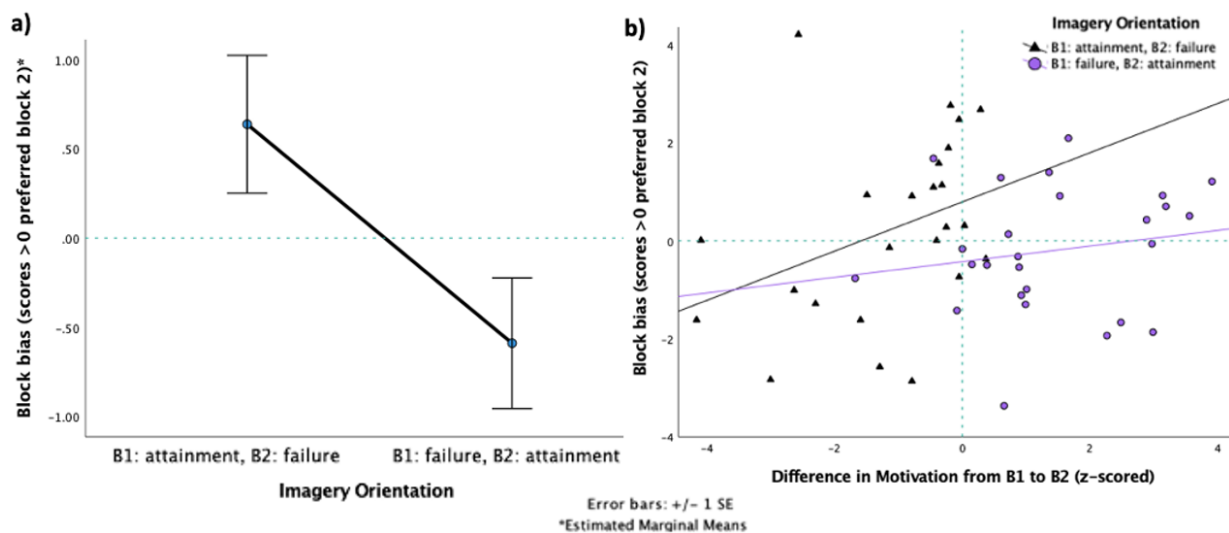
Trait proneness to imagery (H3c): Analyses showed that the effect of imagery orientation on preferences trended towards significance at the multivariate level ($F_{3,46} = 2.549$, $p = .068$, $Wilks' \Lambda = .852$, $np^2 = .148$) when accounting for the interaction of Imagery Orientation x SUIS ($F_{3,46} = 1.793$, $p = .110$, $Wilks' \Lambda = .794$, $np^2 = .109$). A significant univariate effect and interaction was found on binary preferences (main effect: $F_{3,46} = 5.512$, $p = .023$, $np^2 = .107$; interaction: $F_{3,46} = 3.313$, $p = .045$, $np^2 = .126$), but not for continuous preferences ($p \geq .224$). Examination of the plot (Supplementary Figure 6a) and further analyses found a significant positive correlation between bias (based on binary preferences) and proneness to mental imagery for those who visualised goal-failure in the first block ($r_{26} = .593$, $p = .001$), but not for those who visualised goal attainment ($r_{24} = -.067$, $p = .756$). The significant bias observed towards preferring stimuli encountered in the block when visualising goal failure was offset by higher levels of imagery ability.

Motivation (H4): We hypothesised that the effects of imagery orientation on perceived reward value would be modulated by differences in motivation, with individuals who demonstrate a greater change in motivation showing a greater bias for preferring stimuli encountered when visualizing mental imagery relating to goal-attainment. There was a significant multivariate effect of imagery orientation on perceived reward value ($F_{2,47} = 3.188$, $p = .033$, $Wilks' \Lambda = .825$, $np^2 = .175$) when including for differences in motivation (covariate: $p = .263$), with a significant univariate effect on binary choices ($F_{2,47} = 4.055$, $p = .05$, $np^2 = .079$) but not on continuous preference ratings (high probability: $p = .723$; low probability: $p = .805$). Participants demonstrated a significant preference (based on binary choices) for stimuli encountered when visualising goal-failure (Figure 8a) when accounting for the effect of differences in motivation (Figure 8b). Examination of the plot in Figure 8b and post-hoc correlational analyses showed that participants who visualised goal attainment in the first block

and showed a greater change in motivation between B1 and B2 tended to have a bias towards preferring stimuli encountered when visualising goal attainment ($r_{26} = .593, p = .001$); however, no significant correlation was found for those in the opposite imagery condition ($r_{24} = .171, p = .405$).

Figure 8

Plots showing **a)** the Main Effect of Imagery Orientation on Block Bias (binary) after Accounting for Motivation and **b)** the Effect of Motivation on Block Bias by Imagery Orientation Condition.

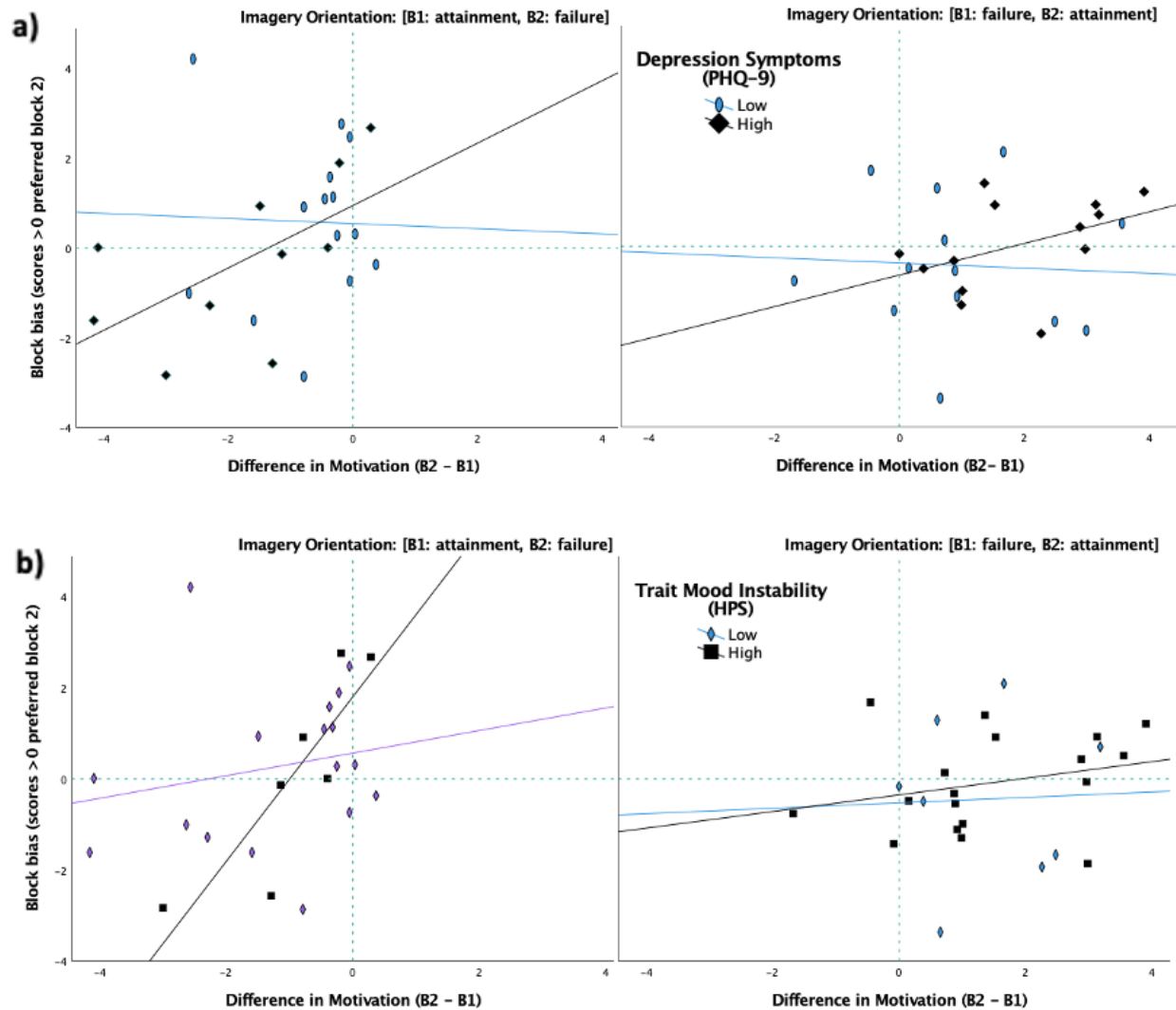


Note. Participants demonstrated a significant preference for stimuli encountered when visualising goal-failure **(a)** when accounting for the effect of differences in motivation **(b)**. Correlational analyses showed that participants who visualised goal attainment in the first block and showed a greater change in motivation between B1 and B2 tended to have a bias towards preferring stimuli encountered when visualising goal attainment, but no significant correlation was found for those in the opposite imagery condition.

A further exploratory analysis was conducted to examine whether interaction between depression symptoms (PHQ-9) and change in motivation from B1 to B2 modulated binary preferences based on imagery orientation. A second analysis also examined whether interaction between trait mood instability (HPS) and change in motivation from B1 to B2 modulated binary preferences. A trend-level effect of imagery orientation on perceived reward value ($F_{2,47} = 4.611, p = .037, np^2 = .089$; the Bonferroni corrected threshold was $p = .025$) was found when accounting for the significant interaction between depression symptoms and change in motivation from B1 to B2 ($F_{2,47} = 4.611, p = .024, np^2 = .104$; the Bonferroni corrected threshold was $p = .025$). The second analysis also showed a trend level effect on preferences based on imagery ($F_{2,47} = 4.804, p = .033, np^2 = .093$) when accounting for the trend level interaction between trait mood instability and change in motivation ($F_{2,47} = 4.773, p = .034, np^2 = .092$; the Bonferroni corrected threshold was $p = .025$). A median split was conducted on PHQ-9 and HPS scores to assist with exploring the interaction effects (low PHQ-9 scores $\leq 7 \leq$ high PHQ-9 scores; low HPS scores $\leq 40 \leq$ high HPS scores). Examination of the plots (Figures 9a) showed that in both imagery conditions those participants with more depression symptoms were more strongly biased by changes in motivation between B1 and B2 in terms of their preference for stimuli encountered when visualising goal-attainment. This same pattern was also observed across imagery conditions for those participants with higher levels of trait mood instability (Figure 9b). This pattern of bias was strongest for participants who visualised goal-attainment imagery in the first learning block prior to goal-failure.

Figure 9

The Effect on Binary Preferences of the Interaction with Change in Motivation for **a)** Depression Symptoms and **b)** Trait mood Instability, by Imagery Orientation.



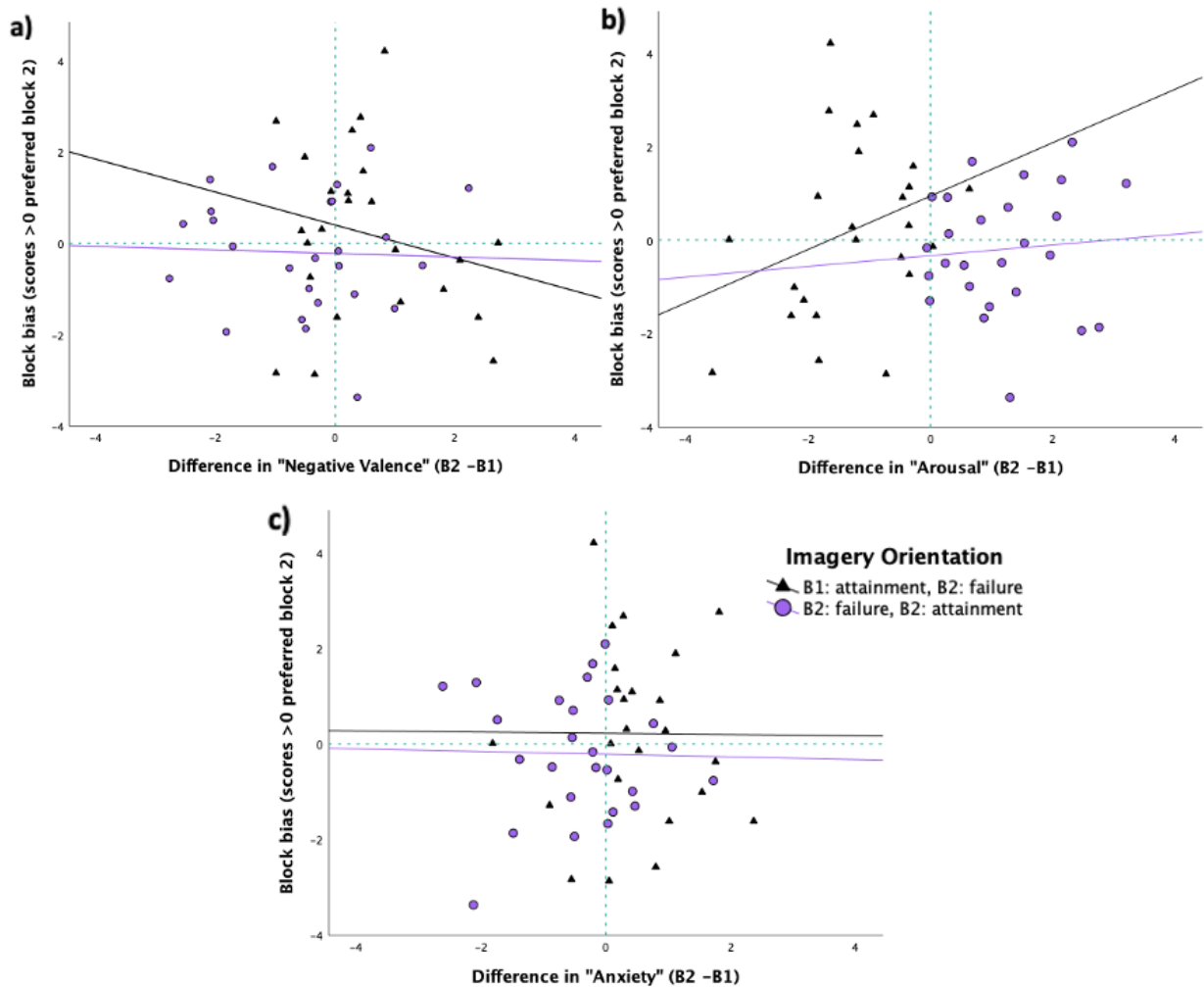
Note. Those participants with more depression symptoms who showed a greater change in motivation between B1 and B2 tended to have a stronger bias (based on binary choices) towards preferring stimuli encountered when visualising goal-attainment (**a**). This same pattern was also observed across imagery conditions for those participants with higher levels of trait mood instability (**b**).

Finally, exploratory analyses tested whether the effects of goal-oriented mental imagery on binary preferences were modulated by mood as denoted by the three Mood Zoom factors identified via principal component analysis (see section 3.1.1). These were: 1) “Negative Valence,” 2) “Arousal,” and 3) “Anxiety.” Given the inverse correlations of two of these factors with change in motivation from B1 to B2 (i.e., with Arousal being positively correlated with change in motivation, and Negative Valence being negatively correlated with change in motivation), it was expected that controlling for their combined modulating effects would reduce any bias on preferences observed in the previous analyses to a level of non-significance. We also anticipated that preferences would be modulated by the three Mood Zoom factors, with the factor denoting positive affect (i.e., Arousal) increasing bias for preferring stimuli encountered when visualizing goal-attainment, and the factors denoting negative affect (i.e., Negative Valence and Anxiety) decreasing this bias. Analyses showed that the effect of imagery orientation on binary preferences was at trend level ($F_{3,46} = 3.353, p = .074, np^2 = .069$) when accounting for the combined effects of the three Mood Zoom factors. Each of three factors alone did not show significant modulating effects on preferences based on imagery orientation (Negative Valence: $p = .454$; Arousal: $p = .166$; Anxiety: $p = .943$). However, examination of the plots did show inverse effects of Negative Valence and Arousal for participants who visualised positive imagery in the first block, whereby increased Arousal increased bias towards preference for stimuli encountered when visualising goal-attainment (Figure 10a) and increased Negative Valence had the opposite effect of decreasing this bias (Figure 10b). Interestingly, little bias was observable from these plots for participants who visualised imagery in the opposite order across the two blocks (i.e., negative imagery in the first block), and nor did the Anxiety factor appear to have any observable effect on preferences (Figure 10c).

Figure 10

Plots Showing the Modulating Effects on Block Bias (binary) of the Three Mood Zoom Factors:

a) Negative Valence, b) Arousal, and c) Anxiety.



Note. The effects of the three Mood Zoom factors on preferences are shown by imagery orientation. Inverse effects of "Negative Valence" and "Arousal" were observed for participants who visualised positive imagery in the first block. More "Arousal" increases bias towards preference for stimuli encountered when visualising goal-attainment (a), whereas more "Negative Valence" has the opposite effect of decreasing this bias (b). The "Anxiety" factor did not appear to have any observable effect on preferences in either imagery group (c).

Given the differences in block bias (when quantified as binary preferences) based on change in Negative Valence and Arousal from B1 to B2 (i.e., observed from the plots in Figure 13), further exploratory analyses were conducted to examine whether these two mood factors interacted with measures of trait mood instability and depression symptoms. Analyses did not find a significant main effect of imagery orientation on preferences ($p \geq .243$) or interaction with Negative Valence for either of the two trait/symptom measures (interactions: $p \geq .379$; the Bonferroni corrected threshold was $p = .025$). There were also no significant main effects on preferences or interactions with Arousal for the two trait/symptom measures following Bonferroni correction of $p = .025$ (main effects: $p \geq .042$; PHQ-9 x Arousal: $p = .036$; HPS x Arousal: $p = .09$; the Bonferroni corrected threshold was $p = .025$).

4. Discussion

4.1 Summary and Discussion of Findings

In this study, we examined whether goal-oriented mental imagery can bias the perceived reward value during learning. Participants completed a brief, online-based manipulation in which they generated mental images related to goal-attainment and goal-failure with a view to increasing and decreasing motivation, respectively. We were able to confirm that this manipulation was effective in modulating mood (H1a and H1b; Supplementary Figure 5) and motivation (H2a; Figure 4). We then quantified the impact of the imagery manipulation on reward perception, by sampling preferences in pairwise comparisons of stimuli encountered under goal-attainment versus goal-failure imagery which, by design, had the same objective reward probabilities. Findings with respect to this “reward perception bias” were mixed. Whilst the reward perception bias was modulated by imagery-led changes in momentary motivation (H4, Figure 8b) and further by depression symptoms (Figure 9a), there was some evidence of an overall bias towards preferring stimuli encountered when visualising goal-failure, rather than goal-attainment, inconsistent with our predictions (H3a; Figures 7a and 8a), which was offset in analysis when accounting for trait proneness to mental imagery (H3c, Supplementary Figure 6). Analyses to explore other factors influencing the observed bias for preferring stimuli encountered when visualising goal-failure found that accounting for three Mood Zoom factors representing “negative valence,” “arousal” and “anxiety” served to reduce any effect of imagery in biasing preferences to trend-level. In additional exploratory analyses, the Mood Zoom factor denoting Arousal demonstrated some interaction with depression symptoms in biasing preferences, but this effect did not withstand Bonferroni correction at a threshold $p = .025$. These factors allowed for reduction of the six mood states within the completed analyses of effects of mood on reward perception bias. As each factor consisted of multiple emotional

components, this also served to control for potential confounds attributable to subjective differences in how participants labelled and rated the six mood states during the task. It was therefore hoped that this would reduce noise and increase the statistical power of our analyses to detect any effects of mood on reward bias, as well as interactions with trait/symptom measures.

4.1.1 Efficacy of the Imagery Manipulation (H1 and H2)

As hypothesised, our findings showed that visualising goal-oriented mental imagery had a significant effect on both motivation and mood, whereby visualising goal-attainment was shown to increase subjective levels of motivation and positive affect, with goal-failure imagery having the opposite effect. These effects were observed robustly across the six emotional states captured via Mood Zoom ratings, and also for mean motivation and happiness ratings sampled throughout the learning blocks. Furthermore, using principal component analysis we were able to show that “Negative Valence” and “Arousal” components also captured opposing responses to mental imagery, with goal-attainment imagery increasing Arousal and decreasing Negative Valence. These findings support previous evidence to suggest a relationship between mental imagery and emotion through which internally visualising events can act as an ‘emotional amplifier’ (Holmes et al, 2008; Holmes & Matthews, 2005). This is the first time such a manipulation has been utilised in a reinforcement learning context, whereas previously the method used to induce mood has been external, either using monetary gain (Eldar & Niv, 2015) or performance feedback on general knowledge quiz (Vinckier et al, 2018).

It was shown that people with higher levels of depression symptoms were more responsive to effects of the intervention on happiness and motivation. Specifically, a larger increase in happiness and motivation was seen in response to visualising goal attainment for

those who reported higher levels of depression symptoms, whereas a larger decrease in motivation and happiness was seen in response to visualising goal-failure. The effects observed on motivation and happiness ratings when visualising goal-attainment suggests that visualising positive imagery is most effective for individual with reporting more depression symptoms, and therefore that encouraging depressed individuals to visualise positive outcomes can be effective in countering the effect of negative imagery and increasing motivation and positive affect. Counter to our predictions, we did not find evidence that higher trait mood instability led to greater impact of imagery on ratings of happiness or motivation. This is surprising given that previous work would suggest that these “bipolar-vulnerable” participants should be more responsive to mental imagery (Holmes et al, 2008, 2011).

The modulating effects of trait proneness to mental imagery on efficacy of the imagery manipulation are relevant to exploring whether individual propensity to mental imagery per se could make people more susceptible to the affective impact of goal-oriented mental imagery. While several studies included in our earlier review (see Part One) found measures of imagery vividness modulated effects of imagery-based interventions on depression symptoms (Renner et al, 2017; Torkan et al, 2014), there was only limited evidence (based on one study with a relatively small sample size) that higher individual propensity to mental imagery (based on SUIIS scores) increased efficacy in impacting symptoms (Lang et al, 2012). In this respect, our analyses found no significant effects of trait proneness to mental imagery in modulating efficacy of the imagery-based manipulation. This finding may be advantageous to development of future interventions in inferring that goal-oriented mental imagery is equally effective in impacting mood and motivation regardless of individual proneness to mental imagery. This therefore suggests that the efficacy of goal-oriented mental imagery in impacting mood and motivation may be more broadly generalised.

The present experiment has methodological implications for research into the effects of motivational and affective states on reward perception during learning. Indeed, the robustly observed impact of goal-oriented mental imagery on multiple facets of mood and motivation, including in increasing motivation and ‘arousal,’ and inversely in decreasing ‘negative valence,’ proffers the efficacy of this type of mental imagery as a novel means of inducing (or ‘amplifying’) changes in mood and motivation in experimental contexts. Moreover, the heightened efficacy of goal-oriented imagery in impacting motivation in individuals reporting more depression symptoms suggests that inducing this type of mental imagery could have particular psychotherapeutic benefit within interventions seeking to increase motivational drive in this group, especially as our findings infer general efficacy over-and-above individual propensity to mental imagery. This is also in-line with previous findings showing efficacy for imagery-based psychotherapeutic interventions in reducing depression symptoms (Lang et al, 2012; Pictet et al, 2016; Torkan et al, 2014), as well as related symptoms of rumination (Hirsch et al, 2020; Sit et al, 2020; Williams et al, 2013), anhedonia (Blackwell et al, 2015; Pictet et al, 2016), negative affect (Holmes et al, 2009; Rohrbacher et al, 2014; Sit et al, 2020), and behavioural (de)activation (Renner et al 2017; see Part One).

4.1.2 Effects of Goal-Oriented Mental Imagery on Perceived Reward Value (H3 and H4)

Any bias in preference for stimuli was only observed based on binarised ratings comparing stimuli between blocks, and not for the continuous slider ratings comparing only stimuli of evenly matched high and low reward probabilities. This was also the case for all findings subsequently discussed here. Hence, although for more simplistic binary choices participants were able to choose accurately between stimuli of high- and low-reward probabilities on binary trials, it may be that when asked to express the extent of their preference (i.e., via a more nuanced continuous rating) participants found it more difficult to differentiate

between stimuli within each block on the basis of their objective reward probabilities. In this sense, it was likely that the reward learning task put extensive cognitive burden on participants and may have taxed attentional resources which could have otherwise enhanced the generation of affective mental imagery. It is also notable that the binarised measure consists of multiple trials, whereas the slider ratings are for single trials only, so there is less statistical power and more noise for the latter. Nevertheless, stimuli were experienced at a largely consistent objective rate and magnitude across both learning blocks, especially after accounting for individual differences in experienced probabilities, and therefore any preferences exhibited by participants for stimuli encountered in either learning block can be deemed to be attributable to subjective bias in perception of reward value.

While imagery valence alone did not bias preferences for stimuli at test whether quantified as binary choices or continuous preference ratings, it was found that participants who showed a greater increase in motivation between B1 and B2 demonstrated a significant bias towards whichever block/stimuli they experienced in a higher motivational state (i.e., stimuli learned under goal-attainment imagery). There was also a significant effect on preferences when accounting for the interaction of motivation with depression symptoms, and separately at trend level with hypomanic traits, with participants with higher trait/symptoms scores demonstrating more bias towards preferring stimuli encountered when visualising positive imagery. This bias was observed to be strongest for those who visualised goal-attainment in the first block prior to goal-failure. Yet, conversely to what we hypothesised based on previous findings, when accounting for the impact of the manipulation on motivation, an opposite bias emerged; stimuli encountered when visualising goal-failure were preferred over those encountered when visualising goal-attainment. However, the fact that increased motivation served to counter this effect in our investigation suggests that such changes in

motivational state in response to visualising goal-attainment imagery can bias perception of rewards. Indeed, the picture of the effect of mental imagery on various mood states inferred via the Mood Zoom was consistent with the effect of imagery on mood and motivation, and the subsequent effect on preferences. Efficacy analyses suggest that feelings of being motivated or ‘aroused’ (i.e., encompassing feelings of being happier and more energetic) are increased by visualising imagery of a positive valence. However, emotions characterising ‘negative valence’ (encompassing feeling more angry, irritable, and sad), which are observed to run counter to motivation in our analyses, increased in response to imagery of a negative valence.

These findings align with Holmes and Mathews (2005) proposition that emotional processing in the brain is particularly sensitive to imagery and can act as an “emotional amplifier.” Furthermore, our findings are also largely congruent with previous studies showing that when in a more positive or motivated mood state, we are likely to experience events more favourably (Eldar et al, 2016; Schwarz & Clore, 2003) and that normal mood changes bias perception of reward value (Eldar & Niv, 2015). The BAS dysregulation theory (Depue & Collins, 1999) links our finding to biological and psychosocial aspects of bipolar disorder, and specifically demonstrates how levels of motivation, and dopaminergic response to rewards, influence reward perception and consequent decision-making processes. According to this theory, these factors feature within a causal chain whereby individuals demonstrating more activation in the BAS system (in particular, those individuals disposed to ‘mania’ or problems indicative of bipolar disorder) can orchestrate or pursue the very events that trigger an opposite state of deactivation (or depressed mood; Urošević et al, 2008). Indeed, the work of Holmes and colleagues (2008, 2011) suggests that visualising imagery might amplify perceptions and experiences in a manner that could impact on reward perception and decision-making processes engaged within our reward learning task.

In line with Chew et al (2019) these findings point towards endogenous dopaminergic responses linked to motivational state having a key role in the decision-making processes inferred when choosing between stimuli based on perceived reward value. Such bias attributable to motivation may be linked to upregulated dopaminergic response, whereby a little mood bias has been shown to be evolutionarily adaptive and beneficial for identifying rewards (e.g., food) within the environment, but too much may lead to problems such as those experienced in bipolar disorder (Mason et al, 2017). Furthermore, it has been suggested that the utility of mood may be to provide information as to the likelihood and magnitude of rewards in the surrounding environment (Schwarz & Clore, 1983; 2003) as an “overall momentum of recent outcomes” (Eldar et al, 2015). This information can then have a biasing influence on the perception of events which optimises learning by detecting changes in the environment which may signal an increase or decrease in available rewards. However, evidence also suggests that this adaptive mechanism may also lead to superfluous or deficient reward perception which in turn contributes to symptoms of mood disorders (Mason et al, 2017). Our findings extend this previous work, suggesting that it may be motivational state, rather than mood more generally, that serves to signal available rewards and that changes in motivation may bias reward perception.

After accounting for motivation, the bias observed for preferring stimuli encountered when visualising imagery of a negative valence suggests a process whereby, when asked to bring to mind imagery eliciting negative emotional affect, individuals may have focused away from these internal events and attribute more salience to rewarding events occurring in their external environment (Thayer & Lane, 2000). This bias was decreased to a level of statistical non-significance when accounting for the combined effects of the three Mood Zoom factors, suggesting that variability in affective factors (denoting a combination of arousal, negative

valence and anxiety) partly account for this affect. However, the effect did remain at trend level significance after accounting for these emotional factors, which may point towards other compensatory mechanisms. Taken in such a light, this finding could also point towards a compensatory mechanism of attentional control akin to that denoted by higher levels of dispositional mindfulness. Specifically, those with higher levels of attentional control or dispositional mindfulness may be more able to distract away from negative internal events by focusing attentional resources on external events and stimuli within their environment (Kong et al, 2016).

The same opposite effect of imagery valence on preferences was also found to be modulated to significance when accounting for the significant interaction between imagery valence and trait proneness to mental imagery, whereas those with higher SUIS scores demonstrated the opposite bias (i.e., for preferring stimuli encountered when visualising imagery of a positive valence). This finding could suggest that individuals with more proneness to mental imagery were better able to deal with the combined cognitive demands of the learning task and those required to visualise mental imagery. Interestingly, this effect was only observed in response to visualising imagery relating to goal-attainment (which is likely more emotionally tolerable to engage with) and not goal-failure. However, the lack of a relationship between imagery proneness and efficacy on mood and motivation suggests that the intervention impacted individuals equally regardless of imagery propensity. In this sense, it is possible that those with higher imagery ability were more able to hold mental imagery in mind *and* focus on the task (therefore the emotional/motivational state biasing reward perception), whereas poorer imagers were not as able to do both, so they held the emotional/motivational impact but were more distracted from the task. Given that the task was challenging (reward probabilities were on average lower than .33 and .66), and involved multitasking, these factors could provide

some explanation as to how effects on reward bias were more generally weakened or offset by multi-tasking. It is also possible that other related facets of imagery not measured here, such as individual difference in attentional control or mindfulness, contributed to these effects.

4.2 Strengths and Limitations

The current study demonstrated extensive scope with respect to exploring the relationship between mood disorders, mental imagery and decision making. Running the study online, with standardised procedures to ensure consistent methodology and measurements across participants, infers high internal validity. The methods used served to successfully confirm the impact of mental imagery on mood and motivation, and it is clear that the devised intervention, focused on eliciting affective imagery related to goal-attainment and goal-failure, was highly effective and may therefore be considered a particular strength of the study design. In addition, the methods used to measure momentary changes in mood and motivational state provided a clear indication of the differential impact of mental imagery on these variables. We also considered multifaceted aspects of mood, such as motivation and Mood Zoom factors (including negative valence, arousal, and anxiety), which have possibly been oversimplified as constructs by previous studies (Eldar & Niv, 2015; Vinckier et al, 2018; Rutledge et al., 2017). On balance, these factors can all be considered particular strengths of the current investigation.

Having confirmed the efficacy of the intervention in terms of mental imagery effectively impacting mood and motivation, the experiment also sought to extend the previous design used by Eldar and Niv (2015) by testing the effect of changes in mood and motivation induced through visualisation of mental imagery on perception of the reward value of paired stimuli encountered during a reward learning game. In order for the experimental design to be effective in exploring biases in perceived reward value it was imperative that participants

adequately learned the objectively different high and low reward probabilities of the presented stimuli pairs. Analyses of experienced reward probabilities suggested that stimuli pairs were experienced by participants at a rate lower than intended, reward probabilities were of a largely consistent rate and magnitude across the learning blocks (see Table 2.1), and the majority of participants did accurately distinguish between stimuli. Accounting for any residual effects of individual differences in experienced reward probabilities prevented this potential confound from being a limitation to the study.

In terms of identified limitations to the current investigation, the overall lower reward probabilities experienced in the reward learning game will have meant that it was more difficult for participants to accurately differentiate between stimuli of low and high reward probabilities within each pair. It is likely for this reason that 12 participants were found to exhibit below chance performance within the reward learning game. Unfortunately, removal of these participants brought the final sample size ($n=50$) marginally below that which was inferred from the initial power analyses ($n=52$) and may have meant that the planned analyses yielded less statistical power than initially anticipated for detection of more subtle effects and interactions within the data. Practical constraints of time and resources meant that data collected in a third (neutral imagery) learning block and the subsequent test block were not analysed. Furthermore, the application of relevant computational modelling (Eldar & Niv, 2015; Rutledge et al., 2017), could have provided additional insight into the proposed mechanisms operating during learning, rather than for example at recall. Specifically, without the application of relevant computational modelling it is not possible to assert that the biases were operating during learning blocks rather than during test blocks. For example, it may be that participants made choices based on mood-related associations with stimuli rather than

biases in reward perception per se— “I will choose the fractal on the left, because I remember feeling happier when I saw that one.”

In relation to competing hypotheses relating to the effect of imagery on reward perception, the current task was likely made harder due to participants being required to dual task between visualising imagery and learning the reward value of stimuli. Given the additional attentional burden that visualising mental imagery likely put on participants, the learning task may have been suboptimal for revealing reward bias; making the learning task easier may have reduced the competing attentional demands of learning and imagery.

4.3 Clinical Implications and Future Directions

The findings of the current investigation demonstrate the efficacy of a brief online-based intervention in eliciting goal-oriented mental imagery which is highly effective in impacting mood and motivational states. This lends support to the suggestion that mental imagery can act as an ‘emotional amplifier’ and has important implications for understanding the role of mental imagery and motivational state in both alleviating and perpetuating mood disorders. Furthermore, it was also shown that differential change in momentary motivation in response to visualising mental imagery of positive and negative valence modulated biases in perception of reward value. Although trait mood instability and depression symptoms were not uniquely observed to modulate the effect of imagery valence on perception of reward value, both of these measures were observed to have modulating effects on ratings of happiness, and for depression symptoms in modulating the effect of mental imagery on motivational state.

Of particular clinical relevance, a larger increase in ratings of happiness and motivation was observed in response to goal-attainment imagery for those participants who reported more depression symptoms. These findings are congruent with previous studies pertaining to

behavioural activation which have shown that people with depression are equally responsive to positive and negative events (Ekers et al, 2014), and also studies showing that happiness is modulated by reward outcomes equally in both depressed patients and controls (Rutledge et al, 2017). Such studies typically argue that depressed individuals have become disconnected from (or avoidant) of situations that would improve their mood (but with intervention can be equally as responsive as non-depressed people when they do put themselves in those situations).

The tendency for those suffering with depression to become caught up in ruminative cycles which then impact adversely on mood and motivation, may explain the increased response to visualising goal-failure in these individuals. However, being prompted to visualise mental imagery relating to goal-attainment may serve to boost motivational drive and increase reward salience. Hence, the degree of change in motivation in response to visualising mental imagery appears to be a key factor in modulating reward biases. Moreover, for those with more trait proneness to mental imagery— who we propose were likely better able to multitask on both reward learning and imaging aspects of the experiment— visualising goal-attainment appeared to counter the impact of visualising goal-failure on perception of reward value and may infer that being able to visualise vivid mental imagery related to positive outcomes can provide a protective mechanism.

These findings have important clinical implications and may provide the foundations for development of an intervention geared towards boosting (or preserving) the protective aspects of mental imagery, whilst also fostering cognitive mechanisms or strategies which counter unhelpful effects on mood, motivation and reward perception. However, it is first necessary to replicate the observed effect of goal-oriented mental imagery on reward bias, and also to elucidate the mechanisms by which this effect is modulated by factors of motivation, trait mood instability, depression symptoms, and individual proneness to mental imagery.

Computational modelling utilising or building on previous work (i.e., Mason et al, 2017) using choice behaviour to infer the subjective reward value of options and quantify how much this was biased away from their objective value by their current mood state may be particularly useful to this end.

4.4 Conclusions

The current investigation explored the impact of goal-oriented mental imagery (in particular, on momentary mood and motivation), and also to what extent changes in mood and motivation influence perception of the reward value. It also sought to extrapolate the role of trait mood instability, current depression symptoms, and individual proneness to mental imagery in modulating any effects of mental imagery on mood and motivation, and also subsequently on subjective bias for outcomes experienced when in particular mood or motivational states.

In conclusion, the brief intervention developed to elicit goal-oriented mental imagery was highly effective in impacting mood and motivational states, thus inferring important implications for understanding the role of mental imagery and motivational state in both alleviating and perpetuating mood disorders. Furthermore, the observed effect of change in momentary motivation in modulating perception of reward value suggests that the degree of change in motivation in response to visualising mental imagery is a key factor in modulating reward biases.

These findings may provide the foundations for development of a mental imagery-based clinical intervention to counter dysregulation of mood, motivation and reward perception. While the findings of this investigation inform knowledge of mood disorders more generally, they are perhaps of particular relevance to understanding how mechanisms of emotion and

motivation could contribute to biases in reward perception and decision making that can lead individuals (particularly those prone to [hypo]mania) to orchestrate or pursue the very events that trigger an opposite state of deactivation and depressed mood (Urošević et al, 2008).

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Part Three: Critical Appraisal

1. Introduction

This critical appraisal discusses some of my reflections on completing the thesis. This includes the relevance of my background to selection of a project, the process of formulating of a research question for the empirical study and systematic review, and the experimental design.

2. Background and Selection of a Project

The clinical experience that I had gained prior to starting training as a clinical psychologist was varied. It was whilst studying my MSc in Psychology at Birkbeck College, University of London, that I decided to move away from my pastoral role in a London secondary school to gain experience working with people with complex mental health issues. In terms of factors influencing this decision, I would say that these were complex and multi-faceted— a college module on abnormal psychology that initially sparked my academic interest, volunteer work with young carers and several months spent abroad assisting young people who were homeless, various mental health related modules studied at undergraduate and postgraduate level, but also personal experiences, including those of witnessing family members struggles with mental and physical health problems. In this sense, I had known for some time that my interests were more aligned towards a career within mental health settings than they were towards a career in education. However, that is not to say that I did not significantly value working within a school setting and gain many transferable skills from this experience.

My first experience working with adults experiencing severe and enduring mental health problems was as a support worker in Brixton. I worked across various supported housing locations and was allocated as keyworker for many people with a range of difficulties

over the course of the two years I spent in this service. This work also involved a similar affiliated role supporting people with medication management and stepped transitions between services (i.e., from inpatient care to secondary care via CMHT, and also from secondary to primary care) in close liaison with National Health Service (NHS) staff and services. Over the course of this work, I was privileged to work alongside the people under my care, and their families, to come to understand some of their motivations and hopes for the future. Many of the goals set when support planning with individuals involved making manageable steps towards regaining confidence and autonomy, but progress was rarely quick or simple, and relapse was common (Ascher-Svanum et al, 2010; Bradizza et al, 2006). This process was especially difficult when it came to managing psychotropic medications and finding a balance between assisting people to have improved well-being and quality of life on effective medication, as well as mitigating dependence. Working alongside people in this capacity, affirmed a vehement desire to understand how best to improve outcomes for people struggling with sustained adversity due to complex and enduring mental health difficulties.

My subsequent post-graduate training in low intensity cognitive behavioural interventions (Papworth & Marrinan, 2018), as well as working and gaining experience as a psychological wellbeing practitioner (PWP) in NHS Improving Access to Psychological Therapies (IAPT; Fonagy, 2014), provided me with reasonable grounding in cognitive behavioural models of assessment and treatment. It also cemented my passion for better understanding how such psychotherapeutic interventions could best be utilised to prevent prolonged distress often caused by mental health problems without adequate treatment.

During the projects fair I listened attentively to the presentations of prospective doctoral thesis projects, with my prior experience in mind. Various projects caught my interest, but Dr Liam Mason's presentation of his work with bipolar disorder struck me as having particular

breadth with exploring most holistically the complex interaction between neurobiological fluctuations in mood, cognitive processes and behaviour. His use of the allegory of Icarus, from Greek mythology—the boy who flew too close to the sun against better advice and had his wings burned, before plummeting back to earth—as an analogy for the plight often brought about through extremes of mood in bipolar disorder, reminded me of the chronic struggles with fluctuations in mood and extremes of behaviour (including various addictions) experienced by many of the people I had worked with within supported housing services in Brixton. I was intrigued by Liam’s outline of his prior work and the multi-dimensional approach he proposed towards understanding neurobiological mechanisms underlying mood instability characterising bipolar disorder (e.g., Mason et al, 2012, 2014, 2016, 2017), and also the scope his projects provided to further this understanding towards the development of a structured psychotherapeutic intervention aimed at alleviating the distress caused by such mood instability.

3. Formulating a Research Question

There were outstanding questions from the above work in relation to the impact of changes in mood on perception of reward value, and in particular with respect to bipolar disorder (Mason et al, 2017). Existing work had focused on the use of monetary rewards to induce positive and negative moods (Eldar & Niv, 2015; see Part Two). I wanted to extend this research in a more clinical direction, by marrying it up with clinical theory and practice around mental imagery. This was also consolidated by Liam’s existing knowledge and experience that this plays a key role in psychopathology and perhaps especially bipolar disorder.

It has been suggested that bipolar disorder patients may be particularly imagery-prone, and that mechanisms of mental imagery on emotion may precipitate the extremes of mood

intensity and rapid changes in mood commonly observed in this clinical group (Holmes et al., 2008). Furthermore, findings showing that mental imagery may be heightened in these individuals (Holmes et al., 2008) are consistent with a fundamental phenomenology of intrusive imagery in bipolar disorder (Gregory et al, 2010; Mansell & Hodson, 2009; Mansell & Lam, 2004). This posed the question as to whether this form of imagery can be a target for intervention (Hackmann et al, 2011; Holmes et al, 2007), and, indeed, emerging evidence already suggests efficacy for interventions targeting mental imagery in a range of mood and anxiety disorders (see Part One), including in bipolar disorder (e.g., Holmes et al, 2008, 2011).

We considered the use of mental imagery in impacting mood state in a range of mood and anxiety disorders, including bipolar disorder, and wondered whether mental imagery of a positive or negative valence might be used experimentally to induce mood in a manner similar to how Eldar & Niv (2015) had used external rewards (the unexpected gain or loss of relatively large sums of money). Furthermore, we hoped that after confirming the expected impact of mental imagery on mood and motivation, we may also test its impact on various factors, including trait mood instability, depression symptoms, and individual proneness to mental imagery, which could then be subsequently associated with “reward bias” in a learning task akin to that one used previously by Eldar & Niv (2015). I liked the potential of this design for progressing understanding of the factors modulating reward bias, and also in elucidating the role of mechanisms of mental imagery in impacting on emotional factors, which may then have implications for the future development of targeted psychotherapeutic interventions.

4. Experimental Design

In addition to my research interests (see section 1), another factor that was important to me in selecting a project was the opportunity to develop my knowledge of experimental design and statistical analysis. My MSc dissertation project had a genetic focus, exploring the impact of copy number variants (CNVs) in relation to the autistic phenotype (Vicari et al, 2019). This was a fascinating piece of work to undertake, however the method of analysis used (based around QuantiSNP; e.g., Colella et al, 2017) was not common to psychology and I feel therefore did not consolidate my knowledge of conducting statistical analyses in the way a more typical quantitative dissertation project would have. This was something I voiced to Liam when we first met to discuss the project, and we began to work together on the understanding that I was willing to follow his guidance and to learn from his depth of experience in psychological research methods and experimental design.

Having had extensive discussion (and Liam having advised me on relevant reading in the field which might inform the design), we arrived at an experimental paradigm through which to explore our research questions in relation to mental imagery, biases in reward perception, and potential modulating factors. Based on the prior work of Eldar and Niv (2015), our experiment used an objective reward learning task to facilitate learning of stimuli of matched reward probabilities across two blocks. We then tested for biases in preferences by asking participants to choose between learned stimuli-pairs in a subsequent test block. Departing from Eldar and Niv's (2015) previous design, we decided to use goal-oriented mental imagery (relating to either goal-attainment or goal-failure) to induce changes in affect and particularly motivational state, rather than the monetary-based mood induction that they had used (namely, either winning or losing \$5 on a wheel of fortune draw) as they had done. We also tested factors that might modulate the efficacy of mental imagery on mood and

motivation, and to what extent imagery-led changes in these emotional factors, as well as relevant individual traits and symptom measures (specifically, measures of hypomanic traits, depression symptoms, and individual proneness to imagery), impacted on reward bias.

The experiment demonstrated extensive scope for testing a range of factors potentially modulating the effects of imagery-led changes in mood and motivation on reward perception. However, within the scope of the current project it was not possible to quantify the impact of the mood manipulation using neurological measures (i.e., fMRI) as Eldar and Niv (2015) did; and nor was the application of computational modelling feasible in the timeframe of the project. This could have clarified the dynamics between mood and reward perception during learning, and allowed us to be more confident that the biases we observed were operating during learning blocks rather than at the point of recall in the post-learning test block. It is possible that participants made choices based on mood-related associations with stimuli rather than biases in reward perception per se (e.g., “I will choose the fractal on the left, because I remember feeling happier when I saw that one”), although this possibility was ruled out in the experiment by Eldar & Niv (2015), using computational modelling. Although I had initially hoped to pursue this within the project, the learning curve for learning this highly mathematical knowledge and skills was likely not feasible, especially given the amount of time allocated for research and my training background up until the point of starting the project.

With hindsight, our experimental design put significant emphasis on the requirement of internal and external validity; however, issues pertaining to the utility of highly objective cognitive tasks in studying, complex, multi-faceted and subjective phenomena— as denoted by mental imagery, motivation and happiness in our experiment— complicate this (Myers & Hansen, 2011). While the cross-validation of psychometric measures serves to ensure reliable

construct validity, interpretation of these tests typically relies upon comparison with normative or with external a priori criteria which may not be entirely relevant to phenomena as experienced across all populations (Breakwell et al, 2006). Although bespoke emotional measures including rating scales of, for example, of happiness and motivation, can infer a common measurement of individual experience, there may also be subjective differences in the way these terms are interpreted and responded to which are not easily controlled for, making it difficult to generalise findings between populations (e.g., Dickerson, 1993).

An assumption of the approach we adopted is that the small monetary rewards that people experience during the learning task can generalise to positive and negative life experiences in the real world. However, this is a large leap (earning 5 pence on a trial is a qualitatively different reward from the birth of a child, or even enjoying a meal with a loved one). Indeed, it remains to be shown that behaviour in these tasks does carry over to the real world. Similarly, the kind of “mood” and “motivation” we are detecting are surely very different to the kind of mood that someone experiences following positive or adverse life experiences, but the assumption is that the much shorter-term and circumscribed affect we detect in our experimental paradigm is a building block of real-life moods.

Campbell (1957) proposed that an experiment should only be considered internally valid if a significant difference is found between treatment and a control condition. While our experiment did include a comparison group, the fact that both groups were treated with goal-oriented mental imagery (only in the opposite block/imagery order) makes counterfactual causal inferences difficult to make (Lewis-Beck et al, 2004) as it is difficult to know these effects were not attributable to other aspects of the experiment without the inclusion of a ‘no treatment’ control group. Our experimental design should have ideally included a third condition of this nature.

A significant strength of the experimental design was the ease of random sequence allocation, concealing allocation and blinding of outcome assessment proffered by using an entirely computerised, web-based experiment. This design thus served to minimise interaction between researcher and participants and reduce risk of bias pertaining to these factors. Furthermore, this also ensured high internal consistency with respect to the experimental process which helped to reduce confounds commonly attributable to potential differences in the application of methods that are more reliant on experimenter/therapist involvement. However, the process of building the components of the experiment to run entirely online, including the imagery-based manipulation— which consisted of eliciting relevant goals, and then prompting participants to visualise affective, multisensory imagery in relation to goal outcomes— was particularly exhaustive. This process also included substantive piloting to ensure that the manipulation was effective before running the main experiment.

5. Closing Reflections

Completing the project during the COVID-19 pandemic has brought with it significant challenges. The project was originally intended to be a combination of face-to-face imagery-based manipulation completed with the experimenter, followed by a computerised task completed in the laboratory. The advantage of meeting participants face-to-face is that it would have been possible to check and refine the efficacy of imagery during the manipulation. Although moving the entire experiment online had advantages in terms of ensuring highly consistent methods for eliciting mental imagery, this part of the experiment was arduous to build and I cannot help feeling as though I missed out on gaining certain valuable aspects of experience when meeting participants face-to-face and running the experiment in a laboratory.

My first Band 7 role post-qualification will be working with adults within a personality disorder managed clinical network, and there it is likely that the insights I have gained from completing this project with respect to the impact of imagery on mood, motivation and reward perception will be highly useful within this context. Given the findings relating to the efficacy of imagery-based interventions on mood brought to my attention via the process of completing the systematic review and the empirical study, my intention is firmly to continue to grow my expertise in this area and ensure that I am equipped to make best use of mental imagery within my work. It is my hope to work with Liam towards dissemination of the findings presented in this report via formal publication. Furthermore, the opportunity to be involved with relevant clinical trials of new or novel interventions, including computerised or web-based treatments, would be something I will be seeking out in my career.

6. References

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Appendices

APPENDIX A: Literature Search Strategy

Key concepts*	Therapeutic intervention	Positive imagery
Alternative terms / synonyms	Cognitive behaviour therapy Psychological intervention Cognitive bias modification Psychological treatment imagery training imagery-based training interpretation training interpretation bias modification web-based treatment Intervention in psychotherapy Pilot clinical audit Brief early intervention for depress* Behavioural activation	Positive image* Motivational imagery Mental image* Imagery-based Compassionate image* Imagin* positive events Imagery-focused Positive prospective mental imagery Positive prospective imagery

APPENDIX B: Risk of Bias Tables

Blackwell et al (2015)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomized in a 1:1 ratio to one of two groups, imagery cognitive bias modification or control, within the constraints of stratification by gender and baseline Beck Depression Inventory–II score via a Web-based randomization system
Allocation concealment (selection bias)	Low risk	The researcher who carried out the baseline assessment assigned participants to their allocated intervention via a web-based randomization system
Incomplete outcome data (attrition bias) All outcomes	Low risk	141 (94%) participants completed at least the BDI-II postintervention (primary outcome), and 140 (93%), 129 (86%), and 133 (89%) completed at least this outcome measure at 1-, 3-, and 6-month follow-up, respectively.
Selective reporting (reporting bias)	Low risk	The study was prospectively registered (clinicaltrials.gov identifier NCT01443234). Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	In the face-to-face posttreatment assessment, a researcher blind to participant allocation was assigned to administer the outcome questionnaires, and blinding was achieved for at least the primary outcome with one exception (due to an administrative oversight). Thus, the trial can be considered “double blind.”

Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinding was achieved for at least the primary outcome with one exception (due to an administrative oversight).
Other bias	Unclear risk	Significant difference in PIT scores between groups at baseline, with control group scoring more highly.

Dainer-et al. (2018)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Randomization occurred without human action through URL redirection; participants landed upon a website which was randomized to point to one of two conditions.
Allocation concealment (selection bias)	Low risk	Randomization occurred without human action through URL redirection
Incomplete outcome data (attrition bias) All outcomes	Low risk	Treatment condition: (N = 124), 31% completed the study. NTC: condition (N = 140), 35% completed the study after randomization. Thorough ITT analysis completed.
Selective reporting (reporting bias)	Unclear risk	No protocol registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Participants were blind to their condition, and interaction with experimenters was minimal.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Web-based automation resulted in what was, in essence, a double-blind experiment.

Other bias	Low risk	No other potential bias identified.
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Di Simplicio et al. (2020)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were assigned to receive FIT either immediately or after 3 months (waitlist control) via a randomization code independently prepared by the study statistician.
Allocation concealment (selection bias)	Low risk	Randomization code independently prepared by the study statistician.
Incomplete outcome data (attrition bias) All outcomes	High risk	Attrition for the outcome measures collected over the phone, including the primary outcome, was 24% at 3 months and 37% at 6 months of follow-up. Attrition for the online questionnaires was 50% at 3 months and 71% at 6 months, preventing their inclusion in analyses.
Selective reporting (reporting bias)	High risk	Pre-registered their study but did not complete planned analysis of outcome measures taken at 3- and 6-months due to high attrition.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Waitlist control. Participants were informed of the assigned intervention by the psychiatrist who delivered the therapy sessions.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcomes' assessment was blind to allocation.
Other bias	Low risk	No other potential bias identified.

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomized to one of the three conditions based on a random allocation sequence generated from http://www.random.org by a person not directly involved in the research study, who placed Numbers 1–3 corresponding to the three conditions in sealed envelopes marked with ascending sequence order numbers.
Allocation concealment (selection bias)	Low risk	Researchers opened the envelope at the first experimental session once participants had provided written informed consent.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Twelve participants were excluded due to missing data (technical) issues with E-Prime; n=5) or poor performance on the recognition test (n=7), leaving N=166 for analyses
Selective reporting (reporting bias)	Unclear risk	Researchers did not pre-register the studies.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of the researchers was not possible as researchers guided participants through the first online session, which differed by experimental condition.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Blinding of the researchers was not possible.
Other bias	Low risk	No other potential bias identified.

Hirsch et al. (2020)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomized to one of three conditions based on a random allocation sequence generated from <i>http://www.random.org</i> by a person not directly involved in the research study, who placed Numbers 1–3 corresponding to the three conditions in sealed envelopes marked with ascending sequence order numbers.
Allocation concealment (selection bias)	Low risk	Researchers opened the envelope at the first experimental session once participants had provided written informed consent.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Twelve participants were excluded due to missing data (technical) issues with E-Prime; n=5) or poor performance on the recognition test (n=7), leaving N=166 for analyses
Selective reporting (reporting bias)	Unclear risk	Researchers did not pre-register the study.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of the researchers was not possible as researchers guided participants through the first online session, which differed by experimental condition.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Blinding of the researchers was not possible.
Other bias	Low risk	No other potential bias identified.

Holmes et al. (2009)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Unclear risk	Participants were randomized to either imagery or verbal conditions. No detail of how groups were randomly assigned.
Allocation concealment (selection bias)	Unclear risk	No description of allocation concealment.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcome measures reported for all participants.
Selective reporting (reporting bias)	Unclear risk	No protocol registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	High risk	The experimenter read instructions for the assigned condition.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported whether outcome assessment was blind.
Other bias	Low risk	No other potential bias identified.

Holmes et al. (2006)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Unclear risk	Participants were randomized to either imagery or verbal conditions. No detail of how groups were randomly assigned.

Allocation concealment (selection bias)	Unclear risk	No description of allocation concealment.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Outcome measures reported for all participants.
Selective reporting (reporting bias)	Unclear risk	No protocol registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported whether personnel were blind.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported whether outcome assessment was blind.
Other bias	Low risk	No other potential bias identified.

Ji, Holmes, Blackwell (2018)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomized in a 1:1 ratio to one of two groups, imagery cognitive bias modification or control, within the constraints of stratification by gender and baseline Beck Depression Inventory-II score. Web-based randomization system.
Allocation concealment (selection bias)	Low risk	The researcher who carried out the baseline assessment assigned participants to their allocated intervention via a Web-based randomization system.

Incomplete outcome data (attrition bias) All outcomes	Low risk	141 (94%) participants completed at least the BDI-II postintervention (primary outcome), and 140 (93%), 129 (86%), and 133 (89%) completed at least this outcome measure at 1-, 3-, and 6-month follow-up, respectively.
Selective reporting (reporting bias)	Low risk	The study was prospectively registered (clinicaltrials.gov identifier NCT01443234). Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	In the face-to-face posttreatment assessment, a researcher blind to participant allocation was assigned to administer the outcome questionnaires, and blinding was achieved for at least the primary outcome with one exception (due to an administrative oversight). Thus, the trial can be considered “double blind.”
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Blinding was achieved for at least the primary outcome with one exception (due to an administrative oversight).
Other bias	Unclear risk	Significant difference in PIT scores between groups at baseline, with control group scoring more highly.

Lang et al. (2012)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomised to the positive or control condition by using a computerized random number generator following their assessment.

Allocation concealment (selection bias)	Low risk	Computerized random number generator will have concealed allocation.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Two participants dropped out after the first session of CBM-I. Twenty-six participants therefore completed post-treatment measures, and 25 completed follow-up measures at two-week post-treatment.
Selective reporting (reporting bias)	Unclear risk	No report of protocol being registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Personnel not blind as assessment interviews were conducted by the first author at pre-treatment and post-treatment.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported whether outcome assessment was blind.
Other bias	Low risk	No other potential bias identified.

Linke & Wessa (2017)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Unclear risk	Participant pairs were matched according to reward sensitivity, age, sex, and mental imagery ability and then one person in each pair was randomly assigned to the training and the other to the wait condition. No detail provided of how groups were randomly assigned.
Allocation concealment (selection bias)	Unclear risk	No description of allocation concealment.

Incomplete outcome data (attrition bias) All outcomes	Low risk	All individuals allocated to treatment and control completed outcome assessment.
Selective reporting (reporting bias)	Unclear risk	No report of protocol being registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Web-based treatment. Participants and personnel were unaware of group assignment.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessments completed online and therefore reducing any risk of influencing data.
Other bias	Low risk	No other potential bias identified.

Murphy et al. (2015)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Randomisation of participants to a training group was performed by the study Chief Investigator, who otherwise had no contact with the participants. Randomisation was stratified by scores on the BDI-II.
Allocation concealment (selection bias)	Low risk	Allocation of participants performed by the study Chief Investigator, who otherwise had no contact with the participants.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Compliance with the training schedule was 96% for participants completing all 12 training sessions.

Selective reporting (reporting bias)	Unclear risk	No report of protocol being registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Personnel would have been aware of participant group assignment
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported whether outcome assessment was blind.
Other bias	Low risk	No other potential bias identified.

Pictet et al. (2016)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomised with a computer random number generator
Allocation concealment (selection bias)	Low risk	Allocation was concealed to participants.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Adherence to the online CBM intervention was high, with 97% of participants in the imagery CBM group and 94% in the control CBM group completing all 4 sessions of the intervention. All participants completed the follow-up assessments.
Selective reporting (reporting bias)	Low risk	No report of protocol being registered. Clear pre-specified aims and hypotheses stated and addressed.

Blinding of participants and personnel (performance bias) All outcomes	Low risk	Web-based treatment. Participants and personnel were unaware of group assignment.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Outcome assessments completed online and therefore reducing any risk of influencing data.
Other bias	Low risk	No other potential bias identified.

Renner et al. (2017)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Participants were randomized in a 1:1 ratio to one of two groups, imagery cognitive bias modification or control, within the constraints of stratification by gender and baseline Beck Depression Inventory–II score (mild-to moderate score of 28 or less vs. severe score of 29 or more)
Allocation concealment (selection bias)	Low risk	The researcher who carried out the baseline assessment assigned participants to their allocated intervention via a Web-based randomization system
Incomplete outcome data (attrition bias) All outcomes	Low risk	141 (94%) participants completed at least the BDI-II postintervention (primary outcome), and 140 (93%), 129 (86%), and 133 (89%) completed at least this outcome measure at 1-, 3-, and 6-month follow-up, respectively.
Selective reporting (reporting bias)	Low risk	The study was prospectively registered (clinicaltrials.gov identifier NCT01443234). Clear pre-specified aims and hypotheses stated and addressed.

Blinding of participants and personnel (performance bias) All outcomes	Low risk	In the face-to-face post-treatment assessment, a researcher blind to participant allocation was assigned to administer the outcome questionnaires, and blinding was achieved for at least the primary outcome with one exception (due to an administrative oversight). Thus, the trial can be considered “double blind.”
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinding was achieved for at least the primary outcome with one exception (due to an administrative oversight).
Other bias	Unclear risk	Significant difference in PIT scores between groups at baseline, with control group scoring more highly.

Rohrbacher et al. (2014)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Unclear risk	Participants were randomly assigned to standardized CBM-I-, self-generation CBM-I, or a control group. No detail of how groups were randomly assigned.
Allocation concealment (selection bias)	Unclear risk	Cover story. All participants told that the purpose of the study was to examine the association between memory effects and spatial representations. However, unclear detail of concealment on assignment.
Incomplete outcome data (attrition bias) All outcomes	Low risk	All individuals allocated to treatment and control completed outcome assessment
Selective reporting (reporting bias)	Unclear risk	No report of protocol being registered. Clear pre-specified aims and hypotheses stated and addressed.

Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	In order to decrease expectancy as well as demand effects, participants were provided with a cover story.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported whether outcome assessment was blind.
Other bias	Low risk	No other potential bias identified.

Sit et al. (2020)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	High risk	A pilot, non-blind, non-randomized controlled trial.
Allocation concealment (selection bias)	High risk	Allocation was not concealed
Incomplete outcome data (attrition bias) All outcomes	Low risk	Attrition from group allocation to analysis < 20%
Selective reporting (reporting bias)	Unclear risk	No protocol registered. Pilot study. Aims clearly stated.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Participants and personnel would have been aware of group assignment.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Outcome assessment was not blind.

Other bias	Low risk	No other potential bias identified.
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Torkan et al. (2014)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Unclear risk	Participants with major depression were randomly assigned to complete either 1-week of daily sessions of the positive imagery CBM-I, or a control program. No detail of how groups were randomly assigned.
Allocation concealment (selection bias)	Unclear risk	No description of allocation concealment.
Incomplete outcome data (attrition bias) All outcomes	High risk	Attrition > 30% in both treatment group and control group at 2-week follow-up
Selective reporting (reporting bias)	Unclear risk	No report of protocol being registered. Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported whether personnel were blind.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported whether outcome assessment was blind.
Other bias	Low risk	No other potential bias identified.

Williams et al. (2013)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	The 69 people who completed an electronic informed consent were randomized by an independent person via a true randomization process (www.random.org).
Allocation concealment (selection bias)	Low risk	Allocation was concealed by randomisation process.
Incomplete outcome data (attrition bias) All outcomes	High risk	Attrition >20% from treatment group allocation (n = 38) to completion of CBM-I (n = 26). Further attrition (>20%) also observed from post-CBM-I outcome assessment (n = 26) to post-iCBT assessment (n = 20).
Selective reporting (reporting bias)	Low risk	The study was prospectively registered (clinicaltrials.gov identifier NCT01488058). Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Web-based treatment. Participants and personnel were unaware of group assignment.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessments completed online and therefore reducing any risk of influencing data.
Other bias	Low risk	No other potential bias identified.

Williams et al. (2015)

Bias	Authors' judgement	Support of judgement
Random sequence generation (selection bias)	Low risk	Eligible participants accepted into the study were randomised based on an allocation sequence generated by an independent person not involved in the study via a true randomisation process (www.random.org).
Allocation concealment (selection bias)	Low risk	Participants remained blind to group allocation.
Incomplete outcome data (attrition bias) All outcomes	High risk	Attrition >20% from treatment group allocation (n = 60) to completion of CBM-I (n = 36). Attrition rate was lower from post-CBM-I outcome assessment (n = 36) to post-iCBT assessment (n = 32).
Selective reporting (reporting bias)	Low risk	The study was prospectively registered on <i>clinicaltrials.gov</i> (NCT01787513). Clear pre-specified aims and hypotheses stated and addressed.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Web-based treatment. Participants and personnel were unaware of group assignment.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessments completed online and therefore reducing any risk of influencing data.
Other bias	Low risk	No other potential bias identified.

Supplementary Table 1

Mean and Standard Deviation for Subjective Ratings of Relative Excitement, Disappointment and Vividness for Imagery Relating to Goal-Attainment and Failure Following Initial Prompts.

Subjective Rating (0=least; 10=most)		
	<i>Mean</i>	<i>SD</i>
Goal-Attainment		
Excited	8.53	1.67
Vivid	8.02	1.47
Goal-Failure		
Disappointed	8.18	2.32
Vivid	7.60	1.89

Supplementary Table 2

Audio/Text Prompts Provided Before Block 1 and Block 2 of the Reward Learning Game.

Prompt	Imagery Valence	
	Positive	Negative
Intro 1	<p><i>Before beginning the next round, we will first work on consolidating the image in your mind's eye of the moment when you achieve your chosen goal outcome.</i></p> <p><i>This image should be for the same outcome that you imagined and rated as being most vivid previously in this experiment. [visual prompt shown below text]</i></p>	<p><i>Before beginning the next round, we will first work on consolidating the image in your mind's eye of the moment when you do not achieve your chosen goal outcome.</i></p> <p><i>This image should be for the same outcome that you imagined and rated as being the most vivid previously in this experiment. [visual prompt shown below text]</i></p>
Intro 2	<p><i>We are going to ask you to focus in on the exact moment when you achieve your goal, so that it is as vivid as possible and like it is really happening.</i></p> <p><i>Creating a vivid image for each outcome is the most important part of the task, so please make sure that you are not distracted and do your best.</i></p>	<p><i>We are going to ask you to focus in on the exact moment when you do not achieve your goal, so that it is as vivid as possible and like it is really happening.</i></p> <p><i>Creating a vivid image for each outcome is the most important part of the task, so please make sure that you are not distracted and do your best.</i></p>
1	<p><i>OK, can I get you to close your eyes and visualise the moment when you achieve your chosen goal.</i></p> <p><i>Let's spend a minute or so on that...</i></p> <p><i>Take a moment to think about where you are in this image and then press the record button to talk me through the exact moment as you achieve your goal.</i></p>	<p><i>OK, can I get you to close your eyes and visualise the moment when you do not achieve your chosen goal.</i></p> <p><i>Let's spend a minute or so on that...</i></p> <p><i>Take a moment to think about where you are in this image and then press the record button to talk me through the exact moment when you realise that you have not achieved your goal.</i></p>
2	<p><i>You might describe the image as if you are there, describing what you can see, hear, smell, feel or taste.</i></p> <p><i>This could include colours, dimensions or other particular aspects that stand out to you. You could also describe what is happening around you and whether there are other people with you as you achieve your goal.</i></p> <p><i>You don't necessarily need to include all of those aspects, but just what seems relevant to your image.</i></p>	<p><i>You might describe the image as if you are there, describing what you can see, hear, smell, feel or taste.</i></p> <p><i>This could include colours, dimensions or other particular aspects that stand out to you. You could also describe what is happening around you as realise that you have not achieved your goal.</i></p> <p><i>You don't necessarily need to include all of those aspects, but just what seems relevant to your image.</i></p>
3	<p><i>I would like you to continue to view the image in this way—that is as if viewed through your own eyes and experienced through your own body.</i></p> <p><i>Now that you're imagining the goal in this way, are there any other important bits or details that would get you really excited to imagine?</i></p>	<p><i>I would like you to continue to view the image in this way—that is as if viewed through your own eyes and experienced through your own body.</i></p> <p><i>Now that you're imagining not achieving your goal in this way, are there any other important bits that would make this outcome more emotive to imagine?</i></p>
4	<p><i>How does it feel to achieve your goal?</i></p> <p><i>Close your eyes...</i></p> <p><i>You may notice changes in your body as you visualise and anticipate succeeding in your goal, such as changes in your heart rate or energy levels for example.</i></p>	<p><i>How does it feel to not achieve your goal?</i></p> <p><i>Close your eyes...</i></p> <p><i>You may notice changes in your body as you anticipate failing in your goal, such as changes in your heart rate or energy levels for example.</i></p>

Supplementary Figure 1

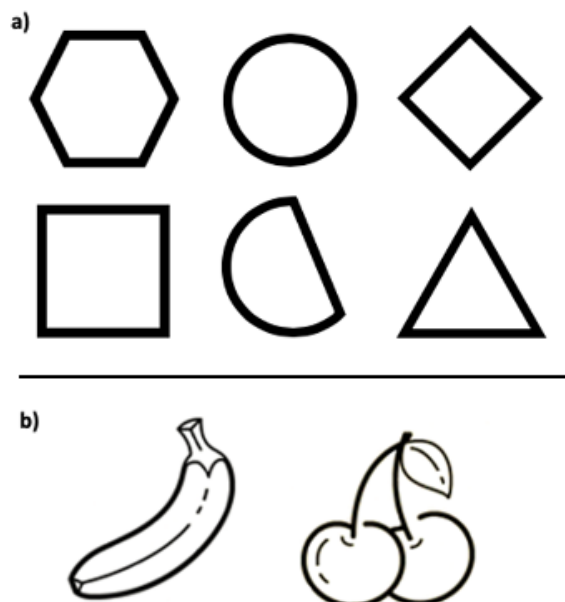
Mood Zoom Rating Display with Continuous Slider Scales for Six Emotional States.

Please rate to what extent the following words describe your
CURRENT MOOD:

Not at all	<input type="range"/>	Anxious	<input type="range"/>	Very much
Not at all	<input type="range"/>	Happy	<input type="range"/>	Very much
Not at all	<input type="range"/>	Sad	<input type="range"/>	Very much
Not at all	<input type="range"/>	Angry	<input type="range"/>	Very much
Not at all	<input type="range"/>	Irritable	<input type="range"/>	Very much
Not at all	<input type="range"/>	Energetic	<input type="range"/>	Very much

Supplementary Figure 2

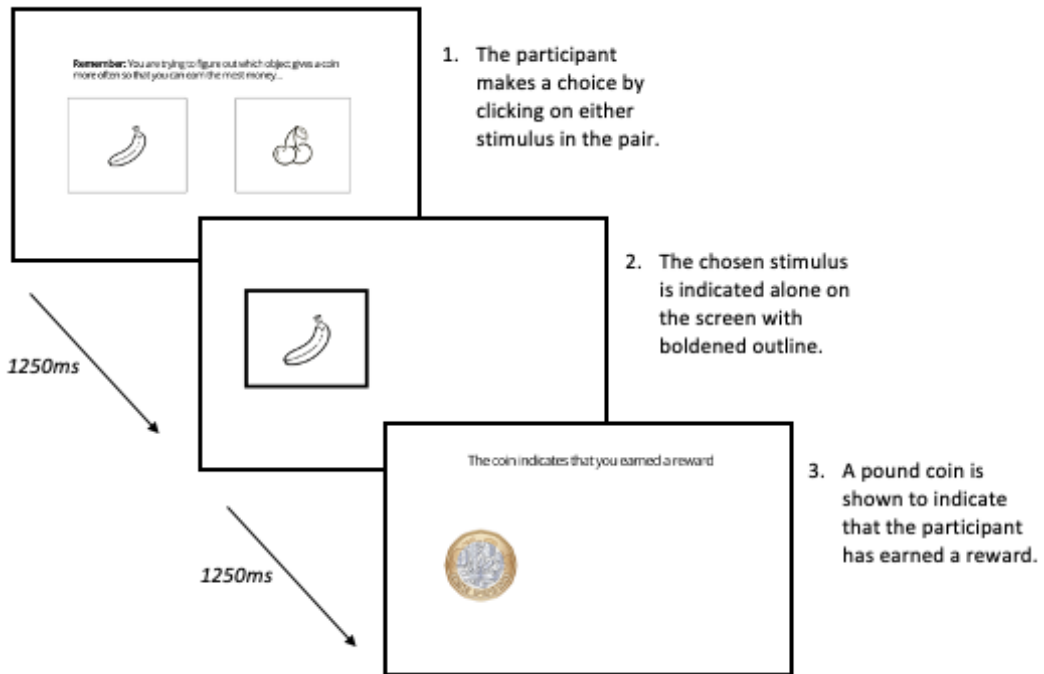
Stimuli Used in the Reward Learning Game and Practice Trials.



Note. As above: **a)** Six shape stimuli randomised to create stimuli pairs in the reward learning game; and **b)** Two alternative fruit stimuli used in the practice trials – a banana (left) and cherries (right).

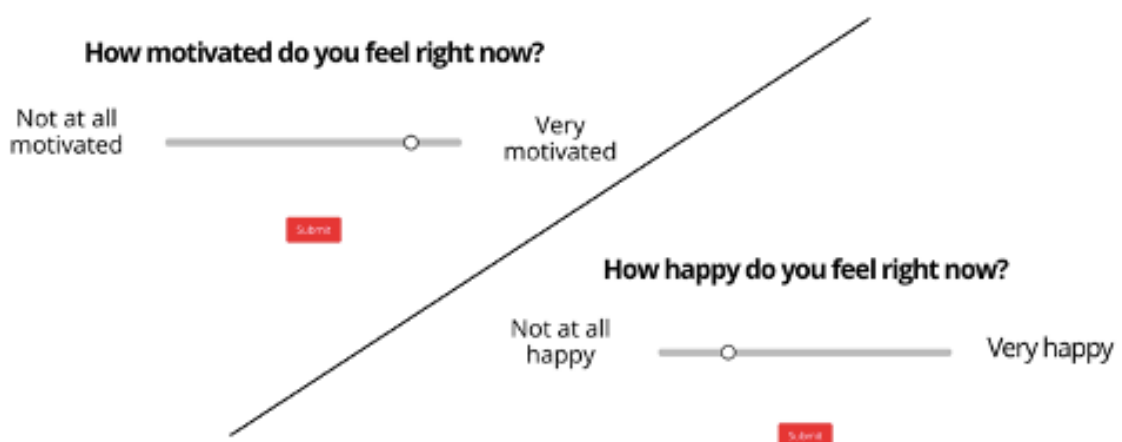
Supplementary Figure 3

Process Diagram for One of 12 Practice Trials Completed by Participants Prior to the Reward Learning Game.

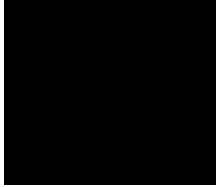


Supplementary Figure 4

Separate Motivation (left) and Happiness (right) Rating Displays with Continuous Slider Scales.



APPENDIX C: Approval from the Departmental Ethics Committee

A4	Approval from the Departmental Ethics Committee	
	<i>(Approval cannot be given by the principal researcher of this project – if necessary the application must be sent to an Ethics Officer from a different Research Department, or to the College Ethics Committee, for approval)</i>	
	<p>Declaration by the Research Department Ethics Chair:</p> <p>I have reviewed this project and I approve it. X</p> <p>The project is registered with the UCL Data Protection Officer and a formal signed risk assessment form has been completed.</p>	
	<p>Allocated Departmental Project ID Number for the approved application:</p> <p>_CEHP/2020/580</p>	
	<p>Name of the Research Department Ethics Chair (type in): Jean-Baptiste Pingault</p> <p>Date: 20/06/2020</p>	

APPENDIX D: Participant Information Sheet

PARTICIPANT INFORMATION SHEET

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Study Title: Experimental investigation of the impact of motivational imagery on learning and decision making

Researcher: Joe Flynn

Principle Researcher: Dr Liam Mason

What is this study?

We are inviting you to take part in a research study that is investigating the impact of motivational imagery on learning and decision making.

Before you decide if you agree to take part in the study, it is important that you understand why the research is being done and what it will involve. Please read this leaflet carefully.

Ask us if anything is unclear or if you would like more information. Take time to decide whether you wish to take part. Whether you decide to take part or not is completely up to you. Choosing not to take part will not disadvantage you in any way.

Why are we running this study?

Research has told us that people differ in the degree that momentary changes in their mood influence how they perceive events. This poses the question as to whether mental imagery (those images imagined with the mind's eye, e.g. an image in your mind of your favourite fruit) can also influence how we perceive events.

Why have I been invited to take part?

We are inviting people aged 18-65 who are members of online research recruitment platforms.

Do I have to take part?

No. Taking part is completely voluntary. You are free to stop taking part at any time during the study without giving a reason. If you decide not to take part, or to stop taking part, this will not affect any care you receive, now or in the future.

What will I have to do if I decide to take part?

If you decide to take part in the study, you will be asked to complete some questionnaires to complete that ask about various aspects of your mood and experiences of mental imagery. You will then be asked to visualise some imaginary scenarios in relation to a goal you are looking forward to. This imagery will then be recalled throughout a computerised task in which you will learn the attributes of several objects and then be asked to choose between them based on your preferences.

Are there any risks in taking part in this study?

There are no major risks to you in taking part in this study. However, you might find some of the questions a bit difficult to answer, for example about your mental health and mood. If you feel uncomfortable or upset during the study then you can stop at any time. A member of the research team will be contactable if you wish.

Are there any benefits to taking part?

There are no specific benefits for taking part. Participants often report finding it an interesting exercise to practice generating mental images. You will be reimbursed £7.50 per hour at the end of the study for your time and effort in taking part.

Who is organising and funding the research?

The study is part of Dr Liam Mason's program of research in the Psychology and Language Sciences department at University College London.

Who has reviewed the research?

The research has been reviewed by the Ethics Chair of the Department of Clinical, Educational and Health Psychology at University College London.

What other information would you collect about me?

We will ask you to provide some personal information - for example your age and gender. This is to help provide some background information about the people who take part. This information will be made anonymous - it will be attached to a unique code so that nobody except the study researchers will be able to identify you from the data we keep.

What happens to information you collect about me?

All the information you give will be treated as confidential. The data collected from the questionnaires and the computerised tasks, our copies of the consent forms, and the other information we collect will be stored on secure servers [if completed online]. If completing the study in person, crucial study documents will be stored in a locked cabinet at University College London at UCL. Your data will be labelled with a numbered code to protect anonymity. Anonymised data may be shared with other researchers at UCL or other institutions, to help answer new research questions, but they will never be given your name or contact details. Once names and contact details are no longer required for the research project, they will be deleted, and all data will then become fully anonymised. Only researchers directly involved in the study have access to your name and contact details. We will not tell anyone how you responded to the questionnaires, unless you tell us about actual or potential harm to yourself or to someone else. In this case we would need to tell other people or services (for example emergency services).

We will keep your information until it is no longer needed. After this time all information will be destroyed. If you decide that you want to stop taking part in the study, then your information can be destroyed if requested.

Data Protection Privacy Notice

The data controller for this project will be University College London (UCL). The UCL Data

Protection Office provides oversight of UCL activities involving the processing of personal data and can be contacted at data-protection@ucl.ac.uk. UCL's Data Protection Officer is Lee Shailer and he can also be contacted at data-protection@ucl.ac.uk. UCL's privacy notice can be found at: <https://www.ucl.ac.uk/legal-services/privacy/participants-health-and-care-research-privacy-notice>

Your personal data (name, contact details, gender) will be processed as described in this information sheet. The legal basis for this is that you provide your consent (by completing and signing the study consent form) to perform a task in the public interest.

If you are concerned about how your personal data is being processed, please contact UCL in the first instance at data-protection@ucl.ac.uk. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO). Contact details, and details of data subject rights, are available on the ICO website at: <https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/>

How will study findings be shared?

We will write a report about the data collected from the study. We will send you a copy of this report if you would like one. The study results will be presented as scientific papers in peer reviewed journals, at conferences, and in student dissertations.

What if something goes wrong?

If you wish to raise a complaint, then please contact Dr Liam Mason at l.mason@ucl.ac.uk. If you feel that your complaint has not been handled to your satisfaction, you can contact the Chair of the UCL Research Ethics Committee at ethics@ucl.ac.uk. If something happens to you during or following your participation in the project that you think may be linked to taking part, please contact Joe Flynn or Dr Liam Mason.

Who can I contact for more information?

The study researchers are very happy to answer any questions. Please call, email or write:

Joe Flynn
Trainee Clinical Psychologist
University College London
Department of Clinical, Educational and Health Psychology

Phone: 07545068867

Email: joseph.flynn.16@ucl.ac.uk

Thank you for reading this information sheet and for considering to take part in this research study.

APPENDIX E: Participant Consent Form

CONSENT FORM

Experimental investigation of the impact of motivational imagery on learning and decision making UCL Ethics Committee approval ID Number: CEHP/2020/580

Department: Psychology and Language Sciences

Researcher(s): Joe Flynn

Principal Researcher: Dr. Liam Mason

UCL Data Protection Officer: xxxxxxxx

Please complete this Consent Form after you have read the Information Sheet and had the opportunity to speak to the researcher. If you need any further information to help you decide whether or not to take part, then please speak to the researcher before completing this form. You will be given a copy of this Consent Form to keep for your records.

To give your consent to take part in this investigation you need to read the statements below and, if you agree with the statements, initial in each box. Un-initialled boxes mean you do not agree to the statement. To take part in the investigation you need to agree to all of the following statements:

[Please Initial]

- I have read and understood the Information Sheet for this experiment. I have had an opportunity to consider the information and what will be expected of me, and to contact the researchers with any questions I may have.
 - I consent to the processing of my personal data for the purposes explained to me in the Information Sheet. I understand that my information will be handled in accordance with all applicable data protection legislation and ethical standards in research.
 - I understand that my personal data (name, contact details etc.) will be held securely. Personal data will only be accessible to the study team and individuals authorised by the study team or the research funder working with them.
 - I understand that I am free to withdraw from this experiment at any time without giving a reason and this will not affect my future legal rights.
 - I understand the potential benefits and risks of participating, the support available to me should I become distressed during the experiment, and who to contact if I wish to lodge a complaint.
 - I understand the inclusion and exclusion criteria in the Information Sheet. I confirm that I do not fall under the exclusion criteria.
 - I understand that my linked anonymised personal data can be shared with others for future research, shared in public databases and in scientific reports.
 - I voluntarily agree to take part in this experiment.
- I consent to being contacted about related studies from this research team. If you consent then we will keep your name and contact details on a secure database so our research team can contact you. You do not have to take part in these future studies.

Name of Participant

Date

Signature

Researcher

Date

Signature

[For online version we will state instead: "By clicking continue, you consent to the above conditions and understand that you can terminate the study at any time, simply by closing your browser." Participants will check each of the above boxes and click 'continue' button to consent. No signatures will be required.]

APPENDIX F: Mental Health Support Information Sheet

MENTAL HEALTH SUPPORT

If you have concerns about anxiety, depression or other aspects of your mental health then these helplines and websites can offer expert support and advice.

Mind

Promotes the views and needs of people with mental health problems.

Phone: 0300 123 3393 (Monday to Friday, 9am to 6pm)

Website: www.mind.org.uk

Samaritans

Confidential support for people experiencing feelings of distress or despair.

Phone: 116 123 (free 24-hour helpline)

Website: www.samaritans.org.uk

SANE

Emotional support, information and guidance for people affected by mental illness, their families and carers.

SANEline: 0300 304 7000 (daily, 4.30pm to 10.30pm)

Textcare: comfort and care via text message, sent when the person needs it most: www.sane.org.uk/textcare

Peer support forum: www.sane.org.uk/supportforum

Website: www.sane.org.uk/support

Rethink Mental Illness

Support and advice for people living with mental illness.

Phone: 0300 5000 927 (Monday to Friday, 9.30am to 4pm)

Website: www.rethink.org

Anxiety UK

Charity providing support if you have been diagnosed with an anxiety condition.

Phone: 03444 775 774 (Monday to Friday, 9.30am to 10pm; Saturday to Sunday, 10am to 8pm)

Website: www.anxietyuk.org.uk

Supplementary Tables 3a-e

Main Effects and Interactions of Imagery Orientation on Preferences Prior to Controlling for Experienced Reward Probabilities

a) Main Effects

	<i>df</i>	<i>F</i>	<i>p</i>	<i>np²</i>	<i>Wilks' Λ</i>
Multivariate Effects					
<i>Main Effect</i>	1,48	2.264	0.94	.129	.871
Univariate					
<i>Binary</i>		0.754	.389	.015	.
<i>High Probability</i>		0.003	.960	<.001	.
<i>Low Probability</i>		0.965	.331	.020	.

b) Effects when accounting for trait mood instability (HPS)

	<i>df</i>	<i>F</i>	<i>p</i>	<i>np²</i>	<i>Wilks' Λ</i>
Multivariate Effects					
<i>Main Effect</i>	3,46	1.364	.266	.085	.915
<i>IO x HPS</i>		0.724	.631	.047	.908
Univariate Effects					
<i>Main Effect</i>					
<i>Binary</i>		0.872	.355	.019	.
<i>High Probability</i>		0.564	.456	.012	.
<i>Low Probability</i>		0.323	.573	.007	.
<i>IO x HPS</i>					
<i>Binary</i>		0.414	.664	.018	.
<i>High Probability</i>		0.512	.597	.022	.
<i>Low Probability</i>		0.432	.652	.018	.

c) Effects when accounting for depression symptoms (PHQ-9)

	<i>df</i>	<i>F</i>	<i>p</i>	<i>np</i> ²	<i>Wilks' Λ</i>
Multivariate Effects					
<i>Main Effect</i>	3,46	1.364	.266	.085	.915
<i>IO x PHQ-9</i>		0.724	.631	.047	.908
Univariate Effects					
<i>Main Effect</i>					
<i>Binary</i>		0.872	.355	.019	.
<i>High Probability</i>		0.564	.456	.012	.
<i>Low Probability</i>		0.323	.573	.007	.
<i>IO x PHQ-9</i>					
<i>Binary</i>		0.414	.664	.018	.
<i>High Probability</i>		0.512	.597	.022	.
<i>Low Probability</i>		0.432	.652	.018	.

d) Effects when accounting for trait imagery propensity (SUIS)

	<i>df</i>	<i>F</i>	<i>p</i>	<i>np</i> ²	<i>Wilks' Λ</i>
Multivariate Effects					
<i>Main Effect</i>	3,46	1.806	.160	.110	.890
<i>IO x SUIS</i>		1.291	.270	.081	.845
Univariate Effects					
<i>Main Effect</i>					
<i>Binary</i>		3.280	.077	.067	.
<i>High Probability</i>		0.041	.840	.001	.
<i>Low Probability</i>		1.242	.271	.026	.
<i>IO x SUIS</i>					
<i>Binary</i>		2.137	.130	.085	.
<i>High Probability</i>		0.736	.484	.031	.
<i>Low Probability</i>		1.047	.359	.044	.

e) Effects when accounting for difference in motivation (B2 – B1)

	<i>df</i>	<i>F</i>	<i>p</i>	<i>np</i> ²	<i>Wilks' Λ</i>
Multivariate Effects					
<i>Main Effect</i>	2,47	2.697	.057	.152	.848
<i>Motivation</i>		1.095	.361	.068	.932
Univariate Effects					
<i>Main Effect</i>					
<i>Binary</i>		3.417	.071	.068	.
<i>High Probability</i>		0.286	.596	.006	.
<i>Low Probability</i>		0.106	.746	.002	.
<i>Motivation</i>					
<i>Binary</i>		3.048	.087	.061	.
<i>High Probability</i>		0.517	.476	.011	.
<i>Low Probability</i>		0.298	.587	.006	.

Binary = Preferences quantified from binary choices;

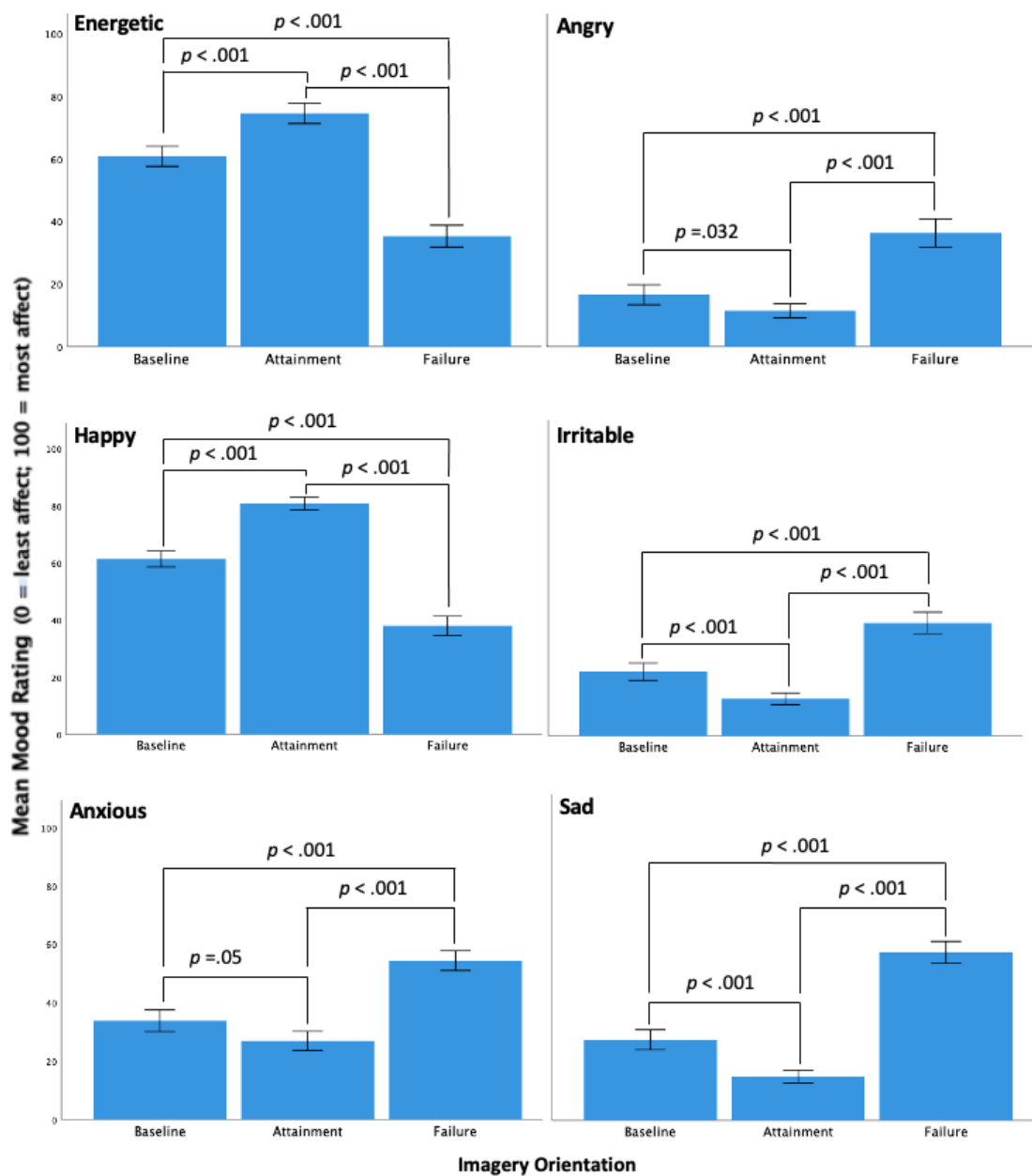
High Probability = Preferences quantified from continuous preference ratings for evenly-matched high probability stimuli between learning blocks;

Low Probability = Preferences quantified from continuous preference ratings for evenly-matched low probability stimuli between learning blocks;

HPS = Hypomanic Personality Scale; PHQ-9 = Patient Health Questionnaire-9; SUIS = Spontaneous Use of Imagery Scale; IO = Imagery Orientation

Supplementary Figure 5

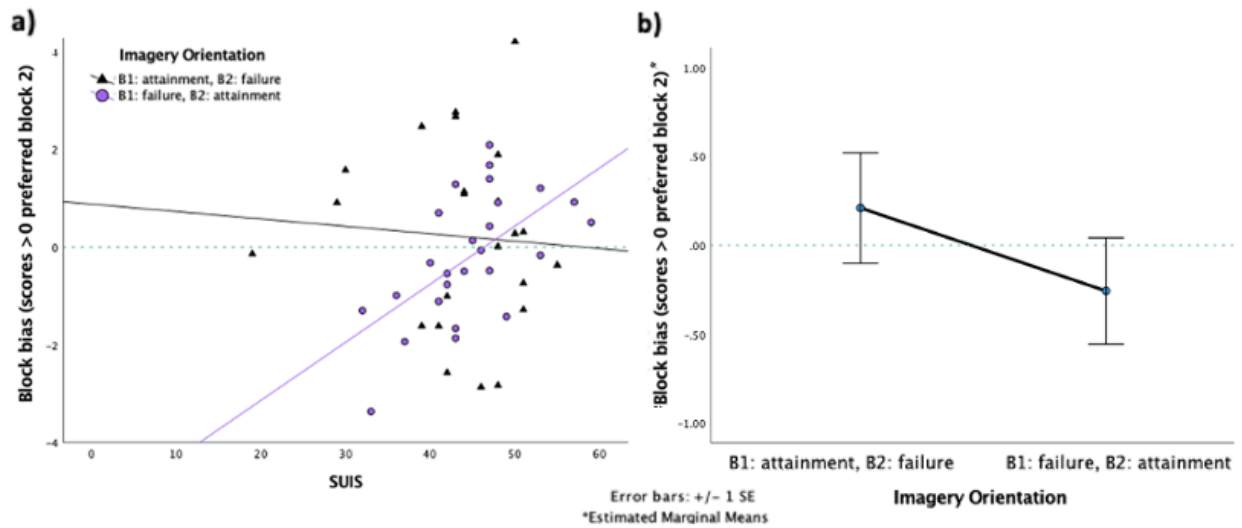
Mood Zoom Ratings for each Mood State Pre- and Post-Imagery Manipulation.



Note. Effects on mood were observed. Subjective ratings of positive affect (i.e., feeling happy and energetic) were significantly increased when visualising goal-attainment compared to baseline compared to baseline and the block when visualising goal-failure, whereas ratings of negative affect (i.e., feeling sad, anxious, irritable, and angry) decreased. effects were observed when visualising goal-failure, with positive affect decreasing and negative affect increasing, whether visualised prior to block 1 or block 2.

Supplementary Figure 6

Plots Showing **a)** the Interaction of Block Bias (binary) by Proneness to Mental Imagery (SUIS) and **b)** the Main Effect of Imagery Orientation on Block Bias after Accounting for the Interaction.



Note. Those with higher SUIS scores who visualised goal-failure first preferred stimuli encountered when visualising goal-attainment, whereas those with lower SUIS scores demonstrated an opposite preference for stimuli encountered when visualising goal-failure (**a**). A preference for stimuli encountered when visualising goal-failure was also observed when accounting for the interaction (**b**).

