Positive moods are all alike? Differential affect amplification effects of 'elated' versus 'calm' mental imagery in young adults reporting hypomanic-like experiences

Caterina Vannucci[1,2,3], Michael B. Bonsall[4], Martina Di Simplicio[5], Aimee McMullan[2,6], Emily A. Holmes[7] and Stephanie Burnett Heyes[2]

1 School of Psychology and Education, University of Bologna, Italy

2 School of Psychology, University of Birmingham, U. K.

3 MoMiLab Research Unit, IMT School for Advanced Studies, Italy

4 Department of Zoology, University of Oxford, U. K.

5 Division of Psychiatry, Department of Brain Sciences, Imperial College London, U. K.

6 Warwick Medical School, University of Warwick, U. K.

7 Department of Psychology, Uppsala University, Sweden

Correspondence concerning this article should be addressed to Stephanie Burnett Heyes, School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT. Email: s.burnettheyes@bham.ac.uk

Abstract

Positive mood amplification is a hallmark of the bipolar disorder spectrum (BPDS). We need better understanding of cognitive mechanisms leading to such elevated mood. Generation of vivid, emotionally compelling mental imagery is proposed to act as an 'emotional amplifier' in BPDS.

We used a positive mental imagery generation paradigm to manipulate affect in a subclinical BPDS-relevant sample reporting high (n=31) vs. low (n=30) hypomanic-like experiences on the Mood Disorder Questionnaire (MDQ). Participants were randomized to an 'elated' or 'calm' mental imagery condition, rating their momentary affect four times across the experimental session.

We hypothesized greater affect increase in the high (vs. low) MDQ group assigned to the elated (vs. calm) imagery generation condition. We further hypothesized that this change would be driven by increases in the types of affect typically associated with (hypo)mania, i.e., suggestive of high activity levels.

Mixed model and time-series analysis showed that for the high MDQ group, affect increased steeply and in a sustained manner over time in the 'elated' imagery condition, and more shallowly in 'calm'. The low-MDQ group did not show this amplification effect. Analysis of affect clusters showed high-MDQ mood amplification in the 'elated' imagery condition was most pronounced for *active* affective states.

This experimental model of BPDS-relevant mood amplification shows evidence that positive mental imagery drives changes in affect in the high MDQ group in a targeted manner. Findings inform cognitive mechanisms of mood amplification, and spotlight prevention strategies targeting elated imagery, while potentially retaining calm imagery to preserve adaptive positive emotionality.

Positive moods are all alike? Differential emotional amplification effects of generating 'elated' versus 'calm' mental imagery in young adults reporting hypomanic-like experiences

Positive mood amplification which can at times escalate rapidly and be maladaptive is a hallmark of the bipolar disorder spectrum (BPDS). BPDS is characterized by disabling mood states reflected in manic or hypomanic episodes (e.g., elevated, expansive, or irritable mood, and hyperactivity; American Psychiatric Association, 2013; Charney et al., 2020), depressive episodes (e.g., low mood or loss of interest or pleasure), as well as mixed mood episodes (Kraepelin, 1921; Swann et al., 2013) and/or chronic affective instability (Marwaha et al., 2014). BPDS is associated with high rates of disability (World Health Organization, 2001), medical comorbidities (Fiedorowicz et al., 2009; Rødevand et al., 2021; Rowland & Marwaha, 2018) and suicidality (Kozloff et al., 2010). Hypomania is a sub-manic state characterized by elevated and sometimes irritable mood, and can be measured along a continuum of experiences using self-report questionnaires (Hoyle et al., 2015). The presence of high levels of self-reported hypomanic-like experiences is associated with risk for developing bipolar disorder (Rock et al., 2013). Critically, we lack early or preventative *psychosocial* interventions specifically able to target hypomanic mood escalation. This is problematic as anti-manic pharmacological agents may not be favoured by young people at risk, due to their potential for side effects. We need better understanding of the cognitive mechanisms underlying hypomanic-like mood symptoms across the clinical and subclinical BPDS, in order to develop better psychological prevention and treatment strategies (Holmes et al, 2018).

The current study focuses on the hallmark process leading to elevated mood, termed positive mood amplification. While positive affective states are often beneficial and appropriate, dysregulated positive mood is a key feature of (hypo)mania and BPDS (Cochran et al., 2018; Gruber et al., 2008) comprising frequent, intense, long-lasting and context-insensitive positive affect and heightened responses to positive stimuli (Chang et al., 2004; Farmer et al., 2006; Gruber et al., 2011, 2014; Hofmann & Meyer, 2006; Lawrence et al., 2004). Elevated mood is interlinked with risk-taking, reduced sleep and socially inappropriate behaviour in BPDS, the so-called 'dark side' of positive emotion (Gruber et al., 2011, 2013; Weintraub et al., 2020). While the extreme facets of mania are targeted pharmacologically, there is a need for psychological

interventions to address earlier positive mood escalation at preventative stages, especially in young people at risk of developing BPDS (Nusslock et al., 2009; Rock et al., 2013). However, on the flipside, positive affective experiences are centrally important for quality of life, and the desire to retain positive emotionality may undermine treatment compliance in BPDS (Prajapati et al., 2021). We need better cognitive-mechanistic understanding of the boundary between benign versus maladaptive positive mood amplification, and the timescales on which this can operate. Such understanding could promote psychological interventions that reduce potentially harmful positive mood, while preserving aspects that are benign and indeed beneficial for quality of life. To this end, the current experimental study investigated two distinct drivers of positive mood amplification in a subclinical BPDS-relevant sample.

One cognitive mechanism hypothesised to drive mood amplification in BPDS is mental imagery (Holmes, Geddes, et al., 2008). Mental imagery has been identified as a potential transdiagnostic risk mechanism and treatment target in a number of mental disorders (Brewin, 2010; Hackmann et al., 2011; Hirsch & Holmes, 2007; Holmes and Mathews, 2010; Ji et al., 2019; Kanstrup et al., 2021; Rachman, 2007). Consequently, mental imagery paradigms are a potent experimental tool for manipulating affect (e.g. picture-word cue imagery generation paradigm; Holmes et al. 2009). Mental imagery is defined as the experience of perception in the absence of eliciting sensory input (Kosslyn et al., 2001); mental imagery of past, present, future or fantasy events triggers affective processing in a manner like perception. Various attributes of mental imagery, such as the tendency to use imagery in daily life (Reisberg et al., 2003), as well as vividness and emotional impact, have been shown to vary between individuals (Cui et al. 2007). In BPDS, mental imagery is hypothesized to drive pathological mood amplification, exacerbating both manic and depressed states (Emotional Amplifier Theory; Holmes et al., 2008; Holmes & Mathews, 2005). Correlational and experimental evidence indicates greater tendency to experience mental imagery across the clinical and subclinical BPDS, and greater emotional impact of this imagery (Deeprose & Holmes, 2010; Di Simplicio et al., 2016; Holmes et al., 2011; Holmes, Geddes, et al., 2008; Malik et al., 2014; McCarthy-Jones et al., 2012; Ng et al., 2016). The current study therefore used an experimental mental imagery paradigm adapted from a prior study (O'Donnell et al. 2018) to manipulate affect in a subclinical BPDS-relevant sample.

In our previous experimental study, we showed that a subclinical young adult sample reporting high levels of hypomanic-like experiences showed greater changes in self-reported affect in response to (i.e. pre/post) a computerized positive mental imagery generation task, compared to controls (O'Donnell et al., 2018). This shows evidence that mental imagery drives short-term changes in affect in a BPDS-relevant sample in a manner congruent with mood amplification. However, a number of questions remain. First, how specific is this effect to the eliciting conditions? Is BPDS-relevant positive mood amplification best characterized as a non-specific response across categories of affective stimuli (cf. Gruber et al., 2008), or can the degree of amplification differ depending on the eliciting stimulus (cf. Gable & Harmon-Jones, 2008, 2010; Gruber & Johnson, 2009)? Second, how specific is the effect in terms of affective response? Is BPDS-relevant positive mood amplification characterized by non-specific amplification across affect categories, or is amplification related to particular categories of affect, namely goal-directed positive affect related to approach behavior (vs. positive consummatory affect) that is typically associated with (hypo)mania (Gruber & Johnson, 2009), and/or negative affective states that can additionally characterize hypomania and mixed states (Edmiston et al., 2020; O'Donnell et al., 2018)?

To address the first question (stimulus specificity), we sought to compare changes in self-reported affect across two eliciting stimulus categories, comprising 'elated' vs. 'calm' mental imagery generation conditions. Both experimental conditions consisted of affectively positive imagery generation stimuli; in the elated condition, stimuli featured reward-pursuit, ambitious achievements and competitive scenarios (Gruber & Johnson, 2009) while in the calm condition, stimuli depicted scenarios characterized by peace/contentment, rest and self-acceptance/belonging (Hartig et al., 2003). To address the second question (response specificity) we investigated task-dependent changes in self-reported affect across distinct affect clusters, e.g. negative affect, positive affect associated with approach behaviour and excitement, and positive affect associated with calmness and contentment. Both stimulus specificity and response specificity hypotheses reflect distinctions between positive affect as approach motivation, and positive affect as consummatory and reflective subjective states (Shiota et al., 2021). We investigated affect change at a micro-level, i.e. within an experimental session, by eliciting self-reported affect ratings at four time-points:

before, twice during, and after the imagery task; enabling us to map the temporal profile of hypothesised mood change.

Participants comprised a non-clinical community sample of young adults reporting either low or high levels of hypomanic-like experiences (Hirschfeld et al., 2000). Adopting this spectrum approach takes into account the wide variability of symptoms at the subclinical level while remaining unconfounded by acute illness or medication state (Akiskal & Pinto, 1999; Birmaher et al., 2006; McGuffin et al., 2003). Hence, studying a subclinical population on the BPDS can lead to important insights on aetiology and treatment of bipolar disorder (Gruber et al., 2008).

The aim of our study was to identify the impact of specific categories of positive mental imagery stimuli ('elated' vs. 'calm') on bipolar-relevant mood amplification, including across distinct categories of affective experience, since this may be informative for specific risk and treatment mechanisms. We had the following hypotheses and predictions. First, we predicted greater increases in affect following elated (vs. calm) imagery in participants reporting high levels of hypomanic-like experiences (Hypothesis 1: stimulus-specificity). Second, we predicted this effect would be driven by amplification of particular affective clusters (Hypothesis 2: affect-specificity): increased positive (vs. negative) affect; and increased active, goal-directed (vs. calm, consummatory) positive affect. We predicted a moderating effect of imagery vividness on mood amplification, in line with prior studies (O'Donnell et al., 2018). We tested these hypotheses by comparing self-reported affect across groups, conditions and time-points of a positive imagery generation task.

Method

Participants

The sample consisted of 61 adults (45 women, 13 men, 1 other) aged 18-25 (M = 20.53, SD = 1.8; see Table 1). Participants were recruited through posters and online advertisements on social media and specific websites at the University of Birmingham and in the local community. The study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics Ethical Review Committee (ERN_15-1435). Participants gave their written and informed consent at pre-screening and again

before the psychiatric screening and experimental session. After the completion of the session, participants were debriefed and received compensation for their participation (£10/hour).

Participant pre-screening and exclusion criteria. To recruit individuals across a spectrum of hypomanic-like experiences, N=255 young adults were pre-screened online by completing section A of the Mood Disorder Questionnaire (MDQ; Hirschfeld et al., 2000). Participants were categorized according to the number of hypomanic experiences reported on the MDQ section A (0-13): high (≥7; range=7-13), medium (range=4-6), or low (≤ 3; range= 0-3). Participants categorized as high or low on the MDQ were potentially eligible to attend the experimental session. We further implemented screening based on the Spontaneous Use of Imagery Scale (SUIS; Reisberg et al., 2003) to exclude participants with a particularly low tendency to use imagery spontaneously (SUIS score of 23 or less), and who therefore might not be able to perform the experimental task. Our screening resulted in exclusion of 52 participants scoring medium on the MDQ and 3 scoring ≤23 on the SUIS. Subsequently, two eligible participants indicated they were no longer interested in participating. From the remaining sample, high (n= 45) and low (n=31) MDQ scoring participants were contacted to attend psychiatric screening using the Mini International Neuro-psychiatric Interview for DSM-5 (MINI; Lecrubier et al., 1997) (see Supplementary Material). Exclusion criteria (resulting in exclusion of 11 participants) included: (hypo)manic (current and past), depressive and psychotic episodes (current; for full exclusion criteria see Supplementary Material). One participant was excluded due to faulty administration of the psychiatric screening (Lecrubier et al., 1997). Finally, we excluded 4 participants based on poor comprehension of the imagery generation task instructions. The final sample of N=61 consisted of n=31 participants scoring high on the MDQ and n=30 with a low MDQ score.

Procedure

Demographic characteristics were collected at online pre-screening via LimeSurvey. Following the psychiatric screening and a 15-minute break, eligible participants completed self-report baseline affect questionnaires, a self-report measure of current mood, and valence ratings of picture pleasantness (see Measures and Supplementary Material). Participants were then randomised to one of two imagery conditions and in both cases received a standardized imagery generation training procedure followed by the

elated or calm positive picture-word cue imagery generation task (see Measures). Subsequently, participants repeated the valence ratings of picture pleasantness task and gave feedback on the imagery generation task (see Measures). Finally, participants were debriefed, thanked, and compensated. See Figure 1.

INSERT FIGURE 1

Measures

Demographic, pre-screening, and baseline affect questionnaires.

See Supplementary Material.

In-task affect measurement. Participants rated their current mood immediately prior to, at two time-points during, and after the picture-word cue imagery generation task. Four affect measurement time-points were selected as a trade-off between increasing temporal resolution compared to prior studies, versus preserving participant engagement by minimizing repetition and participant burden. We included six scales of the Positive and Negative Affective Schedule Expanded form (PANAS-X; Watson, D., Clark, L. A., & Tellegen, A., 1988; Watson & Clark, 1999) and expanded it with additional BPDS-relevant mood words (see below). We refer to this expanded affect measure as the PANAS+. For each mood descriptor word (e.g. cheerful, afraid) participants indicated "to what extent [they] feel this way right now" on a 5-point scale (1, not at all to 5, extremely). The measure consisted of 34 mood adjectives across the following subscales of the PANAS-X: general positive and negative emotion, joviality, serenity, self-assurance and attentiveness. The additional seven items aimed at increasing sensitivity to 'hypomanic-like' and unstable mood states were: 'dynamic' and 'efficient' from the Behavioural Activation for Depression Scale (BADS; Kanter et al., 2007) to capture affect relating to increase in goal-directed behaviour; 'unstable', 'impatient' and 'self-possessed (reverse scored)' from the Affect Lability Scale (ALS; Oliver & Simons, 2004) to assess key emotions in unstable and mixed states (Swann et al., 2013) and irritability (Snaith & Taylor, 1985); and 'assertive' and 'elated' from the Big-5/Extraversion scale (DeYoung et al., 2007) and a recent bipolar mood monitoring study (Tsanas et al., 2016), as they are reported to be indicators of hypomanic risk (Kirkland et al., 2015).

Mental imagery training. Participants completed a standardised imagery generation training procedure as per O'Donnell et al. (2018). A definition of mental imagery was discussed with participants and they

were trained in generating mental imagery from a field (first person) perspective using a guided imagery exercise and cue cards. For each training stimulus participants were prompted to indicate mental imagery vividness on a scale from 1 to 5.

Picture-word cue mental imagery generation task. Participants completed four neutral or mildly positive imagery practice trials of the computerised picture-word cue imagery generation task followed by 90 'elated' or 'calm' imagery trials according to condition assignment. Each trial consisted of a picture paired with a word or phrase. Participants were asked to look at the picture, read the word or phrase, and then close their eyes and generate a mental image which combined both the picture and the word(s). Each trial consisted of a picture paired with a word or phrase that was designed, when combined to generate a mental image, to result in a positive resolution. All participants saw the same pictures, but the disambiguating word cue altered the emotional resolution dependent upon condition (Figure 2). In the elated condition, all picture-word cues suggested an exciting positive emotional state, whereas in the calm condition, picture-word cues had less extreme, calm, relaxing or more emotionally neutral resolution. For example, a photo of the university library was paired with the phrase 'achieving my best' in the elated condition and 'reading a book' in the calm condition. Stimuli were presented using E-Prime software in blocks of 30. Each picture-word cue was presented for 4500ms (Fig 2a) and followed by a 1000ms auditory tone (Fig 2b). On hearing the tone participants opened their eyes and rated vividness (Fig 2c). Prior to starting the computerized imagery task, and again after each of the three imagery blocks, participants completed the PANAS+ (see above). After every 10 stimuli during the imagery task, the experimenter spoke to participants, providing reinforcement and reminders for task adherence (e.g. use of field perspective, staying in the present moment in their imagery, focusing on imagery rather than verbal thought) (Burnett Heyes et al., 2017; O'Donnell et al., 2018).

Picture stimuli were shown centered on the 13'' VDU against a black background. Pictures varied within a width from 360 and 640, and a height between 338 and 453 pixels. Images comprised photos selected from previous studies (Burnett Heyes et al., 2017; O'Donnell et al., 2018), taken by the authors, or

downloaded from the Internet. Words were displayed centered in white beneath the image, in Arial size 30. Stimuli were presented in a randomised order.

Stimuli in the elated condition represented the following themes relevant to (hypo)manic states and experiences: achievement (i.e. reward pursuit and competition; e.g. picture of a graduation with the phrase 'applause for me'), inflation of self-esteem (e.g. picture of a class with the phrase 'I'm so clever'), and behavioural activation (e.g. picture of a bed at night with the phrase 'still full of energy') (Gruber & Johnson, 2009). Stimuli in the calm condition represented the following themes representing positive emotional experiences not typically associated with (hypo)mania: rest and relaxation (e.g. picture of tea and biscuits with the phrase 'tea break'), affiliation and cooperation (e.g. picture of a team sport with the phrase 'team effort'), and peace and delight implying self-acceptance (Hartig et al., 2003). In addition, each condition incorporated roughly equal proportions of stimuli across each of the following dimensions: 1) self-focus: focus on the participant engaging in the scenario; 2) other-focus: focus on other people present in the scenario; 3) affective hyperesthesia: focus on an object or an event (Hardy et al., 1986).

Vividness Ratings. After imagining each scenario, participants were asked to rate mental imagery vividness on a scale from 1 ('not at all vivid'), to 5 ('extremely vivid'). As in prior studies Holmes, Mathews, Mackintosh, & Dalgleish (2008); Pictet et al., 2011), the rating was used to gather data as well as to encourage compliance.

Valence ratings of picture pleasantness. See Supplementary Material.

Additional measures. At the end of the experimental session, participants completed questionnaires about their subjective experiences of the mental imagery task and demand characteristics. See Supplementary Material.

Analysis

Sample size calculation. We determined *post hoc* an effect size from the between-groups comparison of PANAS+ total score using unequal samples, for the high (n=31) and low (n=30) MDQ groups. For known t-values and sample sizes available, using the formula from Rosnow & Rosenthal (2008, pag. 385),

there is a medium to large effect size (Cohen's d) on expected differences between high vs. low MDQ groups.

Baseline descriptives. Demographic and baseline affect self-report variables comparing low vs. high MDQ groups were analysed using independent t-tests, or chi-square tests for categorical variables.

Mixed effect model analyses of affect across group, condition and time. We used linear mixed effect model analysis to investigate changes in participant affect scores over time, and whether any such changes differed as a function of participant group and imagery condition (Hypothesis 1). Participant was modelled as a random effect while group and condition were fixed effects. Subsequently we explored the time series structure in each group and condition, using model comparisons and likelihood ratio (LR) tests to test for differences (Buse, 1982). Initial linear mixed effects model analysis was conducted using all 41 PANAS+ affect words. Subsequently we analysed dissociable effects of time and condition in each group on distinct affect subtypes (Hypothesis 2). Affect subtypes were identified by conducting a hierarchical clustering analysis on the affect words of the PANAS+. Analysis was completed in R (R Core Team, 2015).

Analysis for moderating effect of vividness. See Supplementary Material.

Valence ratings and additional measures. Subjective experience and demand characteristics were analyzed using two-way univariate ANOVA with MDQ group (low, high) and experimental condition (calm, elated) as fixed factors. We analysed valence of the stimuli with a three-way mixed ANOVA with pleasantness ratings as within-subject factor and MDQ score and experimental condition as between-subject factors.

Results

Demographic information, pre-screening and baseline affect questionnaires

High vs. low MDQ groups did not differ on age (M = 20, SD = 2; mean difference = .2, 95% CI [- .7, +1.1]; t (59) = .5, p = .6), gender (χ^2 (2) = 1.8, p = .4), ethnicity (white vs. other groups combined; χ^2 (1) = .7, p = .4), or occupation (χ^2 (1) = .4, p = .5). Groups did not differ based on psychiatric screening using the MINI (Lifetime Mental Disorders χ^2 (1) = 2.8, p = .09; Anxiety Disorders χ^2 (1) = .8, p = .4; Substance Use Disorder χ^2 (1) = .12, p = .7; Depressive Episode Lifetime χ^2 (1) = 2.5, p = .1; see Table 1). Participant groups did not

differ in recent depressive and anxiety symptom scores (BDI-II; t (59) = 1.2, p = .2; STAI-T; t (59) = 1.84, p = .07). Groups showed distinct patterns of self-reported affective instability (see Supplementary Materials).

INSERT TABLE 1

Mixed effect model analysis of total affect score across group, condition and time

Mixed effect model analysis 1. To begin to understand variation in affect attributable to participant, group, condition, and time, we undertook a mixed effect model analysis using total PANAS+ scores (all 41 items). This showed a positive, linear effect of time (t = 6.89, p < .001) through an autocorrelated (AR(1)) error structure effect and a significant group by condition interaction on total PANAS+ score (t = 2.736, p = .008). The main effect of time indicates affect increases as time proceeds. The group by condition interaction indicates that changes in affect differ depending both on participant group (high vs. low MDQ) and imagery condition (calm vs. elated), potentially consistent with H1. The strong random effect of participant on intercept (SD = 13.77) suggests considerable inter-participant variability. The intercept (PANAS+ score) is significantly different from zero (t = 20.14, p < .001).

Time-series structure. To investigate further the temporal structure with respect to participant, group and condition, including to evaluate whether the direction of effects is consistent with H1, we separated the data into four sets according to group and condition (MDQ group: low [G0], high [G1]; imagery condition: calm [C0], elated [C1]) to explore the time series structure in each of these four datasets. Model comparisons and likelihood ratio tests (LRT) for the individual group/condition level showed no statistical support for correlated error structures: Within each group/condition, each affect score is independent of affect score on the previous time point (G1/C1 LRT = 1.577, p = .2092; G1/C0 LRT = 3.235, p = .0716; G0/C1 LRT = .521, p = .4706; G0/C0 LRT = .1179, p = .7313). The non-linear effects of time vary between groups.

G0. For low MDQ participants there is some evidence that non-linear time effects are important (G0/C0 LRT = 3.774, p = 0.0521; G0/C1 LRT = 3.938 p = .0472). The non-linear pattern in G0 over time depends on condition; for C1 (low MDQ/elated), the non-linear pattern increases but with decreasing amounts i.e. *decelerating*. For C0 (low MDQ/calm) the non-linear fit is not significant due to high between-participant heterogeneity (high random effect SD) (Table 2). That is, low MDQ participants experience

diminishing increases in total affect score over time during elated imagery, with no evidence for affect change during calm imagery.

G1. For G1 participants (high MDQ) there is no evidence for non-linear time effects comparing a quadratic and linear model with time as an explanatory variable (G1/C1 LRT = 2.246, p = 0.1168; G1/C0 LRT = 2.292, p = 0.13). Instead, affect is predicted to increase additively over time (i.e. in a constant sustained manner) for participants in this high MDQ group. Furthermore, as shown by the differences in slope, affect increases faster for participants under C1 (elated) than those under C0 (calm) (Figure 3). That is, high MDQ participants experience sustained increases in total affect score over time during both conditions of the imagery task in a quasi-escalation like manner, with this effect greater in the elated compared to the calm imagery condition.

INSERT FIGURE 3

To investigate the random effects of variability between participants (within each group/condition), Table 2 summarizes the fixed and random effects for model where time is a linear explanatory variable of affect score and participant is included as a random effect. There is greatest heterogeneity amongst participants in G0/C0 (low MDQ/calm) and least amongst participants in G0/C1 (low MDQ/elated).

INSERT TABLE 2

Mixed effect model analysis of affect subtype scores across group, condition and time

Cluster Analysis. Hierarchical clustering of PANAS+ scores (all 41 words) at the first measurement time-point was used to identify affect subtype clusters in each group ('negative', 'calm-positive', 'active-positive') resulting in dependent variables for mixed effect model analysis 2. See Supplementary Material for cluster analysis results.

Mixed effect model analysis 2: Affect clusters.

Negative mood. Linear mixed effect model analysis showed no effect of time or condition on the negative affect cluster in either group. G0. In the low MDQ group there was no effect of time (t = -1.19, p = .238) or condition (t = -.724, p = .470). The intercept differed from zero (t = 20.78, p < .001) and showed a modest random effect of participant (SD = 2.11). G1. In the high MDQ group there was no effect of time (t =

-.292, p = .771) or condition (t = -.032, p = .974) on scores in the negative affect cluster. Here, the intercept differed from zero (t = 12.50, p < .001) with no random effect of participant (SD < .001). Therefore, we find no evidence that negative affect in particular is altered by our manipulation.

Positive affect clusters – Low MDQ. Analysis of the two positive affect clusters in the low MDQ group showed a negative, linear effect of time (*t* = -4.42, *p* < .001) through an autocorrelated (AR(1)) error structure effect, that differed according to affect cluster (*t* = 9.23, *p* < .001) but not condition (t = 1.36, p = .185; see Supplementary Figure 2). This indicates an overall modest decrease in positive affect over time that is consistent across conditions and greater for the calm-positive than the active-positive cluster. The random effect of participant on intercept (SD = 5.91) suggests moderately high inter-participant variability. The intercept is significantly different from zero (*t* = 16.02, *p* < .001).

Positive affect clusters – High MDQ. Analysis of the two positive affect clusters in the high MDQ group showed a distinctly different pattern (Supplementary Figure 3). Here, there was no linear effect of time (*t* = 1.00, *p* = .317), but instead a cluster-by-condition interaction (t = 5.64, p < .001). This indicates a greater than linear difference between the two positive affect clusters ('calm-positive', 'active-positive'). Critically, the highest scores were found in the combination of active-positive affect cluster and elated imagery condition (C1). The random effect of participant on intercept (SD = 3.82) suggests modest inter-participant variability. The intercept is significantly different from zero (*t* = 13.05, *p* < .001).

Vividness. See Supplementary Material.

Subjective experience and demand measures. See Supplementary Material.

Discussion

Overview of findings

This study took an experimental psychopathology approach to investigate positive mood amplification associated with the bipolar disorder spectrum (BPDS). We created a picture-word cue mental imagery generation task (Holmes, Mathews, et al., 2008; Holmes & Mathews, 2005), and used this to successfully model positive mood amplification in our subclinical BPDS-relevant sample (O'Donnell et al., 2018). We found that, for participants reporting high hypomanic-like experiences indicative of BPDS risk (high MDQ

group), affect increased steeply and in a sustained manner over 'micro-time', i.e. during the imagery generation task. This increase was steeper in response to stimuli designed to elicit 'elated' mental imagery featuring (hypo)mania-related content (e.g. approach behaviour, reward-pursuit, excitement), and was markedly shallow in the 'calm' mental imagery comparison condition. In contrast, participants scoring low on the MDQ did not show sustained mood amplification. Furthermore, in the high MDQ group, mood amplification in the elated condition was most pronounced for active-positive affect. Together, these results suggest that the magnitude and nature of BPSD mood amplification is amenable to experimental manipulation, through altering the type or content of mental imagery generated.

Mental imagery amplifies mood dependent on MDQ group and positive imagery condition [H1]

Prior research indicates that mental imagery is vivid and emotionally evocative across the bipolar spectrum and at-risk groups, including young adults scoring highly on the MDQ (Deeprose & Holmes, 2010; Hales et al., 2011; Holmes et al., 2011; Holmes, Geddes, et al., 2008; Malik et al., 2014; McCarthy-Jones et al., 2012; Ng et al., 2016). In a prior study, we showed that generating vivid mental imagery in response to generically positive picture-word cues amplified mood more strongly in high (vs. medium and low) MDQ young adults (O'Donnell et al., 2018). However, the experience of imagery in BPDS is thought not to be 'generic' but particular (e.g. compelling, future-oriented; Holmes et al., 2011). Furthermore, the wider literature attests to distinct types and dimensions of mental imagery, such as visual perspective and self-relevance, with differing impact on emotion and action (Ayduk & Kross, 2010; Libby et al., 2007). In our study, the high MDQ group's steeper increase in affect over time in the elated imagery condition suggests that all positive mental images are 'not equal' (Orwell, 1949) in terms of their risk for mood amplification in BPSD. Generating elated, approach-related imagery leads to sustained mood amplification in a quasi-escalation like manner in high MDQs, whereas the low MDQ group experienced a decelerating pattern of mood increase, such that their initial mood increase levelled off. In turn, high MDQ mood amplification by calm imagery appeared negligible, in other words, mood stable. Therefore, in providing empirical evidence for Emotional Amplifier Theory as applied to hypomanic-like mood amplification (Holmes, Geddes, et al.,

2008), we further show that the magnitude of this amplification varies depending on the type or content of mental imagery. This is of clear therapeutic interest.

Based on our results, future investigations should test whether positive calm imagery may be employed 1) to modulate the degree of positive mood amplification in (hypo)manic states, and 2) to improve positive affect and thereby reduce depressive affect in BPDS in a way that helps minimize low risk of positive mood switch/amplification. Previous research has proven that time-series analysis is key to capturing mood instability over days/weeks in BPDS (Bonsall et al., 2012; Holmes et al., 2011, 2016). Here we demonstrate for the first time the potential of employing this approach to understanding affect change in BPDS at a micro-level, i.e. within an experimental session. This approach is also in keeping with other models highlighting that the chronometry of approach motivation system responses may explain variability of affect subtypes in BPDS (Urošević et al., 2008). Overall, our findings shed a unique light on aetiologic cognitive mechanisms of positive mood amplification in BPDS and inform research into developing better psychological prevention and treatment strategies.

Differential amplification effects on distinct affect clusters [H2]

Given our finding that mood amplification is dependent on hypomanic-like experiences and category of imagery stimuli, we proceeded to explore the impact across categories of affective response. Cluster analysis of affect scores revealed the expected major divide between positive and negative affect (Posner et al., 2005), as well as two positive affect clusters: one comprising active mood states (e.g. elated, excited, energetic; 'active-positive' cluster), the other comprising alertly calm affect mood states (e.g. relaxed, at ease, interested; 'calm positive' cluster; see Supplementary Material). Our positive mental imagery task did not have any impact on the negative affect cluster, but only an impact on positive affect. This partly extends and also differs from our previous study (O'Donnell et al., 2018), in which a positive imagery task amplified combined positive and negative affect on the PANAS-X, although imagery vividness was specifically relevant to amplifying positive affect only. The discrepancy may be secondary to refining the imagery task stimuli such that the picture-word combinations are less prone to subjective interpretation and led more

directly to affective states consistent with excitement/approach readiness or contentment. Another explanation might be that the high (vs low) MDQ sample in our previous study presented with a more significant past history of anxiety and other psychiatric comorbidities compared to this study. We speculate that these clinical differences may have played a role in the modulation of positive and negative affect via positive imagery generation. What is critical however from a translational perspective, is the relevance for positive affect.

Interestingly, the impact of imagery on positive affect clusters differed markedly according to the presence of hypomanic-like experiences. In the high MDQ group, maximum affect scores occurred in active-positive cluster in the elated imagery condition, with lower scores in the calm condition. Hence, we suggest that, in line with our hypothesis, the elated imagery condition exerts a targeted impact on approach-related, hypomanic-relevant mood in high MDQ participants, driving mood amplification. This is congruent with evidence for intense reward and achievement-focused positive emotions in BPSD (Gruber & Johnson, 2009), with potential functional consequences for cognition, action tendency, creativity, risk-taking and wellbeing (Baas, 2010; Baas et al., 2008; Gable & Harmon-Jones, 2008, 2010; Gruber et al., 2011). Here, we show that the magnitude of these approach-motivated emotions, while potentially a characteristic response tendency of this participant group, can be manipulated experimentally based on the category of mental imagery stimuli. It also indicates potential validity of our procedure as an experimental model of BPDS (hypo)manic mood escalation. By contrast, in the low MDQ group we observed a steady decline in overall positive mood across both imagery conditions that was most pronounced for calm (vs. active) positive mood, consistent with a non-specific mechanism (e.g. fatigue or disengagement).

Mechanisms, clinical implications and suggestions for future research

Our findings shed new light on cognitive mechanisms of mood amplification in BPDS and suggest a number of potential implications. We show a specific mood amplification effect on a targeted population. That is, in participants scoring highly on hypomanic-like experiences, generating 'elated' mental imagery drives strong, sustained mood amplification, whereas, for 'calm' mental imagery the degree of amplification,

while still sustained, is shallower. These findings are in line with existing studies on dysregulation of positive emotion in BPDS following exposure to elated visual stimuli, e.g. film clips (Gruber & Johnson, 2009; Johnson, Edge, et al., 2012; Meyer et al., 2001). Our results extend these prior findings about external stimuli to people's own self-generated mental imagery in response to experimental cues. This paradigm may help efforts to model the escalation of mood due to imagination and fantasy rather than outside perceptual cues.

Future research should explore the link between our findings and potential functional consequences. For example, our calm vs. elated positive imagery stimuli could be used to explore the association between imagery, creativity (e.g. divergent thinking) and approach-motivation (Baas et al., 2008, 2020; Gable & Harmon-Jones, 2008, 2010; Johnson, Murray, et al., 2012). In doing so, future studies could help to understand how BPDS can be 'touched by fire', and crucially, when and why it 'gets burnt' (Jamison, 1996; Johnson, Murray, et al., 2012). It would be interesting to examine clinical BPDS samples including through periods of euthymic vs. (hypo)manic mood to determine whether the current BPDS-relevant subclinical findings extend, whether they apply across mood periods, and therefore whether imagery-based interventions are best applied to prevent vs. treat bipolar mood amplification

Research on modifiable mechanisms of positive mood escalation can be harnessed in developing psychological interventions for BPDS. Critically, we suggest that that current results illuminate an intervention strategy which would seek to identify, modify and dampen elated mental imagery whilst preserving or even promoting calm imagery. Interventions utilizing such strategies could be well-tolerated by patients as they could enable retention of some aspects of positive emotionality (i.e. calmness), while potentially reducing the risk of escalation (i.e. elation).

We suggest that, combined with methods for identifying periods in which an individual may be at increased risk of mood amplification (e.g. monitoring mood, activity and life events c.f (Bonsall et al., 2012; Holmes et al., 2016)), creating targeted mental imagery interventions could provide a clinician- or self-administered psychological tool to 'flatten the curve' of maladaptive mood amplification while sustaining beneficial positive mood experiences.

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Table 1. Demographic Characteristics, Emotional Measures and General Imagery Measures for High and Low MDQ

Characteristics	**Low MDQ (n= 30)**		**High MDQ (n= 31)**	
	M	SD	M	SD
Age (years)	20.63	1.93	20.42	1.68
SUIS	39.27	7.46	42.16	7.07
BDI-II	6.93	4.43	7.57	6.20
STAI-T	39.57	9.79	45.32	14.10
ALS-SF	1.73	.08	1.79	.1
ACS *	2.92	.71	3.5	.91
AIM *	3.49	.47	3.78	.50
Gender (# / %)				
Female	22 (73.3 %)		25 (80.6 %)	
Male	8 (26.7 %)		5 (16.1 %)	
Other	0 (0 %)		1 (3.2 %)	
Occupation (# / %)				
Student	28 (93.3 %)		30 (96.8 %)	
Non-student	2 (6.7 %)		1 (3.2%)	
Ethnicity (# / %)				
White	24 (80.0 %)		22 (71 %)	
Other	6 (20 %)		9 (29 %)	
DSM-5 Disorder (# / %)				
Lifetime	12 (38.7 %)		19 (61.3 %)	
Anxiety	6 (40 %)		9 (60 %)	
Substance Use	3 (42.9 %)		4 (57.1%)	
Depressive Episode	10 (37 %)		17 (63%)	

Note. SUIS = Spontaneous Use of Imagery Scale, BDI-II = Beck Depression Inventory-II, STAI-T = Spielberger State-Trait Anxiety Inventory, ALS = Affective Lability Scales- Short form, ACS = Affective Control Scale, AIM = Affective Intensity Measure, DSM-5 Disorder = Mini psychiatric diagnosis. * P < .5

Table 2. Fixed and random effects for each group/condition using random effects model: PANAS SCORE ~ time, ~1 | participant. Table reports intercepts and slopes for fixed effects of time (with standard errors) and the standard deviation (sd) associated with the random effects around the intercept.

Treatment	Fixed Effects	Random Effects
Group 1/ Condition 1	Intercept: 79.09 4.51 Slope: 5.04 1.04	Intercept (sd): 14.01
Group 1/ Condition 0	Intercept: 67.60 3.87 Slope: 3.26 0.88	Intercept (sd): 11.71
Group 0/ Condition 1	Intercept: 70.56 3.71 Slope: 4.36 0.851	Intercept (sd): 11.52
Group 0/ Condition 0	Intercept: 76.70 5.58 Slope: 3.98 1.10	Intercept (sd): 18.17

Figure 1. Study procedure

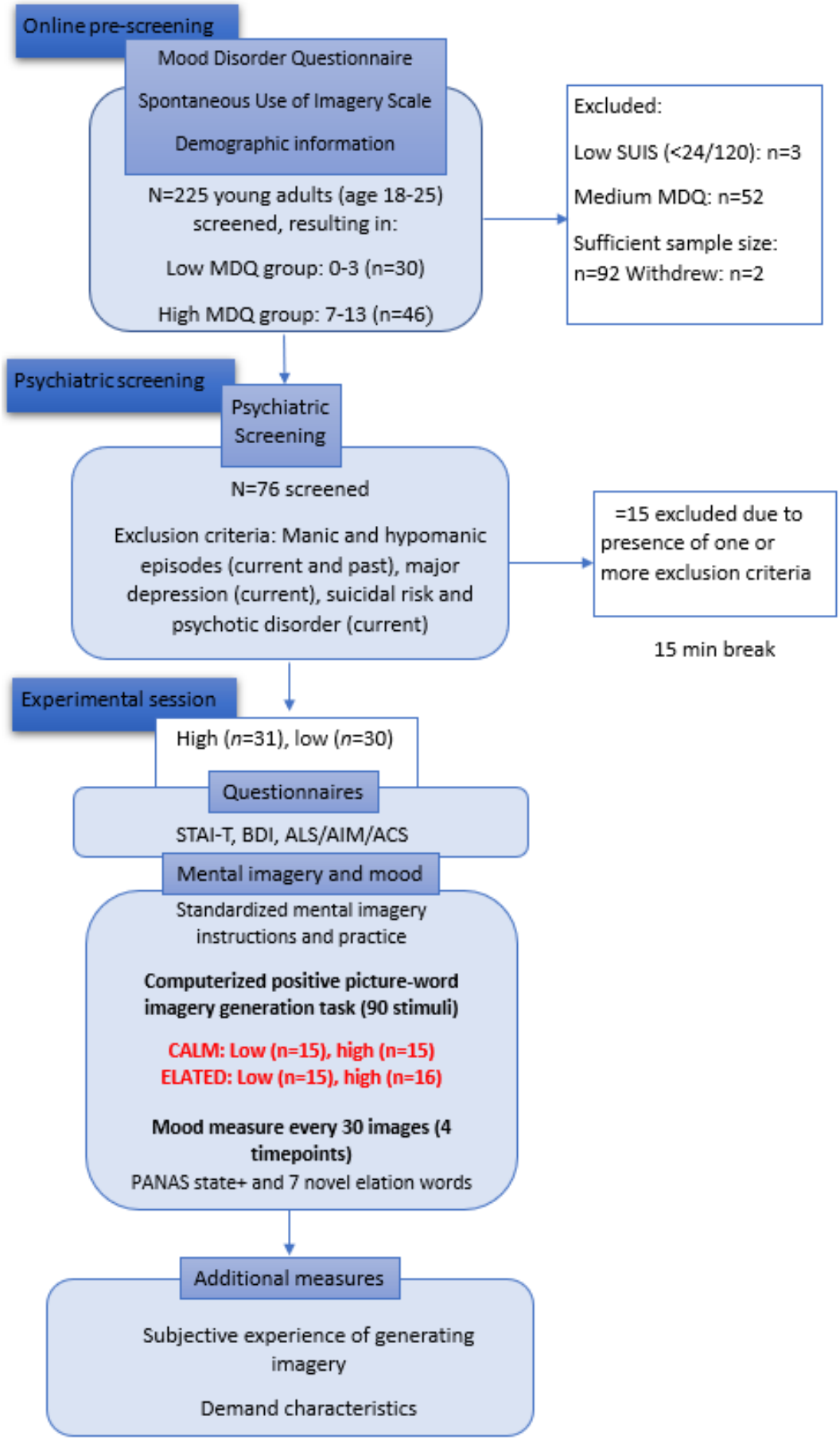


Figure 2: Task. Participants completed 90 trials of a picture-word cue imagery generation task. The set of pictures was identical across group and condition, but the caption differed depending on condition assignment (elated, left; calm, right).

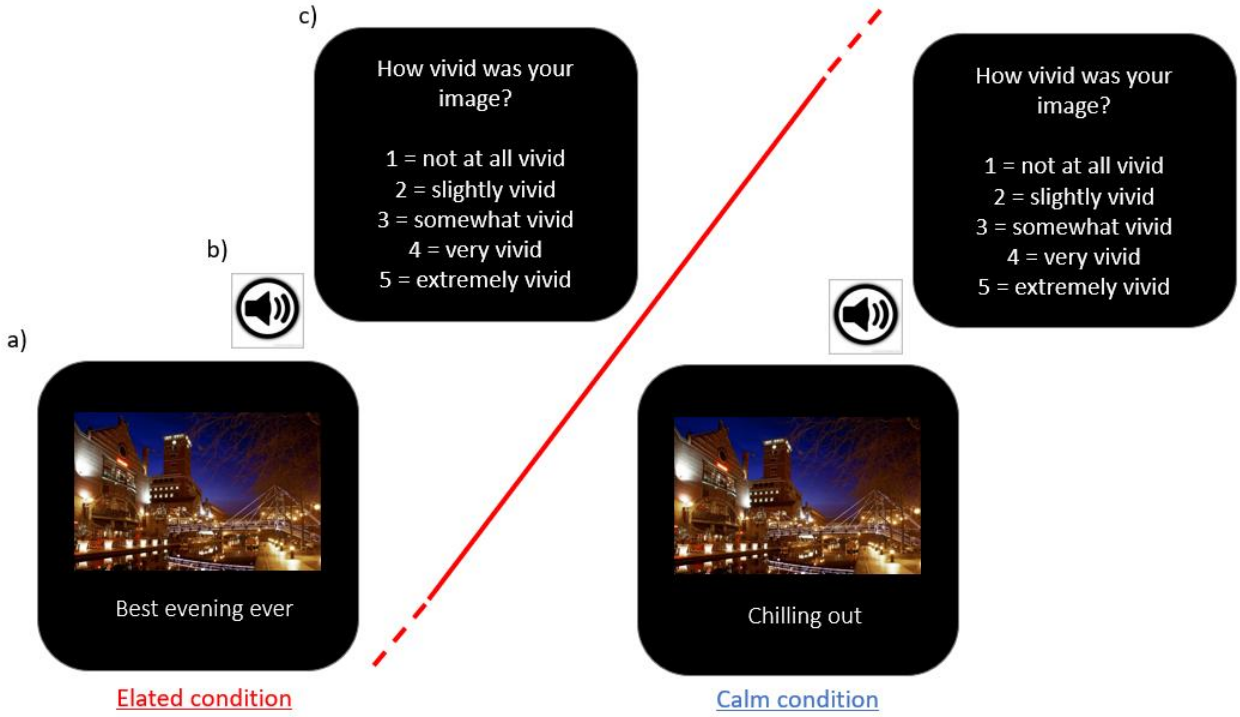
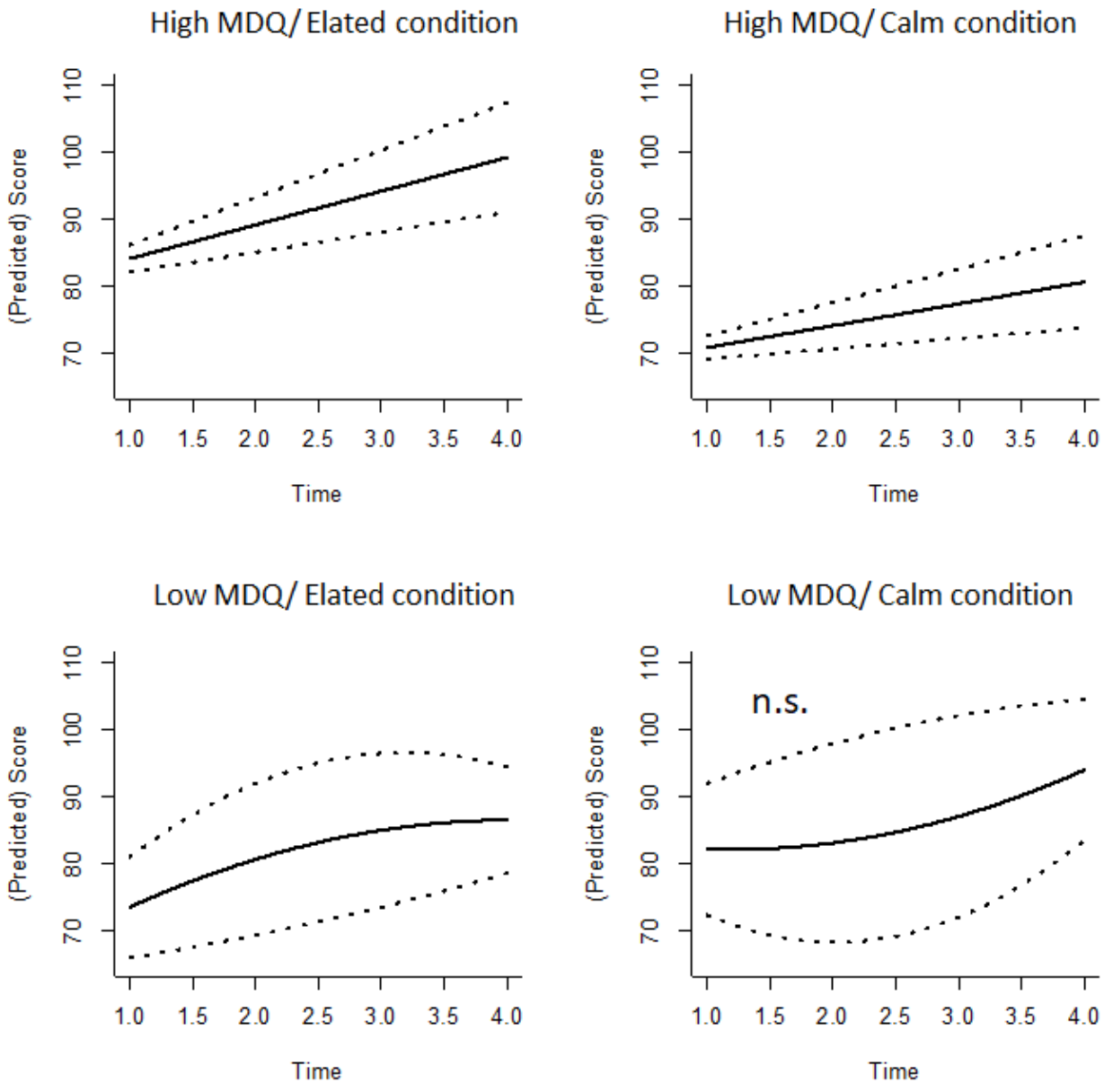


Figure 3. Predicted relationship between affect score and time for each participant group. Participants in the high MDQ group are predicted to have additive increases in affect score through time, irrespective of imagery condition, with this increase steeper in the elated than calm imagery condition. Participants in the low MDQ group are predicted to have multiplicative increases in affect score through time, with this change significant in the elated condition only (decelerating). Solid line shows predicted relationship from linear or linear mixed model analysis; dashed line 95% confidence intervals.



Supplementary Material

Positive moods are all alike? Differential affect amplification effects of 'elated' versus 'calm' mental imagery in young adults reporting hypomanic-like experiences (Vannucci, Bonsall, Di Simplicio, McMullan, Holmes and Burnett Heyes).

1. Supplementary methods

Psychiatric screening. Psychiatric screening was conducted using the Mini International Neuro-psychiatric Interview for DSM-5 (MINI; Lecrubier et al., 1997), a brief structured interview for assessing current and lifetime major psychiatric disorders in DSM-5 and ICD-10 (American Psychiatric Association, 2013; World Health Organization, 1992).

Before administration of the MINI, two questions were asked to assess history or presence of bipolar symptoms: 1) have you ever been diagnosed with any psychological distress or mental illness? If yes, do you know what? Exclusion from the study would follow if the answer were bipolar disorder I or II; 2) have you ever received any support for psychological distress or mental illness? If yes, what? Participants were excluded if they reported having taken or currently taking mood stabilizers. Psychiatric exclusion criteria based on the MINI were as follows: meeting criteria for either lifetime bipolar disorder I and II (since experimentally escalating positive mood may be harmful for these participants), or one hypomanic episode which caused "severe problem" as reported on the MDQ; meeting criteria for current depressive episode, experiencing frequent and moderate (or more) suicidal thoughts or psychotic symptoms (as these participants may have reduced ability to generate positive mental images). To verify the irrational content of psychotic ideas and major consequences, two more questions were asked with exclusion following if the participant answered YES to both: 1) Do you believe 100% in this? 2) Have those thoughts or experiences made you do something that had a major impact on your life, or has it stopped you from doing something?

Demographic information, psychiatric screening, and baseline affect questionnaires. The demographic information questionnaire asked participants to report on their gender identity, age, marital status, current education status (student or non-student) and ethnicity.

Section A of the Mood Disorder Questionnaire (MDQ; Hirschfeld et al., 2000) lists 13 examples of hypomanic-like experiences (e.g. 'you had much more energy than usual'). For each item participants indicate (yes, no) whether they experienced it during a period of time in which they were 'not their usual self'. This measure captures between-participant variability in hypomanic-like experiences (Rock et al., 2013) and has previously been used in young adult samples (Miller et al., 2011).

The Spontaneous Use of Imagery Scale (SUIS; Reisberg et al., 2003) is a self-report questionnaire measuring the tendency to use mental imagery in everyday life. For each of 12 items (e.g., 'When I think about a series of errands I must do, I visualize the stores I will visit') participants rate how appropriate the statement is to them (from 1, never to 5, always). The SUIS has been found to show good internal consistency ($\alpha = 0.98$) and good convergent validity (Nelis et al., 2014).

The Beck Depression Inventory-Second Edition (Beck et al., 1996) measures current depressive symptomatology over the preceding two weeks.

The State Trait Anxiety Index-Trait (STAI-T; Spielberger et al., 1983) assesses trait anxiety.

The Affective Lability Scale, Short form (ALS-SF; Oliver & Simons, 2004) measures the self-reported temperamental tendency to change rapidly from euthymic mood to more extreme emotional states including elation, depression and anger. It has good reliability and high internal consistency ($r = 0.94$) (Oliver & Simons, 2004), even in the bipolar population, with Cronbach's α ranging 0.77–0.88 (Aas et al., 2015).

The Affective Control Scale (ACS; Williams et al., 1997) assesses regulation difficulties (i.e. fear of losing control) across a range of affective states. It has a very good internal consistency and test-retest reliability ($\alpha = .94$), discriminant ($r = –0.17$) and convergent ($r = –0.72$) validity.

The Affective Intensity Measure (AIM; Larsen et al., 1986) assesses self-reported strength of affective responses to typical life situations, with good internal consistency ($\alpha = 0.90–0.94$), test-retest reliability and construct validity. Together, these three affective measures (ALS, ACS and AIM) have been recommended

to characterise affective instability across a number of populations (Marwaha et al., 2014), and are widely used in BPSD samples (Aas et al., 2015; Henry et al., 2008; Look et al., 2010).

Valence ratings of picture pleasantness. This measure was included to test for mood-congruent changes in interpretation bias, (that is, greater evaluative conditioning) in line with past studies (Burnett Heyes et al., 2017; Holmes, Geddes, et al., 2008; O'Donnell et al., 2018; Pictet et al., 2011). Before and after taking part in the positive picture-word imagery generation task, participants viewed fifty photograph stimuli (i.e. images without words) selected randomly from the set of 90 from the imagery generation task, and rated the pleasantness of each photo on a scale from 1 ('extremely unpleasant') to 9 ('extremely pleasant') (Holmes, Geddes, et al., 2008; Pictet et al., 2011).

Additional measures. At the end of the experimental session, participants completed a questionnaire about their subjective experience of having generated mental images. This included questions on imagery ease (how difficult they found the task; how difficult they found it to combine the picture with the word), how much they verbally analysed the picture-word combinations, and how much they used the field (first person) perspective. Participants reported their answers on scale from 1 ('very easy/none of the time) to 9 ('very difficult/all the time) (Pictet et al., 2011). Demand characteristics of the task were also investigated (Holmes, Mathews, et al., 2008). Participants reported whether they thought mental imagery during the task affected their positive and negative emotions on a 9-point scale (1, 'no change in how positive/negative I felt'; 9, 'great change in how positive/negative I felt').

Analysis for moderating effect of vividness on mood amplification. Since participants rated vividness on each trial but mood after each block of 30 trials, we computed summary measures of vividness for each block. Three summary measures were computed: Moment metric (unbiased mean), vividness covariance, and a measure encapsulating the relationship between the two. Interestingly, the covariance measure did not differ significantly from zero, indicating no autocorrelation effects on vividness. This means that imagery vividness is independent across trials and participants. As such,

it is potentially a valid, accurate indication of imagery vividness on each trial that is unconfounded by individual participant response tendencies and cumulative effects across the task. We subjected the three vividness summary measures to linear mixed model analyses to pinpoint any the relationship between their change over time and relative mood change, MDQ group and imagery condition. Results are shown below in the Supplementary results section.

2. Supplementary results

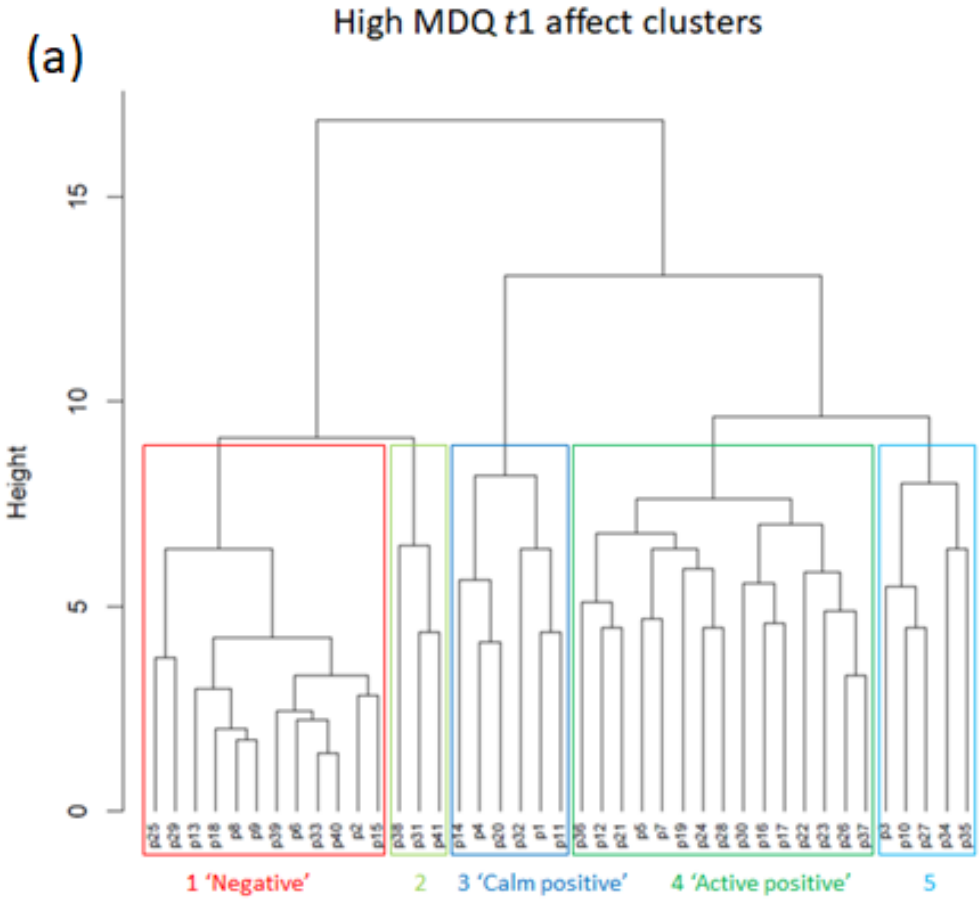
Baseline affect questionnaires. High and low MDQ Groups showed distinct patterns of mood instability with the high MDQ group reporting greater fear of affect change (ACS; $t(58) = -2.6$, $p = .01$) and greater intensity of mood lability (AIM; $t(59) = -2.4$, $p = .02$), with no difference in self-reported mood oscillations (ALS-SF; $t(59) = -.5$, $p = .6$).

Valence ratings of picture pleasantness. A three-way mixed ANOVA on valence ratings from pre- ($M = 5.99$, $SD = .08$) to post- ($M = 6.29$, $SD = .09$) the imagery generation task showed a significant increase in picture pleasantness ($F(1,55) = 19.7$, $p < .001$) across participants, with no effect of MDQ group ($F(1,55) = .99$, $p = .32$), condition ($F(1, 55) = .11$ $p = .74$) or their interaction ($F(1,55) = .19$, $p = .66$), consistent with an increase in positive interpretation bias.

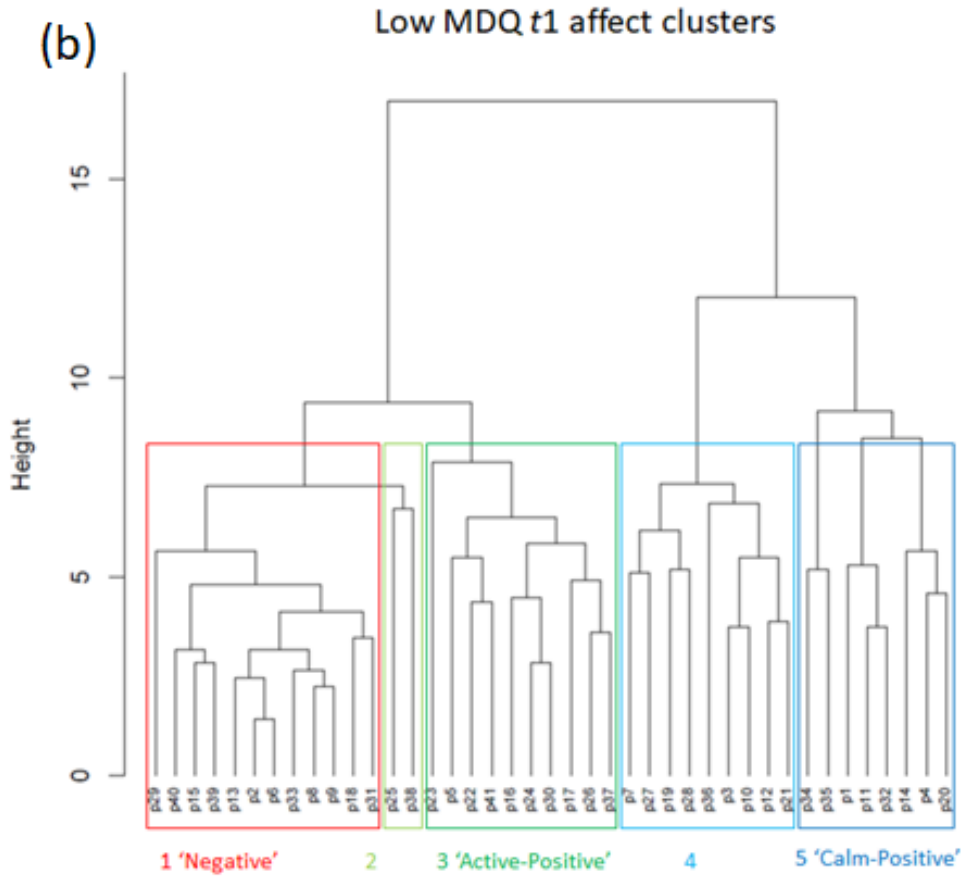
Cluster analysis results. Most relevant natural clusters from the word groupings identify five distinct groups of which three have a priori relevance for our analysis (**Supplementary Figure 1**). These are negative, calm-positive, active-positive clusters. From this hierarchical clustering analysis, we identify two main results. The first result is that negative mood forms a distinct cluster from positive mood. While this grouping is similar, it is not identical between the low and high MDQ groups with 11 words shared out of a total of 13 across the negative clusters. The second

result is that within the positive mood cluster, we identify calm and active classifications. Again, there are similarities between the low and high MDQ groups with 5 unique words shared (out of a total of 9 words) in the calm positive grouping and 9 words shared (out of a total of 15 words) in the active positive grouping. As this clustering analysis highlights differences between these MDQ groups, we performed the linear mixed effect model analysis on time and condition in each group separately.

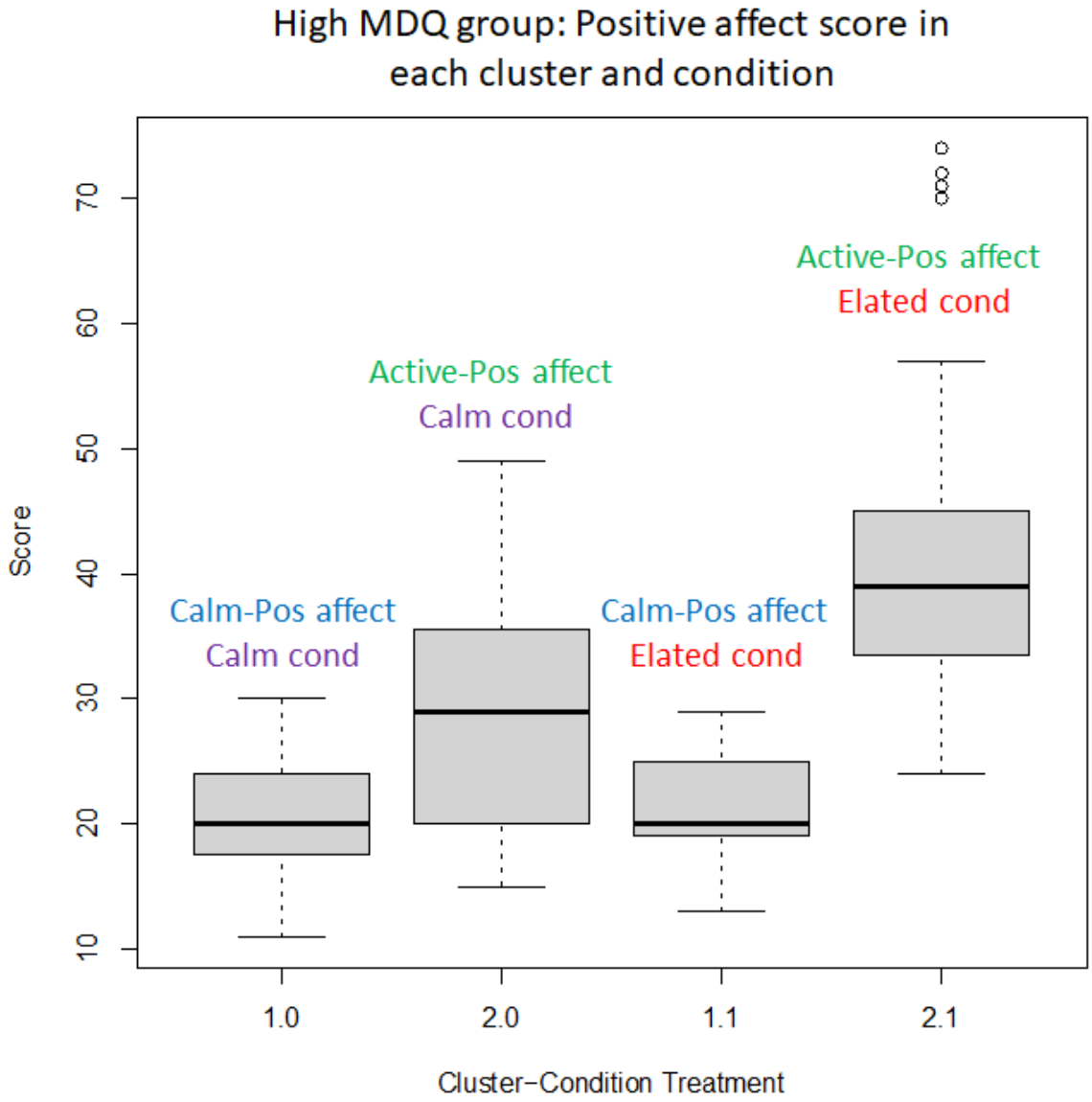
Supplementary Figure 1. Cluster analysis of PANAS (p) mood words at baseline
1(a) High MDQ Group. Cluster analysis revealed three clear mood clusters (1, 3, 4) and two smaller clusters (2, 5). Proposed cluster labels and words included in each cluster are as follows. **Cluster 1 'negative'.** Nervous (p25), jittery (p29), hostile (p13), ashamed (p18), guilty (p8), scared (p9), impatient (p39), upset (p6), afraid (p33), unstable (p40), distressed (p2), irritable (p15). **Cluster 2.** Self-possessed (p38), daring (p31), dynamic (p41). **Cluster 3 'calm positive'.** Concerned (p14), interested (p4), attentive (p20), relaxed (p32), at ease (p1), calm (p11). **Cluster 4 'active positive'**. Assertive (p36), joyful (p12), lively (p21), bold (p5), strong (p7), enthusiastic (p19), energetic (p24), determined (p28), active (p30), excited (p16), proud (p17), inspired (p22), fearless (p23), delighted (p26), elated (p37). **Cluster 5** – happy (p3), cheerful (p10), confident (p27), alert (p34), efficient (p35).



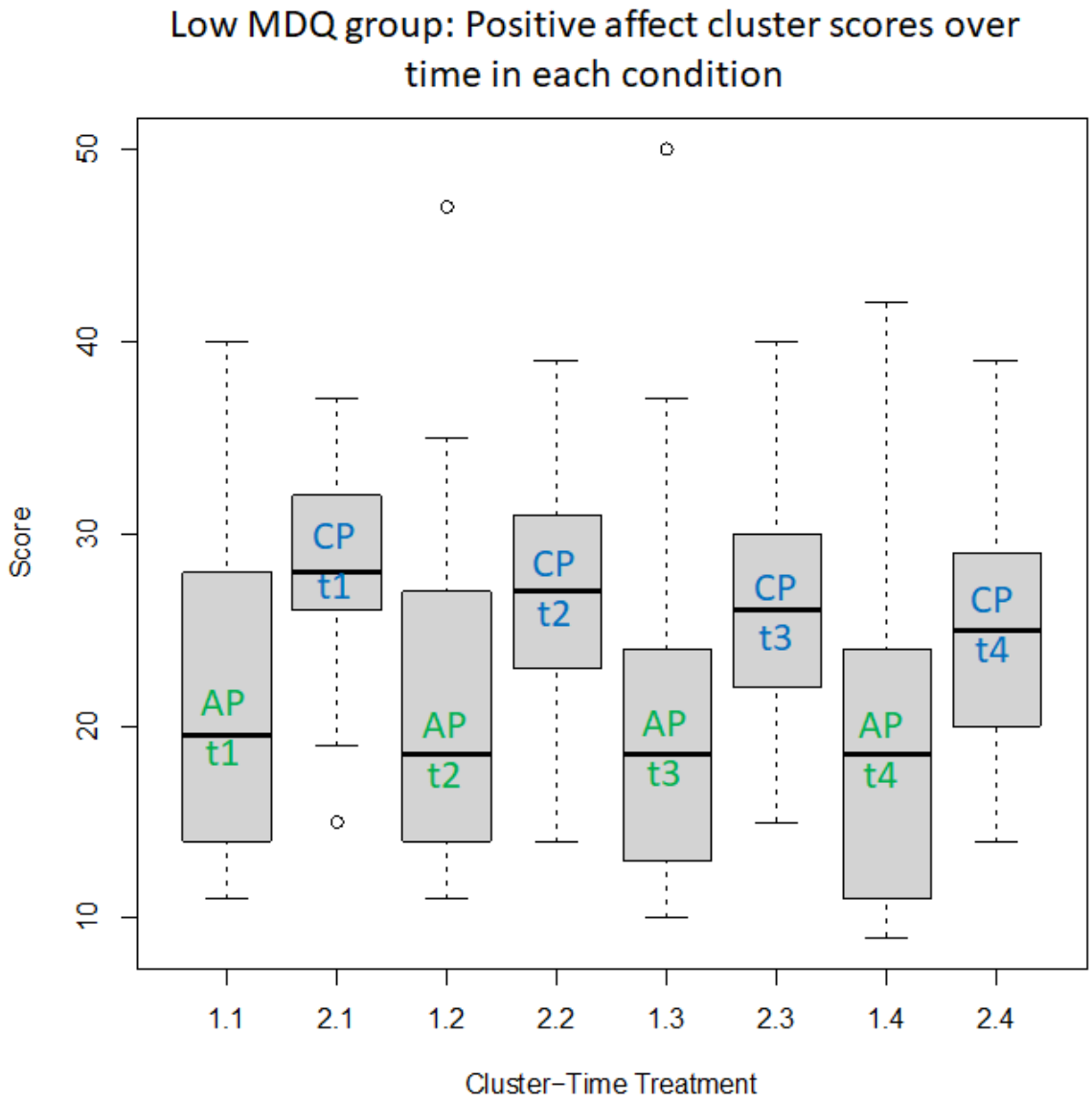
1(b) Low MDQ Group. Similar but not identical, five clusters were identified: three clear and roughly comparable to the High MDQ Group (1, 3, 5) and 2 less clear clusters (2, 4). Proposed cluster labels and words included in each cluster are as follows. **Cluster 1 'negative'.** Jittery (p29), unstable (p40), irritable (p15), impatient (p39), hostile (p13), distressed (p2), upset (p6), afraid (p33), guilty (p8), scared (p9), ashamed (18), daring (p31). **Cluster 2**. Nervous (p25), self-possessed (p38). **Cluster 3 'active positive'.** Fearless (p23), bold (p5), inspired (p22), dynamic (p41), excited (p16), energetic (p24), active (p30), proud (p17), delighted (p26), elated (p37). **Cluster 4.** Strong (p7), confident (p27), enthusiastic (p19), determined (p28), assertive (p36), happy (p3), cheerful (p10), joyful (p12), lively (p21). **Cluster 5 'calm positive'.** Alert (p34), efficient (p35), at ease (p1), calm (p11), relaxed (p32), concentrating (p14), interested (p4), attentive (p20).



Supplementary Figure 2. Boxplot showing the effects of the Calm-Positive and Active-Positive mood subcluster and Condition on affect score in the High MDQ Group. Linear mixed model analysis reveals a significant interaction between cluster and condition (slope=10.914 (SE=1.936) p<0.001) but no effect of time (slope= 1.039 (SE=2.201), p=0.64). Intercept is significantly different from zero (intercept=20.639 (SE=1.581), p<0.001). x-axis increments as follows: Cluster: 1=Calm-Positive, 2=Active-Positive; Condition: 0=Calm, 1=Elated. Affect score is highest for Active-Positive Affect in the Elated imagery condition.



Supplementary Figure 3. Boxplot showing effects of Calm-Positive and Active-Positive affect subcluster and time on affect score in the Low MDQ Group. Linear mixed model analysis reveals significant effects of affect cluster (slope=6.615 (SE=0.717) p<0.001) and time (slope=-0.968 (SE=0.219) p<0.001) with no effect of condition (slope=-3.165 (SE=2.329), p=0.185). Intercept is significantly different from zero (intercept= 24.078 (SE=1.813), p<0.001). x-axis increments as follows: Cluster: 1=Calm-Positive, 2=Active-Positive; Time: 1=t1, 2=t2, 3=t3, 4=t4. Positive affect score decreases with time irrespective of imagery condition. The decrease is steeper for the Calm-Positive cluster.



Vividness results. To test the hypothesis that vividness exaggerates the impact of the experimental imagery manipulation, we used a linear mixed model to investigate how vividness changes with relative mood change (defined as the log difference between total PANAS score at time t and total PANAS score at time t-1 (log(Mt/Mt-1)), MDQ group and condition.

As vividness was determined over 30 individual trials, three different measures of vividness were computed to deal with autocorrelation effects in vividness: (i) a moment matric (based on the mean, variance and skewness in vividness for each participant over the 30 trials within a mood trial; (ii) the AR(1) covariance in vividness for each participant over the 30 trials within a mood trial and (iii) the dominant eigenvalue in the AR(1) variance-covariance matrix.

There were no statistically significant effects of mood change, MDQ or condition on vividness across the three mood trials (for any of the vividness measures). These results are summarized in the tables below.

Supplementary Table 1. Vividness Measure: Moments

	Intercept		Mood Change		MDQ Group		Condition	
	F-value	p-value	F-value	p-value	F-value	p-value	F-value	p-value
Time 1	3080.923	<0.001	0.196	0.659	0.571	0.452	1.353	0.250
Time 2	3491.310	<0.001	1.373	0.246	0.074	0.786	0.557	0.458
Time 3	3342.669	<0.001	2.275	0.137	2.995	0.089	0.093	0.762

Vividness moment metric is significantly different from zero, with no effect of mood change, MDQ group or condition on this metric.

Supplementary Table 2. Vividness Measure: AR(1) Covariance

	Intercept		Mood Change		MDQ Group		Condition	
	F-value	p-value	F-value	p-value	F-value	p-value	F-value	p-value
Time 1	0.207	0.658	0.308	0.581	0.467	0.497	0.03	0.854
Time 2	1.044	0.311	0.232	0.632	0.004	0.946	0.538	0.466
Time 3	0.788	0.379	0.001	0.970	0.006	0.771	0.303	0.584

Vividness covariance is not significantly different from zero, indicating no significant autocorrelative effect (i.e. vividness ratings at each trial are independent), with no effect of mood change, MDQ group or condition on this metric.

Supplementary Table 3. Vividness Measure: AR(1) Var-Covar Matrix

	Intercept		Mood Change		MDQ Group		Condition	
	F-value	p-value	F-value	p-value	F-value	p-value	F-value	p-value
Time 1	431.707	<0.001	0.913	0.343	0.312	0.578	0.968	0.329
Time 2	175.653	<0.001	1.059	0.308	0.105	0.747	1.238	0.271
Time 3	184.466	<0.001	4.659	0.0351	0.02	0.889	0.703	0.405

Dominant eigenvalue of t the AR(1)-V-C matrix is significantly different from zero (expected as this is the principal axis of variance). No significant effect of mood change at time point 1 or 2. The significant effect of mood change on time point 3 using the AR(1) V-C metric is a result of a high mood score associated with a single participant. No effect of MDQ group or condition on this metric of vividness.

Subjective experience and demand measures. Overall, participants did not report difficulty in generating mental images (M = 3.3, SD = 1,5), in combining the picture with the word-cue (M = 3.3, SD = 1.5) and in adopting field imagery (M = 7.6, SD = 1.7) without verbally analysing (M = 3.9, SD= 2.3). Furthermore, participant groups did not differ on these variables (see Manuscript, Table 2). There was no group difference in participants' subjective perception that their negative mood had changed after the imagery task (M = 3.3, SD = 2.2). Groups did however differ in their subjective perception that their positive mood had changed, with the high MDQ group reporting that they felt more positive after the imagery task (low MDQ, M = 5.3, SD =.39; high MDQ, M = 6.4, SD = .33) regardless of the imagery condition to which they had been assigned (see Supplementary Table 4, below).

Supplementary Table 4. Results of two-way univariate ANOVA on Subjective Experience and Demand Characteristics

Two-way univariate ANOVA	**Interaction**		**MDQ**		**Condition**	
	F	p-value	F	p-value	F	p-value
Generate Mental Images	.02	.88	.02	.88	.09	.75
Combine Picture Word-cue	.03	.87	.03	.87	.46	.5
Use of Field Perspective	.74	.39	.35	.56	.04	.83
Verbally Analyse	.56	.46	.17	.68	.4	.53
Change of Positive Emotions	.83	.37	4.4	.04*	2.5	.11

Post hoc analysis of correspondence between mood change and subjective experience of mood change in the high MDQ group. Above, we found that self-reported (i.e. subjective) change in positive mood was greater in the high vs low MDQ group, with no effect of condition. We conducted a post hoc analysis to explore the basis of this effect in the high MDQ group. We conducted a Spearman's rank correlation between high MDQs' subjective positivity scores and change in PANAS positive mood score from time point 1 to time point 4, collapsed across conditions. In other words, this analysis tests whether individual variation in high MDQ participants' overall sense of whether their mood became more positive corresponded to individual variation in PANAS positive mood score change. We conducted this analysis separately for previously validated PANAS positive mood words versus the 'hypomanic-like' positive mood words added for the current study.

The Spearman's rank correlation between subjective demand score and difference in total PANAS score for standard positive words was 0.217. However, this sample correlation is not significantly different from zero (t=1.196 on 29df p=0.121; from a resampling distribution: 2.5% quantile= -0.145, 97.5% quantile = 0.546). Similarly, the Spearman's rank correlation between subjective demand score and difference in total PANAS score for unique positive words is 0.243. Again, this sample correlation is not significantly different from zero (t=1.349 on 29df p=0.094; from a resampling distribution: 2.5% quantile= -0.154, 97.5% quantile = 0.535).

3. Supplementary discussion

No effect of vividness [H3]

Based on prior work (O'Donnell et al., 2018) we hypothesised that mood amplification across the mental imagery generation task would be dependent on imagery vividness. For each picture-word cue, participants generated mental imagery and used a numeric scale to rate imagery vividness. Since participants rated vividness on each trial but mood after each block of 30 trials, we

computed summary measures of vividness for each block. Three summary measures were computed: Moment metric (unbiased mean), vividness covariance, and a measure encapsulating the relationship between the two. Interestingly, the covariance measure did not differ significantly from zero, indicating not autocorrelation effects on vividness. This means that imagery vividness is independent across trials and participants. As such, it is potentially a valid, accurate indication of imagery vividness on each trial that is unconfounded by individual participant response tendencies and cumulative effects across the task. Therefore, we recommend vividness ratings continue to be elicited in future studies, and we further recommend the summary metrics we use here.

We subjected the three vividness summary measures to linear mixed model analyses to pinpoint any the relationship between their change over time and relative mood change, MDQ group and imagery condition. Contrary to our hypothesis, we found no significant effects. That is, mood amplification did not depend on vividness ratings.

There are a number of potential explanations for this null effect. First, vividness may operate as a threshold mechanism, with a certain level of imagery vividness required to see an emotional impact but beyond this level, increasing vividness does not increase emotional impact. Since we excluded participants who reported low imagery vividness in daily life (based on the SUIS), this is conceivable in our study. Indeed, evidence suggests that imagery vividness is not amenable to improvement via training (Rademaker & Pearson, 2012), in contrast to metacognitive awareness of mental imagery (Pearson et al., 2011; Rademaker & Pearson, 2012). Second, our vividness scale had a limited range (five discrete rating points), and perhaps not enough potential variance to capture hypothesised effects, especially at the high end of the scale. Third, the scale had a dual purpose in our study. In addition to providing vividness data on every trial, the scale was used to provide a common language for discussing mental imagery and optimising its vividness. During the training phase and after every 10th trial, the experimenter spoke to the participant to enquire

about their images and experience of the task, giving reinforcement and reminders where needed (e.g., to use field perspective, to focus on imagery instead of verbal thoughts). Therefore, potentially, the experimental procedure produced demand characteristics on the vividness ratings (although the lack of autocorrelative effects counters this notion). Finally, the null effect of vividness could indicate that imagery specifically does not give rise to the mood amplification effects in our study, and instead the task acts more as a general mood induction procedure. This explanation seems unparsimonious given evidence that mental imagery accompanies sensory perception and stimulus-independent processing, and its generation alters affective states across a variety of populations (Hirsch & Holmes, 2007; Hoppe et al., 2021; Kessler et al., 2018; Rachman, 2007). We suggest that future studies further explore the role of vividness using an expanded operating range for vividness scores and converging behavioural and neurophysiological imagery markers (Cui et al. 2007; Pearson et al., 2015).

Subjective experience and demand measures. To better understand findings from mixed model analysis 1 indicating that mental imagery amplifies mood dependent on MDQ group and positive imagery condition [H1] we examined the results from analysis of scores on the additional measures, specifically whether participants felt their mood had changed as a result of the imagery task. This analysis revealed that the high (vs. low) MDQ group reported experiencing significantly greater change in positive mood after both conditions of the experimental imagery task. There are multiple potential reasons for this result. It might be that high MDQs were aware of their mood changes, showing some insight on their emotional sphere. Our post hoc analysis did not show support for this possibility, but nevertheless the effect warrants further investigation (especially given evidence that positive therapeutic outcomes are strengthened by the psychological mindedness of patients (Nyklíček et al., 2010; Piper et al., 1994). Alternatively, the increased subjective change in positive mood in the high vs. low MDQ group could reflect greater sensitivity to task demands.

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