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ORIGINAL ARTICLE

The effect of positive mental imagery versus positive verbal thoughts on anhedonia

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Abstract

Anhedonia, the loss of interest in and pleasure from previously enjoyable activities is a core symptom of depression and presents a major challenge to treatments. Interventions involving positive mental imagery generation have been suggested to reduce anhedonia. However, it is not clear whether the imagery component of such interventions is crucial for these effects. The current study aimed to test this by contrasting repeated generation of positive mental imagery versus positive verbal thoughts. Over a one-week period, 53 mildly anhedonic adults completed five sessions of a computerized training program involving the generation of either positive images or positive sentences. Compared to participants who generated sentences, participants who generated imagery showed greater improvements from pre- to post-training on an individualized multi-facetted measure of anhedonia (the Dimensional Anhedonia Rating Scale), but not on standardized measures of

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anticipated pleasure (the Snaith-Hamilton Pleasure Scale), depression symptoms, or positive affect. The present study supports the proposal that positive imagery could provide a route to improve anhedonia, with generation of imagery in particular (as opposed to positive thoughts in general) as an important driving mechanism for these effects. This has theoretical and clinical implications for understanding the role of imagery in anhedonia and its treatment.

KEYWORDS

anhedonia, cognitive bias modification, depression, mental imagery, positive affect

INTRODUCTION

Anhedonia is defined as the loss of interest in or enjoyment from previously enjoyed activities (American Psychiatric Association, 2013). While anhedonia is a core symptom of major depression, it poses a major clinical challenge: First, treatments that may be very effective for other symptoms of depression often have a much more limited impact on anhedonia (e.g., Alsayednasser et al., 2022). Second, anhedonia and the broader associated deficits in positive affect are predictive of poorer prognosis and worse treatment outcomes (Alsayednasser et al., 2022; Craske et al., 2016; Uher et al., 2012). Anhedonia is therefore an important focus for treatment development work (e.g., Craske et al., 2023; Dunn et al., 2023), and identifying how best to target the underlying mechanisms may provide a promising route forward.

One key component of anhedonia is the reduced anticipation of pleasure from upcoming events or activities (e.g., Hallford & Sharma, 2019). A possible target for interventions aiming to increase the anticipation of pleasure and thus reduce anhedonia is positive mental imagery (Blackwell et al., 2015). Mental imagery can be defined as "representations and the accompanying experience of sensory information without a direct external stimulus" (Pearson et al., 2015; p. 590), and is often described as "'seeing with the mind's eye,' 'hearing with the mind's ear,' and so on" (Kosslyn et al., 2001; p. 635). Most people experience mental imagery frequently in everyday life, and this type of imagery is thought to play a role in a number of cognitive processes, such as thinking about the future, decision-making, planning, and emotion regulation (Blackwell, 2021). For example, if someone receives a message from a friend inviting them to a party the following weekend, while reading this message the individual may already imagine themselves being at the party and enjoying catching up with friends. Due to the 'as if reality' nature of mental imagery (Ji et al., 2016) and its ability to evoke strong emotions (Holmes & Mathews, 2010), via such imagery the individual may 'pre-experience' the event and what it would be like if they really were there; if this imagery is positive and feels enjoyable, this may then lead to them feeling positive anticipatory emotion and motivate them to take the necessary steps to attend the party.

As the above example illustrates, experiencing positive mental imagery of upcoming events could plausibly play an important role in anticipating them as enjoyable (e.g., Hallford, Barry, et al., 2020) and feeling motivated to engage in them (Renner et al., 2019). However, if the person in this example was depressed they would be unlikely to experience such positive future-oriented imagery of the upcoming party, and even if they did the imagery would not be very vivid: Depression and depressed mood are associated with reduced tendency to experience spontaneous future-oriented imagery (Ji et al., 2019), and reduced ability to generate vivid positive future-oriented imagery (Holmes et al., 2016). This deficit in positive future-oriented imagery may then make it more difficult for the depressed individual to anticipate the party as enjoyable, contributing to a lack of motivation and reducing the chance that they actually attend it. Over time, such reduced engagement in potentially rewarding activities may make it even harder to anticipate future activities as enjoyable, due to a lack of accessible recent positive episodic memories (Blackwell, 2023; Renner et al., 2021).

From this perspective, increasing the likelihood that individuals experience positive future-oriented imagery when anticipating upcoming events provides a plausible route for improving their tendency to anticipate pleasure from these events. This could then lead to improvements in anhedonia, both via a direct effect on the anticipatory component, and also indirectly via increasing desire and motivation to engage in enjoyable activities. This in turn could lead to increased actual experience of pleasure (the consummatory component of anhedonia) and greater accessibility of enjoyable positive affect-laden episodic memories to be drawn on when anticipating further events in the future (Blackwell, 2023; Ji et al., 2021; Renner et al., 2019). One approach that has been investigated as a means to do this is a simple computerized cognitive training paradigm, imagery cognitive bias modification (imagery CBM; Blackwell et al., 2015; Blackwell & Holmes, 2010). During imagery CBM participants are presented with ambiguous stimuli and are required to resolve the ambiguity via the generation of mental imagery; in positive versions of imagery CBM, this resolution is always positive. The idea is that via repeated practice in imagining positive resolutions to ambiguous situations and scenes in the training, a new bias or tendency is trained to automatically imagine positive resolutions for ambiguity (e.g., anticipation of upcoming events) in daily life.

The most frequently used version of positive imagery CBM involves listening to brief audio descriptions of everyday situations, structured so that they start ambiguous but always end positively (for example: "You receive a message from a friend inviting you to a get-together the following weekend. As you think about going and what it will be like, you feel sure it you will find it very *enjoyable*"; positive resolution in italics). Crucially, as participants listen to the scenarios, they imagine them happening, as if they were actively involved and actually experiencing the situations. In another version of positive imagery CBM, the ambiguity is presented in the form of a photo of an everyday scene, paired with a positive caption of a word or a few words (for example: a photo of some people at a social gathering with the caption "enjoyable"). In this picture-word paradigm, participants are required to combine the picture and word to form a positive mental image. Experimental studies have found that for both of these training versions, processing the training stimuli via imagery leads to greater changes in state mood than processing the stimuli verbally, supporting the proposition of a close link between imagery and emotion (e.g., Holmes et al., 2009; Holmes, Mathews, et al., 2008).

The first indications that positive imagery CBM may provide a means to improve anhedonia came from a randomized controlled trial by Blackwell et al. (2015). In this trial, 150 adults with current major depression were randomized to complete a four-week training schedule of either positive imagery CBM or a sham training control. The imagery CBM intervention comprised six sessions of scenario-based training and six sessions of picture-word training, preceded by an initial session introducing both training types. The sham training control condition was designed to provide a closely matched training schedule but without the main putative active ingredients of the training, i.e., the contingency that the ambiguity was always resolved positively, and the generation of mental imagery. To this end, the sham training comprised an identical schedule of sessions and session types, but instead of the training stimuli always being resolved positively, half of the time they were instead resolved negatively. Further, instead of being instructed to generate mental imagery, participants were instructed to engage in verbal processing of the training stimuli. Specifically, in the scenario-based sham training condition they were instructed to think about the words and meanings of the training scenarios in a verbal processing style, and in the picture-word sham training, they were instructed to combine the picture and words to form sentences. Unexpectedly, results showed no difference between the active versus control conditions in reductions in symptoms of depression as measured by the Beck Depression Inventory-II (BDI-II; Beck et al., 1996) at post-training (the primary outcome) or any other time point. However, post-hoc analyses found a greater reduction specifically in anhedonic symptoms of depression (using anhedonia items from the BDI-II) in the imagery compared to the control condition. While this result was post-hoc and therefore should be treated with caution, results from other subsequent studies have also been consistent with the idea that imagery CBM could provide a means to reduce anhedonia. For example, Pictet et al. (2016) and Williams et al. (2015) found a greater reduction in anhedonia, as measured via the anhedonia items from the BDI-II, following a one-week imagery CBM training schedule compared to a one-week sham training. Other studies with a variety of different training schedules and control conditions have found reductions in anhedonia on a dedicated anhedonia questionnaire (Bibi et al., 2020; Blackwell et al., 2023; Westermann et al., 2021).

Although the requirement to generate imagery has been assumed to be central to the observed effects of imagery CBM on anhedonia, the control conditions in previous studies have not isolated the effects of imagery generation, and thus these studies do not allow such a conclusion to be drawn. For example, the sham training control condition used by Blackwell et al. (2015) differed from the positive imagery CBM condition not only in the requirement to generate imagery but also in the valence of the resolution of the training stimuli. This study could therefore not test directly whether it was the generation of imagery specifically that resulted in the reductions in anhedonia observed; plausibly the generation of consistently positive resolutions (regardless of whether imagery-based or not) could in itself have been responsible for this effect. Other studies have also not addressed this issue directly: some have used control conditions in which only the training contingency or some other aspects of the intervention were changed, but the requirement to generate imagery remained (Blackwell et al., 2023; Pictet et al., 2016; Williams et al., 2015), whereas others have used a control condition that differed in too many aspects to draw conclusions about any specific component of the imagery CBM (Bibi et al., 2020; Westermann et al., 2021).

Another unanswered question about the effect of imagery CBM on anhedonia is the relevant underlying mechanism. One potential route is a relatively direct one, in that repeatedly imagining taking part in activities or events and experiencing them as rewarding (e.g. enjoyable or fulfilling) could lead to highly accessible representations in memory corresponding to what was imagined (see e.g., Blackwell, 2023; Blackwell & Holmes, 2017). When someone then thinks about engaging in a similar activity in their everyday life, this could lead to automatic retrieval of this imagery-rich representation, including the positive emotions involved. This could then increase their interest in or desire to engage in the activity, and anticipated enjoyment, both of which are core aspects of anhedonia. However, other more indirect routes may also be possible. For example, anhedonia can be conceptualized as relating to deficits in positive affect and reward systems (e.g., Pizzagalli, 2014). Given that individual sessions of imagery

CBM lead to increases in state positive affect (e.g., Holmes et al., 2009; Pictet et al., 2011), multiple sessions could lead to reductions in anhedonia via sustained increases in positive affect over time, or simply via repeated activation of positive affect and reward systems during individual sessions (e.g., Blackwell et al., 2018; Craske et al., 2019). Experimental and clinical studies of imagery CBM have also shown that it can lead to changes in cognitive processes, such as biases in interpretation, that is, how people tend to interpret ambiguous scenarios or visual scenes (e.g., Holmes et al., 2009; Holmes, Mathews, et al., 2008; Pictet et al., 2016; Woud, 2023). Such changes could also plausibly lead to improvements in anhedonia if people interpret upcoming events in a positive manner (e.g., as potentially rewarding). Another potential route via which imagery CBM could have an impact on anhedonia is if the repeated generation of positive imagery resulted in participants being able to generate more vivid imagery when they imagined upcoming events or activities: reduced vividness and detail for simulations of positive future events has been associated with reduced anticipatory pleasure, a core component of anhedonia, in a sample of depressed individuals.

In the current study, we therefore aimed to investigate both the role of imagery generation in imagery CBM's effects on anhedonia and the potential mechanisms underlying these effects. Our primary aim was to test directly whether the generation of positive mental imagery would have a greater effect on reducing anhedonia than generation of positive cognitions that were not imagery-based. To do so, we used the imagery CBM training based on picture-word pairs, as this training version lends itself more easily to testing imagery vs. verbal processing than the audio-based paradigm (Holmes, Mathews, et al., 2008). Participants in the present study were assigned to one of two experimental conditions in which the same set of ambiguous pictures with positive captions were presented. However, in one condition participants were instructed to combine the picture and words to form images, and in the other participants were instructed to combine them to form sentences, thus allowing us to contrast positive imagery vs. positive verbal-based cognition (similar to Holmes, Mathews, et al., 2008). We used a repeated-sessions training schedule over a brief time-frame of one week, as previous studies had indicated this provided sufficient training intensity to observe effects on relevant outcome measures (e.g., Pictet et al., 2016; Williams et al., 2015). As we were interested in examining mechanisms (i.e., which measures were affected by the imagery manipulation) rather than treatment efficacy, we did not recruit a clinical sample or investigate longer-term outcomes. However, to avoid floor effects we recruited a sub-clinical sample of students experiencing at least mild levels of anhedonia and lowered levels of positive affect, and also included an additional follow-up assessment one week after the end of training in case any effects were delayed.

In addition to measures of anhedonia, we also included a range of measures of other clinically relevant outcomes: overall symptoms of depression, and positive and negative affect over the past week. This allowed us to investigate the specificity of any between-group differences found in the effects of the training on anhedonia (as opposed to these reflecting general improvements in mental health or mood). Further, measurement of positive affect over the past week allowed investigation of whether the effect of positive imagery CBM on state positive affect observed in experimental studies (e.g., Holmes et al., 2009; Pictet et al., 2011) leads to more generalized increases in positive affect in participants' daily lives.

Further, we included measures of a range of potential mechanisms of the training to help shed light on those underlying the effects on anhedonia. In relation to possible effects on positive affect systems, in addition to state positive affect during the training sessions themselves and general levels of positive affect over the week of training, we assessed participants' emotional responses to positive pictures (as a measure of reward responsivity, as per Craske et al., 2023). We also measured the vividness with which participants could generate positive future-oriented imagery and interpretation of ambiguous visual scenes.

We hypothesized that participants in the imagery compared to the control condition would show greater improvements in anhedonia over the week of training, as well as at a further one-week follow-up. We further expected that participants in the imagery condition would show greater improvements in other clinically relevant outcome measures compared to participants in the control condition. In relation to the mechanisms measures, all of these related to plausible (and not mutually exclusive) potential mechanisms, and there was not a compelling a priori scientific rationale to predict changes for one but not another. Hence we were primarily interested in observing which measures showed differential between-group effects of the training (and which did not), rather than making specific predictions about one or other of the measures included.

METHODS

Design

The study used an experimental design with two parallel groups (imagery vs. verbal condition). Participants attended two lab-based appointments one week apart (pre-training and post-training), and then completed an online follow-up one week later. A mid-training assessment (completed via e-mail) was also used to try to detect early indicators of change. The study was approved by the ethics committee of the Faculty of Psychology, Ruhr-Universität Bochum (approval no. 329). Data collection took place between January 2017 and June 2019.

Participants and recruitment

Participants were recruited via a larger online study involving the completion of several questionnaires, which were used to screen individuals for potential participation in one or more lab-based studies. While participants could receive course credit for completing the online screening study only, they were recruited with the information that this was screening for lab-based studies for which they could receive either further course credit or cash payment. Recruitment was primarily via paper flyers on the university campus and adverts posted online (a departmental webpage and Facebook groups for students interested in taking part in studies). Inclusion criteria for taking part in the present study were: i) age $\geq$ 18; ii) fluent German; iii) at least mild anhedonia (Snaith Hamilton Pleasure Scale [SHAPS] score $\geq$ 1 or Beck Depression Inventory [BDI] anhedonia item $\geq$ 1) and low positive affect (Extended Positive scale of the Positive and Negative Affect Schedules [PANAS-P] score $\leq$ 67)[1]; iv) a computer on which the training programs would work; v) ready and willing to complete the study procedures. Exclusion criteria were: i) circumstances that would make completing the study procedures difficult or impossible, e.g., severe visual impairment; ii) previous participation in a similar study; iii) severe depression, as indicated by a BDI-II score > 29. Participants who met the inclusion criteria at screening were invited to attend the laboratory to take part in the study. All participants initially provided informed consent for the screening online, and written consent for the main study at the pre-training appointment after having the chance to ask the researcher any further questions. It was originally planned to recruit 80 participants for the study ($n = 40$ per group), but due to recruitment difficulties, the study took longer than planned and had to be stopped earlier for logistical reasons including the onset of the COVID-19 pandemic in early 2020.

Materials

Positive picture-word training

The positive picture-word training was adapted from that used in previous studies (e.g., Blackwell et al., 2015; Holmes, Mathews, et al., 2008). Training stimuli comprised ambiguous pictures of mostly everyday scenes paired with a positive caption of one or more words. For example, a picture of the university cafeteria was paired with the caption "Enjoying the lunchbreak". As per Blackwell et al. (2015), each training stimulus was preceded by a preparation screen with the relevant task instruction (imagery condition: "Imagine ..." ; verbal condition: "Form a Sentence ...") for 1,000 ms. The picture was then displayed with the word caption underneath it for 2,500 ms, followed by black screen for a further 1,000 ms, after which a beep sounded and the participant was requested to rate the vividness of their image (imagery condition) or complexity of the sentence generated (verbal condition) on a scale from 1 (*not at all vivid /not at all complex*) to 5 (*very vivid/very complex*). After the participant had made their rating the next training stimulus was presented (starting with the preparation screen).

There were 5 training sessions, the first of which was completed in the lab, and the rest of which were completed at home by the participants on their own laptops. Each session included 4 blocks of 16 unique training stimuli (i.e. 64 stimuli per session, as per Blackwell et al., 2015, and 320 training stimuli in total). Training sessions started with a brief reminder of the task instructions and one practice training stimulus (except in the initial session, where there were two practice training stimuli). Practice training stimuli were followed by a brief suggestion of an example for an image or sentence for that training stimulus. Between each block was a self-paced break in which participants were shown graphical feedback of their vividness/complexity scores over the previous blocks (minimum, maximum, and mean rating per block) and instructed to reflect on the scores and how they might try to improve in subsequent blocks (as per Westermann et al., 2021). The training was programmed in Java and installed by the researcher on participants' own laptops. At the start and end of each session, participants rated their state mood (3 positive words: happy, calm, optimistic; 3 negative words: sad, anxious, hopeless) on a 5-point scale ranging from 1 (*not at all*) to 5 (*very*). As per Westermann et al. (2021), participants also made further ratings (using the same scale) about the past day at the start of each training session. Specifically, participants rated their mood over the past day using the 3 positive and 3 negative mood words, and then rated the statements "I was able to look forward to different activities and events", "I was able to enjoy different activities and events", "I was an active person and achieved my goals", "Positive thoughts popped into my head", "Negative thoughts popped into my head". These ratings were included as exploratory measures to potentially allow investigation of changes over the course of the training week.

Imagery condition

In the imagery condition, participants were instructed to combine the picture and word caption to form a mental image of the situation in which they were actively involved, seeing the scene through their own eyes (i.e., field perspective; Holmes, Coughtrey, & Connor, 2008). Prior to the first training session in the lab, the researcher provided a verbal introduction to the task, including an explanation of what is meant by mental imagery, instructions to generate field- rather than observer-perspective imagery, and to avoid thinking verbally about or analyzing the picture-word pairs (as per Blackwell et al., 2015). The researcher then led the participant through an imagery exercise involving imagining a lemon followed by two examples of picture-word pairs printed on paper.

Verbal condition

In the verbal condition, participants were instructed to combine each picture and word caption to form a sentence that was grammatically correct and as complex as possible. Prior to the first training session in the lab, the researcher provided a verbal introduction to the task, explaining what is meant by thinking verbally, describing this as like an inner monologue, and giving instructions to avoid thinking in images. They then led the participant through an exercise involving creating several sentences about interacting with a lemon, and two examples of picture-word pairs printed on paper. Participants were asked to simply think the sentence to themselves (i.e., apart from the practice examples, they were not asked to report these or say them out loud).

Clinical outcome measures

Depending on the timepoint of administration (see procedure section for details), the following questionnaires were completed either online (screening, follow-up) via Unipark, on paper (pre- and post-training), or returned via email attachment (mid-training).

Dimensional Anhedonia Rating Scale (DARS; ***Rizvi et al.***, *2015*)

The DARS is a self-report measure of four different facets of anhedonia (desire/interest, anticipated enjoyment, motivation, effort expenditure) across four different domains of activity/event (hobbies/past-times, social activities, food/drink, and sensory experiences). Participants are asked to list two or three of their favorite activities or experiences for each domain. They then answer questions assessing the four facets of anhedonia on scales from 1 (*not at all*) to 5 (*very much*). An extended 26-item version was used in a German translation as reported by Blackwell et al. (2018), and a total score was calculated via taking the mean of the individual item scores. The DARS was administered at pre- and post-training to provide an idiosyncratic and multi-faceted measure of anhedonia, and at post-training participants were provided with the list of activities they had written at pre-training and asked to rate these again. Due to practical difficulties in providing this list when participants were not in the lab, the DARS was not completed at the mid-training or follow-up timepoints. Cronbach's alpha for the DARS in our sample was $\alpha = 0.90$ [0.85,0.93] at pre-training and $\alpha = 0.89$ [0.83,0.92] at post-training.

Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995)

The SHAPS is a widely used self-report questionnaire measuring anticipated pleasure from activities. It comprises 14 items asking about different potentially enjoyable activities (e.g., being with friends and family), and participants are asked to rate how much they would expect to enjoy engaging in each activity over the past few days. Participants rate each item on a scale from 1 (*disagree completely*) to 4 (*completely agree*). Ratings indicating disagreement (1 or 2) are scored as 1 and ratings indicating agreement (3 or 4) are scored as 0, with these items then summed to achieve a total score. Snaith et al. (1995) suggest that total scores greater than 2 indicate abnormal levels of anhedonia. The German version by Franz et al. (1998) was used. The SHAPS was administered at all assessment timepoints. Cronbach's alpha in our sample was as follows: Pre-training: α = 0.66 [0.51, 0.78]; mid-training: α = 0.76 [0.65,0.85]; post-training: α = 0.76 [0.66,0.85]; follow-up: α = 0.81 [0.73,0.88].

Beck Depression Inventory – Second Edition (BDI-II; Beck et al., 1996)

The BDI-II is a widely-used measure of depression symptoms, on which participants rate 21 symptoms on a 0 to 3 scale according to their experience over the past 2 weeks (response options differ for each item). The German version reported by Kühner et al. (2007) was used. The BDI-II was administered at pre-training, post-training, and follow-up. Cronbach's alpha in our sample was as follows: Pre-training: 0.80 [0.68,0.87]; post-training: α = 0.84 [0.77,0.90]; follow-up: 0.86 [0.80,0.91].

Positive and Negative Affect Schedules (PANAS; Watson & Clark, 1994)

The PANAS was used as a measure of positive (PANAS-P) and negative (PANAS-N) affect. Participants rated a set of positive and negative emotion words according to how much they had experienced each emotion over the past week, using a scale from 1 (*not at all*) to 5 (*extremely*). Following previous research using imagery CBM (e.g., Holmes et al., 2009) we used an extended 21-item positive subscale to measure positive affect, but we also included the 10 negative items from the standard PANAS to measure negative affect.[2] Total scores for the positive and negative subscales were calculated via taking the mean of the individual item scores. The German translation by Grühn et al. (2010) was used. The PANAS was administered at all assessment time-points. For the positive scale, Cronbach's alpha was as follows: Pre-training: α = 0.91 [0.87,0.94]; mid-training: α = 0.93 [0.90,0.95]; post-training: α = 0.94 [0.90,0.96]; follow-up: α = 0.93 [0.90,0.96]. For the negative scale, Cronbach's alpha was as follows: Pre-training: α = 0.86 [0.74,0.91]; mid-training: α = 0.89 [0.81,0.93]; post-training: α = 0.88 [0.74,0.93]; follow-up: α = 0.88 [0.81,0.91].

Mechanisms outcome measures

Ambiguous Picture Rating Task (APRT)

As a measure of interpretation of ambiguous scenes, a picture rating task was used (as per previous experimental studies using the picture-word paradigm, e.g., Holmes, Mathews, et al., 2008; Pictet et al., 2011). At both pre- and post-training participants were presented with a set of 25 pictures used in the training and 25 pictures not used in the training, and asked to rate their ‘pleasantness’ on a scale from 1 (*not at all pleasant*) to 9 (*extremely pleasant*). Participants rated the same set of pictures at both pre- and post-training. The APRT Task was presented using Presentation Software.

Prospective Imagery Test (PIT; Stöber, 2000)

The PIT was used as a measure of the vividness with which participants could imagine positive and negative events in their future. In the PIT, participants are provided with a list of positive and negative hypothetical future events and asked to imagine each one happening in their future. They then rate the vividness of their image on a scale from 1 (*not at all vivid*) to 5 (*very vivid*). The total score for each subscale was calculated by taking the mean for the individual item ratings. The German version by Morina et al. (2011) was used. So that participants would complete a different set of items at pre and post-training, 2 parallel versions of the scale were used, each with

5 positive and 5 negative items (as per Blackwell et al., 2023; Westermann et al., 2021). To avoid repetition of items, the PIT was completed only twice, at pre- and post-training. For practical reasons, the order of completion of PIT versions was the same for all participants, i.e., no counterbalancing. For the positive items, Cronbach's alpha was $\alpha = 0.63$ [0.37,0.76] at pre-training and $\alpha = 0.85$ [0.76,0.90] at post-training. For the negative items, Cronbach's alpha was $\alpha = 0.72$ [0.59,0.80] at pre-training and $\alpha = 0.72$ [0.58,0.81] at post-training.

Emotional Picture Rating Task (EPRT)

To provide a measure of reward responsivity, specifically emotional reactivity to positive (vs. neutral) pictures, a task adapted from that used by Craske et al. (2023) was used. Participants viewed a series of pictures (8 positive and 8 neutral) from the International Affective Picture System (IAPS; Lang et al., 2008). Pictures were presented for 6 s each on the computer screen, and afterward participants were asked to rate their emotional response to the image in terms of valence and arousal, both using a 1 to 9 Self-Assessment Manikin (SAM; Bradley & Lang, 1994). Pictures were presented in a random order, with the exception that more than two pictures of the same valence could not be presented consecutively. The EPRT was implemented as a Java desktop application, and completed at post-training only.

Procedure

Prior to the first lab-based session, participants were allocated by the experimenter to the imagery or verbal condition based on a pre-set randomization sequence (generated a-priori by AR). After arriving at the first lab-based session, participants had the chance to ask questions about the study and then provided informed consent. Subsequently, the experimenter installed the training program via USB stick onto their laptop in order to check that it functioned before proceeding. Participants then provided demographic data followed by the PANAS, PIT, SHAPS, DARS, BDI-II, and the APRT. Participants next received the introduction to their allocated training condition and completed the first training session. Before the participant left the lab, the experimenter talked them through the training schedule over the following week, writing down their suggested plan on a paper planner and handing it to the participant.

Over the next week, participants completed their allocated training from home. At the midpoint of the training (3 days after the first session), the researcher emailed the participants the mid-training questionnaires (PANAS, SHAPS), to be returned via email.

At the end of the training week participant returned for the second lab session. They first completed the final training session, followed by the PANAS, PIT, SHAPS, DARS, DARS frequency questions, and the BDI-II. Then then completed the EPRT followed by the APRT. Training data was retrieved from the participant's computer via USB stick.

Two weeks later participants were sent a link for the follow-up questionnaires, which they completed in the following order: PANAS, SHAPS, BDI-II.

Statistical analyses

Analyses were completed using R v.4.2.2 (R Core Team, 2022) running in RStudio 2023.06.2 Build 561 (RStudio, Inc., 2016). Outcome analyses were conducted intention to treat (i.e. including all participants, regardless of whether they provided outcome data or not) via mixed model analysis of variance, run using the package *lmerTest* (Kuznetsova et al., 2017) and maximum likelihood estimation. Between-group effect sizes were calculated by dividing the estimated between-group difference from the mixed model by the observed pooled standard deviation of the change score, with a sample size adjustment (termed "unbiased d" by Cumming, 2012; often called Hedge's g). Within-group effect sizes were calculated by dividing the estimated within-group change from the mixed model by the observed standard deviation of the (within-group) change score.

Analyses for lab-based tasks were conducted as mixed model analyses of variance with effect sizes calculated from the model using the function t_to_d from the package effectsize (Ben-Shachar et al., 2020). We also carried out further exploratory analyses related to mechanisms, details of which are in the exploratory analyses part of the Results section.

RESULTS

Participant characteristics

A total of 54 participants (43 women, 11 men; $M_{age} = 23.04$, $SD_{age} = 6.15$) attended the baseline assessment and were allocated to a training condition, but one was given the introduction to the verbal condition before completing the imagery version of the CBM and thus excluded from analyses.[3] All participants reported being native German speakers and having a school leaving certificate as their highest level of education. Participants were predominantly students ($n = 50$, 94.3%), or in paid employment ($n = 2$, 3.8%), with one (1.9%) selecting 'other' as their employment status. Approximately half the sample ($n = 29$, 54.7%) reported being single, with the rest ($n = 24$; 45.3%) reporting being married or otherwise in a stable relationship. In terms of psychological disorders, two participants (3.8%) reported a current psychological problem (one with adjustment disorder, the other with depression), while 11 (20.8%) reported a past psychological problem (most commonly depression; $n = 5$). Other participant characteristics and baseline scores on the questionnaire measures are presented for the two experimental groups separately in Table 1, and correlations between measures at baseline are presented in Table S3 of the Supplementary Materials.

Adherence and within-session data

One participant (in the verbal condition) did not return for the post-training session and did not provide training data. All other participants completed all sessions of their allocated training. The mean vividness rating (across all picture-word stimuli in the training) in the imagery condition was $M = 3.72$ ($SD = 0.57$), and the mean complexity rating (across all picture-word stimuli in the training) in the verbal condition was $M = 3.27$ ($SD = 0.68$). Mixed model analyses of the state mood data (completed at the start and end of each training session) indicated that on average participants in the imagery condition showed a greater increase in positive state mood from pre to post each training session than participants in the verbal condition (time x condition interaction: $t(463.90) = 2.16$, $p = .03$, $d = 0.20$ [0.02, 0.38]. There was no difference between the two conditions in changes in negative state mood (time x condition interaction: $t(463.88) = 0.49$, $p = .63$, $d = 0.05$ [−0.14, 0.23]. Further details of the session data and these analyses are provided in the supplementary materials.

TABLE 1 Characteristics of participants in each condition at baseline.

	Imagery condition n = 27 M (SD) /N (%)	Verbal condition n = 26 M (SD) /N (%)
Age	23.48 (7.70)	22.54 (4.24)
Gender		
Female	21 (77.78%)	21 (80.77%)
Male	6 (22.22%)	5 (19.23%)
DARS	4.04 (0.52)	4.12 (0.46)
SHAPS	2.22 (2.08)	2.35 (2.28)
BDI	14.70 (6.86)	12.96 (7.69)
PANAS-P	2.88 (0.72)	2.81 (0.48)
PANAS-N	2.24 (0.65)	2.06 (0.68)
PIT-P	3.48 (0.69)	3.68 (0.59)
PIT-N	3.33 (0.77)	2.76 (0.82)

DARS = Dimensional Anhedonia Rating Scale; SHAPS = Snaith-Hamilton Anticipated Pleasure Scale; BDI-II = Beck Depression Inventory-II; PANAS-P = Positive Subscale of the Positive and Negative Affect Schedules; PANAS-N = Negative Subscale of the Positive and Negative Affect Schedules; PIT-P = Positive Items from the Prospective Imagery Test; PIT-N = Negative Items from the Prospective Imagery Test.

Seven participants (2 in the imagery condition, 5 in the verbal condition) did not provide follow-up data.

Clinical outcome measures

For the DARS, there was both a significant effect of time, $t(52.09) = 2.69$, $p = .010$, $d = 0.74$ [0.18, 1.29], and a significant interaction of time x condition, $t(52.26) = 2.25$, $p = .029$, $d = 0.60$ [0.05,1.17], which when broken down by condition indicated a significant increase in DARS scores within the imagery condition, $t(54.08) = 2.64$, $p = .011$, $d = 0.28$ [0.03, 0.54] but not within the verbal condition, $t(54.41) = 0.52$, $p = .61$, $d = -0.06$ [−0.25, 0.13] (see Table 2).

There were no interactions with time for most of the other clinical outcome measures, with only main effects of time (see Table 2 and Figure 1). The exception was the PANAS-N, for which there was a relatively greater reduction in the imagery compared to verbal condition from pre- to mid-training. In general, there was a consistent pattern of small effect sizes in favor of the imagery over the verbal condition, albeit with the confidence intervals including zero.

Measures of mechanisms

Due to technical problems, seven participants had missing data for the Emotional Picture Rating Task. Analyses of valence ratings showed only a main effect of valence, $t(45.00) = 7.78$, $p < .001$, $d = 2.32$ [1.56, 3.07], indicating more positive ratings for positive than neutral pictures. For arousal ratings, there was a main effect of valence, $t(45.00) = 7.82$, $p < .001$,

TABLE 2 Outcomes on questionnaire measures of anhedonia, other clinically-relevant outcomes, and potential mechanisms.

	Pre-training	Mid-training	Post-training	Follow-up
Anhedonia				
DARS				
Imagery	n = 27		n = 27	
M (SD)	4.04 (0.46)		4.18 (0.46)	
Within-group d [95% CIs]			0.28* [0.03,0.54]	
Verbal	n = 26		n = 25	
M (SD)	4.12 (0.46)		4.09 (0.46)	
Within-group d [95% CIs]			−0.06 [−0.25,0.13]	
Between-group d [95% CIs]			0.60* [0.05,1.17]	
SHAPS				
Imagery	n = 27	n = 25	n = 27	n = 25
M (SD)	2.22 (2.28)	1.92 (2.83)	1.37 (2.04)	1.40 (2.47)
Within-group d [95% CIs]		0.04 [−0.29,0.38]	0.38** [0.12,0.65]	0.35** [0.09,0.63]
Verbal	n = 26	n = 26	n = 25	n = 21
M (SD)	2.35 (2.28)	2.43 (2.83)	1.80 (2.04)	2.24 (2.47)
Within-group d [95% CIs]		−0.03 [−0.38,0.31]	0.25 [0.04,0.47]	0.09 [−0.06,0.25]
Between-group d [95% CIs]		0.09 [−0.46,0.64]	0.22 [−0.32,0.77]	0.48 [−0.10,1.08]
Other clinically-relevant outcomes				
BDI-II				
Imagery	n = 27		n = 27	n = 25
M (SD)	14.70 (7.69)		9.48 (7.27)	7.84 (7.30)
Within-group d [95% CIs]			0.78*** [0.40,1.21]	0.98*** [0.48,1.53]
Verbal	n = 26		n = 25	n = 21
M (SD)	12.96 (7.69)		9.20 (7.27)	7.81 (7.30)
Within-group d [95% CIs]			0.48** [0.23,0.75]	0.62*** [0.25,1.02]
Between-group d [95% CIs]			0.30 [−0.25,0.85]	0.29 [−0.29,0.87]
PANAS-P				
Imagery	n = 27	n = 25	n = 27	n = 25
M (SD)	2.88 (0.48)	2.84 (0.63)	3.10 (0.68)	3.06 (0.64)
Within-group d [95% CIs]		−0.04 [−0.37,0.28]	0.29* [−0.02,0.63]	0.25* [−0.08,0.59]
Verbal	n = 26	n = 26	n = 25	n = 21
M (SD)	2.81 (0.48)	2.60 (0.63)	2.86 (0.68)	2.87 (0.64)
Within-group d [95% CIs]		−0.37* [−0.70,-0.05]	0.09 [−0.22,0.41]	0.07 [−0.26,0.41]
Between-group d [95% CIs]		0.33 [−0.22,0.89]	0.30 [−0.24,0.85]	0.26 [−0.32,0.84]

(Continues)

TABLE 2 (Continued)

	Pre-training	Mid-training	Post-training	Follow-up
PANAS-N				
Imagery	n = 27	n = 25	n = 27	n = 25
M (SD)	2.24 (0.68)	1.85 (0.64)	1.82 (0.66)	1.92 (0.74)
Within-group d [95% CIs]		0.54*** [0.20,0.90]	0.60*** [0.29,0.94]	0.49*** [0.18,0.83]
Verbal	n = 26	n = 26	n = 25	n = 21
M (SD)	2.06 (0.68)	1.90 (0.64)	1.82 (0.66)	1.95 (0.74)
Within-group d [95% CIs]		0.23 [0.00,0.47]	0.36** [0.07,0.67]	0.23 [0.00,0.48]
Between-group d [95% CIs]		0.47* [−0.08,1.03]	0.33 [−0.22,0.88]	0.33 [−0.25,0.92]
Potential mechanisms				
PIT-P				
Imagery	n = 27		n = 27	
M (SD)	3.48 (0.59)		2.94 (0.98)	
Within-group d [95% CIs]			−0.60* [−1.22,-0.01]	
Verbal	n = 26		n = 25	
M (SD)	3.68 (0.59)		2.66 (0.98)	
Within-group d [95% CIs]			−1.23*** [−1.89,-0.62]	
Between-group d [95% CIs]			0.39 [−0.16,0.94]	
PIT-N				
Imagery	n = 27		n = 27	
M (SD)	3.33 (0.82)		3.70 (0.69)	
Within-group d [95% CIs]			−0.49 [−1.13,0.12]	
Verbal	n = 26		n = 25	
M (SD)	2.76 (0.82)		3.74 (0.69)	
Within-group d [95% CIs]			−1.24*** [−1.87,-0.68]	
Between-group d [95% CIs]			0.58* [0.03,1.14]	

Note. DARS = Dimensional Anhedonia Rating Scale; SHAPS = Snaith-Hamilton Anticipated Pleasure Scale; BDI-II = Beck Depression Inventory-II; PANAS-P = Positive Subscale of the Positive and Negative Affect Schedules; PANAS-N = Negative Subscale of the Positive and Negative Affect Schedules; PIT-P = Positive Items from the Prospective Imagery Test; PIT-N = Negative Items from the Prospective Imagery Test.

$d = 2.33$ [1.57, 3.08], indicating higher arousal ratings for positive relative to neutral pictures. Additionally, there was also an interaction of valence by condition, $t(45.00) = 2.56$, $p = .014$, $d = 0.76$ [0.15, 1.36]: While there was a greater level of arousal for positive relative to neutral pictures in both the imagery condition, $t(47.09) = 7.64$, $p < .001$, $d = 1.11$ [0.75, 1.47] and the verbal condition, $t(47.09) = 3.97$, $p < .001$, $d = 0.58$ [0.27, 0.88], the interaction indicates that this difference in arousal between the two types of images was relatively greater in the imagery condition (see Table 3 for means and SDs).

For the PIT-P, there was only a main effect of time, indicating reductions in vividness in both conditions. For the PIT-N, there was a relatively smaller increase in vividness in the imagery compared to verbal condition from pre- to post-training (see Table 2).

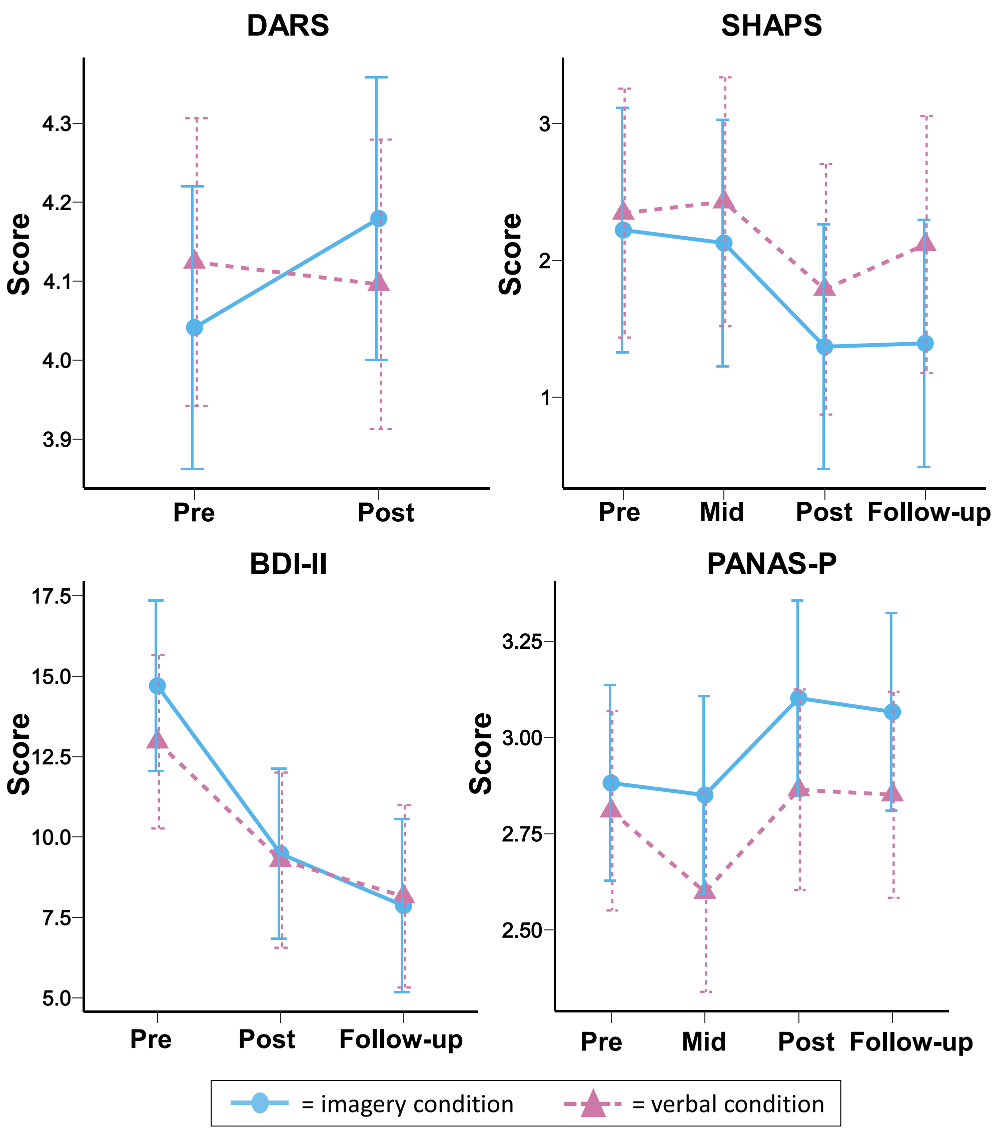

FIGURE 1 Estimated marginal means for the main outcome measures over time.Note. DARS = Dimensional Anhedonia Rating Scale; SHAPS = Snaith-Hamilton Pleasure Scale; BDI-II = Beck Depression Inventory -II; PANAS = Positive and Negative Affect Schedules – Positive scale. Pre/mid/post refer to pre-training, mid-training, and post-training. Scores shown are the estimated marginal means from the linear mixed models presented in Table 2. Error bars show 95% confidence intervals.

Due to technical problems, one participant had missing data for the Ambiguous Picture Rating Task at pre-training, two at post-training, and two at both timepoints. Analysis of the ratings showed only a main effect of picture type (trained vs. untrained), $t(145.66) = 4.30$, $p < .001$, $d = 0.71$ [0.38, 1.05], indicating more positive ratings for trained pictures across both time points, but there were no other main effects or interactions (see Table 3 for means and SDs).

TABLE 3 Ambiguous and emotional picture rating tasks.

	Imagery M (SD)	Verbal M (SD)
Ambiguous picture rating task		
Trained pictures		
Pre-training	5.97 (0.63)	5.96 (0.60)
Post-training	6.16 (0.86)	6.16 (0.75)
Untrained pictures		
Pre-training	5.44 (0.56)	5.51 (0.61)
Post-training	5.68 (0.62)	5.49 (0.59)
Emotional picture rating task		
Valence ratings		
Positive pictures	6.82 (1.04)	6.98 (1.03)
Neutral pictures	5.24 (0.70)	5.29 (0.63)
Arousal ratings		
Positive pictures	4.63 (1.25)	4.01 (1.35)
Neutral pictures	3.01 (1.28)	3.15 (1.37)

Note: Sample sizes for the Ambiguous Picture Rating Task were $n = 26$ for the imagery condition, $n = 24$ for the verbal condition at pre-training, $n = 26$ for the imagery condition, and $n = 22$ for the verbal condition at post-training. Sample sizes for the Emotional Picture Rating Task were $n = 23$ for the imagery condition and $n = 22$ for the verbal condition.

Exploratory analyses

Following the main analyses examining the between-group effects of the experimental manipulation on the clinical outcome and mechanisms measures, we carried out further exploratory analyses to investigate some of the potential mechanisms in more detail.

Effects on imagery generation on different facets of anhedonia

To further investigate the effect of the imagery-based training on different facets anhedonia, we separated the DARS into subscales representing interest/desire, anticipated enjoyment, motivation, and effort, and repeated our analyses for the subscales separately (see also Craske et al., 2023). The effect size for the time by condition interaction was greatest for the motivation subscale, $t(52.20) = 2.31$, $p = .025$, $d = 0.62$ [0.07, 1.18], followed by the interest/desire subscale, $t(52.27) = 1.65$, $p = .11$, $d = 0.44$ [−0.10, 1.00], effort, $t(52.41) = 1.37$, $p = .18$, $d = 0.37$ [−0.18, 0.92], then anticipated enjoyment, $t(52.53) = 0.87$, $p = .39$, $d = 0.21$ [−0.33, 0.76]; see Table S1 for full details.

Effects of imagery generation on pre-session ratings over the course of training

To explore the trajectory of changes in ratings made at the start of each training session during the week of training, mixed model analyses were run with rating as the dependent variable, and session number (as a continuous variable), condition, and their interaction as independent variables, and a random intercept at the participant level (see Figure S2 for a graphical display of the ratings, and Table S8 for full details of the results).

Mood ratings

For positive mood ratings over the previous day, there was a main effect of session number, $t(209.98) = 3.15$, $p = .002$, indicating a general increase in positive mood at the start of each session over the week, but no effect of condition, $t(139.69) = 0.55$, $p = .59$, and no time x condition interaction, $t(209.96) = 1.11$, $p = .27$, indicating no difference in the trajectory of these mood ratings over time between the conditions. For negative mood ratings, there was a main effect of session number, $t(209.95) = 4.63$, $p < .001$, indicating a general decrease in negative mood over the week, qualified by a time x condition interaction, $t(209.94) = 2.06$, $p = .04$, indicating that this decrease was greater in the imagery condition than in the verbal condition. There was no main effect of condition, $t(126.43) = 1.48$, $p = .14$.

Other ratings

A time x condition interaction was only found for the rating "I could look forward to various activities and events", $t(208.00) = 2.44$, $p = .016$, and the rating "I could enjoy taking part in various activities and events", $t(208.00) = 2.38$, $p = .018$, indicating a greater increase in these ratings over time in the imagery condition compared to the verbal condition. There was only a main effect of time for the rating "I was an active person and achieved my goals", $t(208.00) = 2.09$, $p = .038$, indicating an increase over time, and for the rating "Negative thoughts popped into my head", $t(208.00) = 5.03$, $p < .001$, indicating a decrease over time. For the rating "Positive thoughts popped into my head", none of the main effects or the interaction term were statistically significant. See Table S8 for full details.

Mediation analyses

To explore whether the effects of the imagery vs. verbal condition on the main outcomes (DARS, SHAPS, PANASP, BDI) could be mediated via differential effects on any of the potential mechanisms measures included in the study, we carried out mediation analyses for those mechanisms measures for which we had found differential effects of positive imagery vs. sentence generation: change in state positive mood, and emotional response to positive (vs. neutral) pictures. To do so we took the regression-based approach outlined by Kraemer et al. (2002), that is, we conducted regressions with the post-training score as the dependent variable, and as independent variables the pre-training score, training condition (re-coded as −0.5 and +0.5), and the interaction of training condition with mean change in the putative mediator (mean-centered).

State mood change as a mechanism

As participants in the imagery condition showed greater increases in state positive mood from pre to post-training sessions than participants in the verbal condition, we investigated whether these changes in state mood might be a mechanism mediating the effects of the training condition on the main outcomes (DARS, SHAPS, PANASP, BDI). In no cases was the interaction between training condition and mean-centered change in positive mood statistically significant (see Table S9 for details), i.e., these regressions did not support change in positive state mood from pre to post-training sessions as a mediator of the effect of condition on these outcomes.

Differential response to positive versus neural pictures as a mechanism

We investigated whether the differential response to positive versus neutral pictures (as indexed by arousal on the EPRT) could be a potential mediator of the effect of the imagery (versus verbal) training on the main outcomes (DARS, SHAPS, PANASP, BDI). To do this we first created a variable to reflect the differential arousal response to positive versus neutral pictures. We ran a regression with arousal ratings for positive pictures as the dependent variable and arousal ratings for neutral pictures as the independent variable and used the residuals from this regression as our index of differential response. We then ran a regression including a mean-centered version of this variable, its interaction with condition (coded −0.5 and +0.5), and pre-training score for the relevant variable as independent variables, and with post-training score as the dependent variable. For no outcome variable was the interaction term statistically significant, thus not providing support for the idea that the effect of the imagery (vs. verbal) condition on these outcome variables was via its differential effect on emotional response to positive vs. neutral pictures (or the underlying process that this reflects; see Table S10 for full details).

DISCUSSION

This study investigated whether the generation of positive mental imagery can reduce anhedonia, and in particular whether it does so more than generation of positive verbal thoughts. Mildly anhedonic participants were assigned to complete 5 sessions of a computer-based training in which they generated either positive images or positive sentences in response to ambiguous pictures with positive word captions. Participants assigned to the imagery condition showed a greater reduction in anhedonia over the one week of training than those in the verbal condition on an individually tailored measure assessing all aspects of anhedonia, the Dimensional Anhedonia Rating Scale (DARS). There were no between-group differences in changes in anhedonia as assessed by a standardized measure of anticipated pleasure, the Snaith-Hamilton Pleasure Scale (SHAPS), positive affect, or symptoms of depression more broadly, although the pattern of results was generally in the expected direction. After the end of the training week, participants in the imagery condition reported greater emotional arousal in response to viewing positive pictures (relative to neutral pictures) than participants in the verbal condition. Overall, the study's results shed light on the potential for imagery generation to have an impact on anhedonia and the mechanisms via which this may occur.

To summarize, we found partial support for our hypotheses that the generation of positive images would lead to greater reductions in anhedonia and greater increases in positive affect than generation of positive verbal thoughts. In relation to anhedonia, our hypothesis was supported by the results for the DARS but not the SHAPS. The lack of statistically significant between-group difference for the SHAPS is perhaps unsurprising in retrospect when considered that it asks only about anticipated pleasure, which was the subscale for the DARS showing the least difference in change between the two groups. Further, the use of standardized (rather than idiosyncratic) items may have reduced the sensitivity of the SHAPS to detect change, especially in an only mildly anhedonic sample. Generally, however, the pattern of change on the SHAPS was in the hypothesized direction with a medium between-group effect size at follow-up ($d = 0.48$) and it may be that with a larger sample, the between-group comparison would reach statistical significance. Further support for the suggestion that generating positive images led to greater improvements in at least some aspects of anhedonia than generating positive verbal thoughts comes from exploratory analyses of ratings made by participants at the start of each

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training session. Participants' endorsements of the statements "I was able to look forward to different activities and events" and "I was able to enjoy different activities and events" (in relation to the past day) increased at a greater rate over the training week in the imagery condition compared to the verbal condition.

In relation to positive affect, completion of the imagery training sessions was associated with greater immediate increases in state positive affect than completion of the verbal training sessions, in line with previous experimental work (e.g., Holmes, Mathews, et al., 2008). However, this did not translate to greater increases in positive affect experienced in daily life over the course of the training week or follow-up period. This finding of a greater effect of the imagery CBM on anhedonia than on general positive affect in daily life fits with preliminary findings from other studies (Bibi et al., 2020; Westermann et al., 2021). These results are consistent with the suggestion that the mechanism via which the imagery CBM leads to reductions in anhedonia is not via increased experience of positive affect (which had been suggested as one possibility, e.g. Blackwell et al., 2018). Convergent evidence comes from several exploratory analyses. Exploratory mediation analyses did not provide support for the idea that changes in state positive affect during training sessions mediated the between-group difference in anhedonia outcomes. Further, exploratory analyses of the ratings of mood for the past day made at the start of each session did not indicate a greater increase in positive affect over time in the imagery condition compared to the verbal condition.

Interestingly, there was no between-group difference in reduction in overall symptoms of depression, with participants in both groups showing improvements from pre-training to post-training and follow-up. This supports the idea that the effect of imagery on anhedonia as measured by the DARS was a specific, relatively direct, effect rather than caused by general improvements in depressive symptoms, and fits with similar patterns of results from other studies (Bibi et al., 2020; Blackwell et al., 2015, 2023; Westermann et al., 2021). It is also interesting to note that while participants in the verbal condition did show reductions in symptoms of depression, they showed no change in anhedonia or positive affect (except briefly from pre to mid-training), consistent with these being relatively challenging targets for treatment even when depression symptoms in general are reduced (e.g., Alsayednasser et al., 2022; Dunn et al., 2020).

The results for the other measures also provide further insights into the potential mechanisms of the training. There was no difference between the conditions in changes in positive imagery vividness (as measured via the prospective imagery test). In fact, participants in both conditions showed a decrease in vividness ratings, which is unexpected and inconsistent with the pattern of changes across the other measures and with results from other similar studies. However, it is important to note that there was no counterbalancing of the order of the PIT version, meaning that only the between-group effects can be interpreted with confidence, as the main effects of time may simply reflect differences between the two PIT versions used within this sample. There was a between-group difference in change in negative imagery vividness, with participants in the verbal condition showing an increase in vividness while participants in the imagery condition showed no change. While this could be interpreted as an effect in favor of the imagery condition, we had no particular hypothesis about effects on negative imagery vividness (only positive imagery vividness) and hence this result is difficult to interpret and should be treated with caution. There was no effect of the training on ratings for ambiguous pictures (used as a measure of interpretation bias in experimental studies; Holmes, Coughtrey, & Connor, 2008; Pictet et al., 2011). Together, these results do not support the idea that the effect of positive mental imagery generation on anhedonia is via changes in positive imagery vividness or interpretation of ambiguous scenes. However, at post-training, participants in the imagery condition reported higher levels of emotional arousal when viewing positive (relative to neutral) photographs than participants in the verbal condition. This can be explained with reference to Lang's (1979) bioinformational theory of mental imagery, specifically that affective responses to photographs of scenes and people can be driven by retrieval of imagery-rich representations from autobiographical memory, triggering emotional response systems. Participants in the imagery condition had practiced generating emotional imagery in response to ambiguous pictures in the training and therefore may have more readily retrieved emotional imagery in response to viewing positive pictures in the lab-based task, leading to more emotional arousal. This finding and explanation are also consistent with the results of Wilson et al. (2017), who found that participants who were more able to generate vivid positive imagery experienced greater positive emotional responses when viewing positive soothing pictures. However, given that this is a post-hoc explanation for a result found on one of several mechanisms-related measures for which exact hypotheses were not specified, the statistically significant result here could reflect a false-positive and these results should be treated with caution pending further follow-up work or replication. Further, in exploratory mediation analyses, we found no evidence that the effect of the imagery vs. verbal condition on these emotional responses mediated the effects on anhedonia or other outcomes, and therefore this does not appear to be a mechanism for the effects of the training on clinically relevant outcomes.

Although the initial motivation for the current study came from trying to understand the relevance of imagery generation for the effects on anhedonia of one specific intervention, imagery CBM, the results have broader implications for understanding the potential role and effects of mental imagery within interventions aiming to target anhedonia and associated processes. For example, some studies of interventions focusing on enhancing episodic future thinking in the context of depression via imagery generation have found effects on anticipated and anticipatory pleasure (e.g., Hallford et al., 2023; Hallford, Sharma, & Austin, 2020), as well as anhedonia (Hallford et al., 2023). Other studies investigating the effect of imagining specific future activities have found increases in ratings such as anticipated pleasure, anticipated reward, and motivation (e.g., Bär et al., in press; Ji et al., 2021; Renner et al., 2019). However, few have contrasted the effects of thinking about future activities or events in imagery versus thinking about them in a comparable manner but not using imagery. One exception is the study by Ji et al. (2021), which contrasted imagery-experiential elaboration of upcoming potentially rewarding activities to verbal-reasoning elaboration or scheduling only. Participants in the imagery-experiential elaboration condition reported greater increases in both anticipatory pleasure, anticipated pleasure, and self-reported motivation compared to those in the scheduling only condition. However, only the increases in anticipatory pleasure, but not anticipated pleasure or motivation, were greater than those experienced by participants in the verbal reasoning condition. Similarly, in a single-session experimental study, Bär et al. (2023) found that imagining engaging in rewarding activities led to greater self-rated anticipatory reward, but not anticipated reward or motivation, compared to a verbal control condition. The relative lack of imagery vs. verbal processing on anticipated reward in these studies is consistent with the relatively small and non-significant between-group differences in the current study for the SHAPS (measuring anticipated pleasure) and the enjoyment subscale of the DARS and perhaps suggests that imagery generation has relatively less importance for changing this component of anhedonia.

The finding in the current study that the motivation subscale of the DARS was the one showing the greatest relative improvement in the imagery condition compared to the verbal condition is not consistent with the findings of Ji et al. (2021) or Bär et al. (2023) outlined above.

Although this result was exploratory and must be interpreted with caution, one possibility is that the effects of positive imagery generation vs. verbal thinking on motivation emerge over time (e.g. via changes in the accessibility of affect-laden reward representations), rather than necessarily being an immediate effect "in the moment". While the current study did not find evidence for increases in state positive affect during training sessions to be a mediator of the effects on anhedonia, this does not necessarily mean that the immediate effect of positive imagery generation on positive affect is unimportant in the context of anhedonia. For example, results from some experimental studies have suggested that the positive emotional impact of imagining potentially enjoyable or otherwise rewarding activities plays an important role in increasing motivation (e.g., Heise et al., 2022; Ji et al., 2021). Further, imagery may be a particularly useful way to intensify the positive emotion from potential or actual positive events in the context of anhedonia via promoting experiential processing and thus blocking potentially dampening cognitions (Sandman & Craske, 2024). Taking this into account with the results from the current study, while the positive affect associated with positive imagery generation may not directly lead to changes in anhedonia, the process of generating and experiencing this positive affect may be crucial in effecting changes in important cognitive and emotional processes. Overall, the results of the current study support the emphasis on imagery generation in interventions such as those mentioned above, or in more complex multi-component treatments (e.g., Craske et al., 2023; Dunn et al., 2023) aiming to target anhedonia, while also shedding light on those aspects of anhedonia for which imagery generation may be most beneficial.

Limitations of the study include the fact that the target sample size was not reached and the study was potentially underpowered to find effects on all outcome measures. Our originally planned sample size would have provided 80% power to find moderate-to-large between-group effect sizes (Cohen's $d = 0.65$) at $\alpha < .05$. Our achieved sample size gave us 60% power for such an effect size, and 80% power only to find large (Cohen's $d = 0.8$) between-group effect sizes. Further, due to difficulties in recruiting a more severely anhedonic sample, the final sample of participants was only mildly anhedonic, potentially limiting the amount of change in anhedonia or positive affect possible and thus our sensitivity to detect between-group differences. However, the relative size of the effects on the different outcome measures is still informative in indicating the relative importance of the experimental manipulation for these different outcomes, and this in turn sheds light upon potential mechanisms. The study was also not pre-registered, and although it was conceived as an experimental study with an exploratory interest in mechanisms, it could also be classed as a clinical trial and thus require pre-registration on a clinical trials registry. This would include pre-specification of a primary outcome, as the inclusion of multiple outcome measures as in the current study increases the risk of obtaining a false-positive result for one by chance alone. From this perspective, the statistically significant between-group difference in changes in the DARS could reflect a false positive. However, the overall coherent pattern of results (including those from the pre-session ratings) can increase our confidence that participants in the imagery condition did in fact experience greater improvements in at least some aspects of anhedonia than participants in the verbal condition over the course of the training. Finally, it would be preferable in future studies to include anhedonia-relevant measures that were not reliant on self-report. For example, it would be interesting to supplement the emotional picture rating task with psychophysiological measurement (e.g., as used by Craske et al., 2023) and examine whether the effects on self-report arousal were also detectable at a physiological level.

In addition to the above suggestions, the results of the current study also open up a number of interesting future directions for research. In the current study, we investigated mechanisms via our experimental manipulation, that is, examining the effects of the generation of positive imagery by comparing this to the generation of positive verbal thoughts, and then including a range of both clinical and mechanisms-relevant outcome measures. However, in future studies, it would be useful to investigate the mechanisms via which generation of positive imagery could have an impact on anhedonia more formally, for example via examining the time-course of the effect of positive imagery generation on putative mechanisms, as well as on the different facets of anhedonia captured by the DARS (interest/desire, anticipated pleasure, effort, motivation), behavioral activation, and broader symptoms of depression at a more fine-grained temporal level and with a more complex analytic approach. Approaches like Experience Sampling Methods (ESM), which have already shed some light on the phenomenology of and associations between anhedonia, positive affect, motivation, and behavior in the context of depression (e.g., Bär et al., in press; Heininga et al., 2017, 2019), may be particularly useful here. This could help elucidate underlying mechanisms including the temporal order of effects on these different components of anhedonia, and on depression more broadly. A further potential mechanism of the effects of repeated positive imagery generation on anhedonia that would be useful to investigate in future work is involuntary (episodic) retrieval of the images generated during training sessions during everyday life. This suggestion comes from anecdotal reports from participants with depression in clinical studies using training schedules including the picture-word paradigm (e.g., Blackwell & Holmes, 2017). The possibility of inducing involuntary mental imagery using the picture-word paradigm has recently been explored in experimental lab-based research (Bagheri, Woud, Oglou, et al., in press), and here ESM might also provide a particularly useful method to investigate this phenomenon more precisely in daily life. Further, participants could potentially provide their own photographs of scenes from their everyday living environments to increase the likelihood of the positive images generated being subsequently experienced involuntarily (Bagheri, Woud, Simon, et al., in press). From a clinical perspective, incorporating an ESM measurement schedule could also provide the opportunity to add interventional prompts, for example, to retrieve or generate new positive images at various points throughout the day (see e.g., Bär et al., in press; Marciniak et al., in press) in order to enhance transfer to daily life.

Overall, the current study provides support for the suggestion that the generation of positive imagery has greater potential to reduce anhedonia than the generation of positive thoughts that are not imagery-based (e.g., verbal). This is consistent with the theoretical importance of imagery in the anticipation of future events as a driver of interest or desires to engage in the activities and thus motivation (Renner et al., 2019). Further, it supports the role of positive imagery as a means to target anhedonia in clinical interventions, whether this is via simple training interventions (e.g., Blackwell et al., 2023; Hallford et al., 2023) or as part of more complex treatments (e.g., Craske et al., 2019, 2023). Further work optimizing how positive imagery can be best applied to reduce anhedonia could bring significant clinical benefits in tackling this challenging symptom of depression.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known conflicts of interest.

DATA AVAILABILITY STATEMENT

Data, analysis scripts, and materials are available online (https://osf.io/tzyx8/).

ETHICS STATEMENT

The study was approved by the Ethics Committee of the Faculty of Psychology, Ruhr-Universität Bochum (approval no. 329). Written informed consent was obtained from all participants.

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ENDNOTES

[1] At the start of the study more stringent criteria of ≥ 2 on the SHAPS and < 57 on the PANAS-P were used, but due to difficulty finding participants who met these criteria and slow recruitment the criteria were modified to be more lenient. The original SHAPS cut-off was based on the recommendation of Snaith et al. (1995) that scores above 2 indicate abnormal levels of anhedonia, whereas the revised cut-off was taken to indicate at least some level of anhedonia. The original PANAS-P cut-off was estimated to be > 1 SD below the mean of the published validation data of Watson and Clark (1994), whereas the revised cut-off was based on the mean of this data.

[2] We additionally included the 3 positive items that form part of the 10-item standard positive scale but are not in the extended 21-item version, but did not include these in scoring.

[3] Inclusion of this participant in either condition does not change the results reported, but as it is difficult to know how to interpret their data it was felt more accurate to exclude them from either group.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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