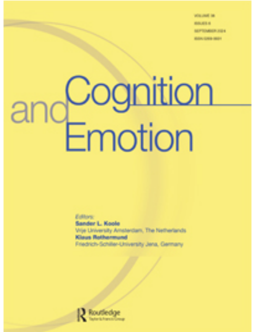

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Investigating the role of mental imagery use in the assessment of anhedonia

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ABSTRACT

Anhedonia, or a deficit in the liking, wanting, and seeking of rewards, is typically assessed via self-reported "in-the-moment" emotional and motivational responses to reward stimuli and activities. Given that mental imagery is known to evoke emotion and motivational responses, we conducted two studies to investigate the relationship between mental imagery use and self-reported anhedonia. Using a novel Reward Response Scale (adapted from the Dimensional Anhedonia Rating Scale, DARS; Rizvi et al., 2015) modified to assess deliberate and spontaneous mental imagery use, Study 1 ($N = 394$) compared uninstructed and instructed mental imagery use, and Study 2 ($N = 586$) conducted a test of replication of uninstructed mental imagery use. Results showed that greater mental imagery use was associated with higher reward response scores (Study 1 & 2), and this relationship was not moderated by whether imagery use was uninstructed or instructed (Study 1). Importantly, mental imagery use moderated the convergence between reward response and depression scale measures of anhedonia, with lower convergence for those reporting higher mental imagery use (Study 1 & 2). Results suggest that higher spontaneous mental imagery use may increase self-reported reward response and reduce the convergence between reward response scale and depression questionnaire measures of anhedonia. [199 / 200 words]

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Anhedonia; reward response; depression; mental imagery

Anhedonia is defined as the diminished capacity to experience pleasure or a loss of interest and engagement in previously pleasurable activities (DSM-V; American Psychiatric Association, 2013). Anhedonia is one of two core components of major depression and is also associated with other psychiatric conditions such as schizophrenia, anxiety, and substance abuse (DSM-V; American Psychiatric Association, 2013). Currently poorly treated, there is growing research and treatment innovation targeting anhedonia in the treatment of depression (Dunn et al., 2023; Meuret et al., 2022; Westermann et al., 2021). Anhedonia in clinical research and practice is often assessed via questionnaires that elicit one's self-reported "in-the-moment" reward response to various reward activities. While valid and accurate assessment of anhedonia is crucial to anhedonia research and treatment, factors that influence responses on anhedonia instruments have received little empirical scrutiny.

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Earlier reward response scales, such as the Snaith – Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995) tended to exclusively assess hedonic response to reward (i.e. liking), e.g. I would enjoy a warm bath or refreshing shower). More recent research into the neurobiology of anhedonia has shown that anhedonia is linked to disruptions across several distinct components of reward processing, including reward valuation, anticipation, and motivation (Der-Avakian & Markou, 2012; Kieslich et al., 2022; Rizvi et al., 2016). As such, contemporary reward response instruments, such as the Dimensional Anhedonia Rating Scale (DARS; Rizvi et al., 2015), are designed to assess multiple components of the reward response, including consummatory pleasure (liking), anticipatory pleasure (wanting), and motivation to expend effort (seeking). Like earlier instruments, the DARS also asks participants to report their "in-the-moment" reward response, i.e. hypothetically how they would respond to the reward stimulus or situation if they were experiencing it "right now".

One cognitive factor known to influence one's "in-the-moment" reward response is mental imagery. Mental imagery is defined as internal perceptual experiences in the absence of external sensory input, commonly referred to as seeing in the "mind's eye," hearing in the "mind's ear" and so on (Kosslyn et al., 2001). Due to the substantial overlap between mental imagery and perception (Dijkstra et al., 2019; Kosslyn et al., 2001; Pearson & Kosslyn, 2015), imagery-based representations of emotional events can enable individuals to *pre-experience* possible future situations and evoke emotional and motivational responding in an *as-if-real* manner (Bradley et al., 2023; Grush, 2004; Lang, 1979; Moulton & Kosslyn, 2009). As such, imagery-based mental representations of emotional events can evoke powerful state emotional responses (Dawes et al., 2022; Fiorito & Simons, 1994; Wicken et al., 2021), and more so than purely verbal-linguistic mental representations (Holmes et al., 2008; Holmes & Mathews, 2005; Mathews et al., 2013). In relation to reward processing, mental simulation of reward consumption has been shown to drive craving responses in relation to food, alcohol, and other substances (Kavanagh et al., 2005; May et al., 2015). Further, imagining oneself engaging in rewarding activities has been found to result in greater increases in anticipated pleasure and self-reported motivation than reasoning about the reasons why one should engage in reward activities (Ji et al., 2021).

Despite the known impact of mental imagery-based mental simulation on emotion and motivation, the influence of mental imagery generation during reward questionnaire completion on self-reporting of "in-the-moment" reward response have not been investigated. Based on these known properties, it is plausible to expect that individuals who vividly imagine engaging in reward activities would report higher levels of "in-the-moment" liking, wanting, and motivation to engage in such activities than individuals who do not vividly imagine activity engagement. The capacity to mentally simulate hypothetical events in order to predict what is likely to happen in the future and how one is likely to feel is widely theorised to be adaptive for survival (Atance & O'Neill, 2001; Bulley & Irish, 2018; Schacter et al., 2008; Wilson & Gilbert, 2005). Thus, it is likely that, even when not instructed to use mental imagery, individuals may spontaneously do so when asked to report how one would respond to a reward activity "in-the-moment", so as to derive judgments of what their reward response would be if it was happening right now.

In addition to reward response questionnaires, anhedonia as a symptom of depression is also assessed within depression questionnaires that index the lack of reward responses over a previous period alongside other symptoms of depression. For example, widely used depression scales such as the Beck Depression Inventory-II (Beck et al., 1996) and the Depression, Anxiety, and Stress Scale (Lovibond & Lovibond, 1996) both contain anhedonia items that ask participants to retrospectively estimate the frequency with which they had experienced deficits in reward responses in daily life. The BDI-II contains three items assessing loss of pleasure (item #4), loss of interest (item #12), and loss of interest in sex (item #21) over the past two weeks, and the DASS-21 depression subscale contains three items assessing absence of pleasure (item #3), motivation (item #5), and excitement (#16).

Given that reward response questionnaires assess "in-the-moment" reward responses, and anhedonia items in depression questionnaires assess the absence of reward responses over the past week(s), one we would expect that the two measures should be strongly and negatively correlated. However, previous research found such correlations to range from small to moderate. For example, Leventhal and colleagues (Leventhal et al., 2006) found that the correlation between SHAPS score (Snaith et al., 1995) and

Fawcett-Clark Pleasure Capacity Scale score (FCPS; Fawcett et al., 1983) and anhedonia subscale score on the BDI-II were $r = -.33$ and $r = -.28$, respectively. For multidimensional reward response instruments such as the DARS (Rizvi et al., 2015), data from a positive imagery training study for depression (Blackwell et al., 2023) showed only moderate associations ($r = 0.38$ between DARS score and QIDS anhedonia item at baseline in a sample of $N = 187$ dysphoric participants, and $r = 0.57$ at post-training, $N = 102$). While the above evidence is by no means a systematic or exhaustive review of studies on this topic, and undoubtedly there are study-level differences that would have contributed to variation across studies, our preliminary review nevertheless indicates that the degree of convergence between reward response questionnaire and depression questionnaire measures of anhedonia varies across studies and is in the small to moderate range.

If mental imagery use during reward response questionnaire completion influences the self-reporting of hypothetical "in-the-moment" reward responses, it is possible that variation in such mental imagery use also relates to variation in the convergence between reward response and depression questionnaire measures of anhedonia. That is, while individuals may generate mental imagery when estimating "in-the-moment" reward responses to their favourite activities (when completing reward response questionnaires), mental imagery generation may be less relied upon when individuals are retrospectively estimating how frequently they had experienced reward responses over the past week or two (when completing depression questionnaire anhedonia items). Thus, it is possible that greater capacity to use mental imagery may correspond to higher estimated "in-the-moment" reward responses, but not the reported frequency of the absence/loss of reward responses over a past time-period, and thereby contributing to discrepancies between these two kinds of measures.

The present research

Two studies were conducted with the aim of investigating the use of mental imagery in the assessment of reward response and anhedonia in the context of depression. Two main hypotheses were tested. First, it was hypothesised that participants instructed to imagine engaging in the activities would provide higher ratings of in-the-moment reward response (liking, wanting, and seeking) as they would experience higher levels of mental imagery use than those participants instructed to think about how frequently they engage in the activities and those provided with no instruction. This hypothesis generated the prediction that within the imagery instructions condition, participants who reported generating more vivid and emotional images would provide higher reward response ratings[1] Relatedly, it was assumed that the degree of mental imagery use on the reward response questionnaire would not be related to anhedonia scores on a depression questionnaire, which reflect retrospective estimations of the frequency of anhedonia symptoms.

Second, given the above hypothesis that greater mental imagery use during reward response questionnaire completion would be associated with higher self-reported reward response (i.e. lower anhedonia), it was hypothesised that the degree of association between reward response scale and depression questionnaire measures of anhedonia would be dependent on the level of mental imagery use during reward response questionnaire completion. Specifically, the magnitude of the (negative) relationship between the two scores would be smaller in individuals reporting higher mental imagery use relative to those reporting lower mental imagery use.

To test the above hypotheses, the Dimensional Anhedonia Rating Scale (DARS; Rizvi et al., 2015) scale was adapted to manipulate (Study 1) and assess (Study 1 & 2) mental imagery use during reward response scale completion. Study 1 was an experimental study (pre-registered at https://osf.io/qpfzh/ [2]) designed to induce variation in mental imagery use via three instruction conditions. Participants were either instructed to deliberately imagine themselves engaging in target reward activities before rating their "in-the-moment" reward response (instructed imagery generation condition) or to estimate how often they engaged in the activities before rating their "in-the-moment" reward response (instructed frequency estimation condition). Study 1 also aimed to examine the extent to which individuals tended to spontaneously imagine themselves engaging in target reward activities when completing reward response questionnaires. Therefore, the study included a third condition that represented the naturalistic conditions under which participants would normally complete the reward response questionnaire (no instruction condition). While the instructed imagery generation condition was intended to promote imagery use, the instructed frequency estimation condition was intended to dampen imagery use relative to the instructed imagery condition. This design enabled the study to additionally explore whether either instruction would result in higher or lower levels of self-reported mental imagery use than the naturalistic conditions. Study 2 conducted a test of replication of Study 1's findings under naturalistic conditions, comprising Study 1's no instruction condition only. Across both studies, all participants rated the extent to which they had engaged in mental imagery while completing the reward response scale, enabling the assessment of actual mental imagery use (irrespective of instruction type).

Study 1

Method

Design

Study 1 adopted an experimental design with three between-group Instruction Conditions (Imagine; Estimate Frequency; No Instruction). The study was conducted online and was embedded within the baseline assessment of a larger longitudinal study investigating separate research questions not described here. Data was collected between November 2017 and February 2019. The measures and procedures described below are therefore a subset of a broader set of measures completed at this baseline assessment.

Participants

The study comprised a total of $N = 394$ participants from both English and German-speaking backgrounds, recruited via poster/flyer/email/online advertisements at Ruhr University Bochum and neighbouring universities, as well as from online forums and social media (Facebook, Twitter). Of the $N = 1,093$ individuals recruited online, $N = 394$ completed the study, with $n = 162$ (41.11%) completing the English language version and $n = 232$ (58.89%) in German. The sample size for this study was determined by the longitudinal component, with recruitment stopping after 200 participants had completed the last longitudinal assessment. Study inclusion criteria were (a) aged 18 or over; (b) willing to complete the study procedures including take the survey repeatedly over a period of three weeks (the longitudinal part of the study); and sufficient knowledge of German or English to understand the study information and complete the survey. Participants received one entry into a prize-draw to win one of 8 €20 Amazon vouchers for completion of this cross-sectional part of the study (completion of further longitudinal assessments resulted in further entries to the prize draw and possible course credit). All participants consented to participating in the study. Ethical approval was granted from the ethics committee of the Faculty of Psychology, Ruhr University Bochum (Nr. 413).

Materials

Questionnaires

Anhedonia and non-anhedonia depression symptoms. Anhedonia and non-anhedonia depression symptoms were assessed using the Depression subscale of the 21-item Depression, Anxiety, and Stress Scale (DASS-21; Lovibond & Lovibond, 1996). The Depression subscale contains seven-items that ask about the frequency with which individuals experienced a range of depression symptoms in the previous week, from "0 – Did not apply to me at all" to "3 – Applied to me very much, or most of the time". Three items were extracted as a retrospective assessment of anhedonia symptom frequency: Item 3: "I couldn't seem to experience any positive feeling at al"; Item 5: "I found it difficult to work up the initiative to do things"; and Item 16: "I was unable to become enthusiastic about anything". The non-anhedonia items of the depression subscale assessed sad mood, hopelessness, worthlessness, and meaninglessness. The anhedonia items of the subscale were scored separately from the non-anhedonia items of the subscale, and both were used for hypothesis testing. Anhedonia scores ranged from 0 to 9, where a higher score indicated more frequent anhedonia symptoms. Internal consistency of the DASS-21 depression subscale was good: full subscale Cronbach's $\alpha = .881$; anhedonia items of the subscale: Cronbach's $\alpha = .737$; non-anhedonia items of the subscale: Cronbach's $\alpha = .837$.

Tasks

Instructed Reward Response Scale (I-RRS). To compare mental imagery use during reward response scale completion under instructed vs. uninstructed conditions, a modified version of the Dimensional Anhedonia Rating Scale (DARS; Rizvi et al., 2015) was developed (see Supplementary Materials Appendix 1 for the task as it appeared in the Qualtrics survey). Internal reliability for the I-RRS task was good, overall sample Cronbach's α = .865 (No Instruction condition Cronbach's α = .875; Imagine condition Cronbach's α = .874; Estimate Frequency condition Cronbach's α = .843).

The I-RRS task comprised three stages:

1. *Activity nomination:* Similar to the DARS [3], all participants were first asked to nominate six reward activities (two for each of three activity types): (a) Pastime/Hobbies (defined to participants as "pastimes/hobbies that are NOT primarily social"), (b) Social (defined to participants as "e.g. meeting friends for a drink, watching a film with your partner"), and (c) Sensory Experiences (defined participants as "e.g. listening to music, watching a sunset, smell, or taste of favourite food or drink").
2. *Instruction:* Different to the DARS, in the I-RRS task participants were randomised to one of three experimental conditions:
   (a) *Imagine* condition: participants were instructed to "Please take a few moments to imagine engaging in these activities before answering the questions below".
   (b) *Estimate Frequency* condition: participants were asked to "Please take a few moments to think about how frequently you engage in these activities at the moment before answering the questions below".
   (c) *No Instruction* condition: participants completed step 1 (*Activity nomination*) and received no further instructions before completing the next step of the task.
3. *Reward response rating.* After receiving instructions, participants were asked to rate their level of reward response for the two nominated activities on three indices: (a) Wanting: "I feel interested in engaging in these activities"; (b) Liking: "Doing these activities would feel enjoyable to me"; and (c) Seeking: "I would take steps or look for opportunities to engage in these activities". Each question was rated on a 5-point Likert scale ranging from "1 - Not at all" to "5 - Very much".[4]
4. *Mental imagery use (quantity) assessment.*. At the end of the task, all participants were asked to rate their experience of mental imagery during the task, in response to the question "While answering the questions about all the different activities/ experiences, to what extent did you imagine yourself engaging in the activities/experiences?". Responses were provided on a 5-point Likert scale ranging from "1 - Not at all" to "5 - All of the time".

Participants in the *Imagine* condition also answered three extra questions about the quality of the imagery: (a) *anticipatory pleasure* ("I felt a sense of enjoyment while imagining the activities/ experiences"); (b) *vividness* ("The images were as vivid as reality"); and (c) *detail* ("The scenes in my mind's eye were as detailed as scenes in reality"), all rated on a scale from 1 (*Not at all*) to 5 (*Very much*). A composite index score of *Imagery Quality* was created by averaging the *vividness* and *detail* ratings, included as an exploratory variable in the study. To control for the effect of completing three additional questions, participants in the *Estimate Frequency* condition also answered three questions at the same point in the study, where they rated the frequency with which they engaged in the hobby, social, and sensory activities, on a scale with the options: "Daily", "Weekly", "Monthly", "Yearly", to "Less frequently than yearly".

Procedure

After selecting language choice (English or German), participants read information about the study and provided informed consent via the study website. At this point they were randomised to Instruction Condition. Randomisation was executed via the inbuilt randomisation process in Qualtrics, which uses a Mersenne Twister algorithm, with the constraint that an equal number of people should be allocated to each condition. Participants then completed demographics questionnaires, followed by the I-RRS and the DASS-21 questionnaire. Additional measures were also completed after these as part of a longitudinal study, which are not relevant to the questions at hand and are not reported further in this paper (see Supplementary Materials Appendix 2 for more information). At the end of the session, participants entered their email address to receive prompt emails about subsequent assessments for the broader longitudinal study. Debriefing information was provided at the end of the final longitudinal assessment.

Openness and transparency statement

Study 1 was preregistered via uploading the study protocol to the Open Science Framework prior to starting (https://osf.io/qpfzh/). Tasks, data, and code for reproducing the analyses are available at https://osf.io/qpfzh/. We describe in the main manuscript how the sample size was determined and all data exclusions and manipulations.

Results

Participant characteristics

All participants who met the study inclusion criteria and completed the testing session were included in the analysis, resulting in a final sample of $N = 394$ participants, with $n = 128$ randomised to the Imagine condition, $n = 134$ to the No Instruction condition, and $n = 132$ to the Estimate Frequency condition.

As shown in Table 1, participants across the three Instruction Conditions did not differ in age, gender, nationality, education, language group, employment, or baseline DASS-21 depression or anxiety score.

Effect of instruction condition on imagery use during the I-RRS

To assess whether instruction condition resulted in differences in degree of mental imagery use during the I-RRS task ("to what extent did you imagine yourself engaging in the activities/experiences"), Imagery Use (Quantity) ratings were compared across the three Instruction Conditions (Imagine; Estimate Frequency; No Instruction).[5] On average, participants reported mental imagery use to be between "3 – Sometimes" to "4 – Most of the time", $M = 3.909$, $SD = .901$ (Imagine condition: $M = 3.805$, $SD = .905$; Estimate Frequency condition: $M = 3.889$, $SD = .933$; No instruction condition: $M = 4.037$, $SD = .853$). A one-way ANOVA (Kruskal–Wallis) on Imagery Use scores found no evidence of differences between the three Instruction Conditions, χ^2 (2) = 4.207, $p = .122$, $\varepsilon^2 = 0.011$, all pairwise comparisons $W \leq | 2.865 |$, $p \geq 0.106$. Results therefore indicate that, when completing the I-RRS, mental imagery use level under naturalistic uninstructed conditions was similar to that of instructed imagery generation as well as instructed frequency estimation. Violin plots of score distributions across the three instruction condition groups are shown in Appendix 3 Supplementary Figure 1.

Effect of instruction condition on I-RRS reward response score

A 3 × 3 × 3 mixed-ANOVA was conducted, with I-RRS score as the outcome variable, Instruction Condition (Imagine, Estimate Frequency, No Instruction) as the between-groups factor, and Reward Activity Type (Hobby, Social, Sensory) and Reward Response Domain (Liking, Wanting, Seeking) as within-subject factors.[6] Descriptive statistics for Reward Response Score by Activity Type (Hobby, Social, Sensory) and Response Domain (Liking, Wanting, Seeking) and Instruction Condition (Imagine, Estimate Frequency, No Instruction) are presented in Table 2. Results revealed a main effect of Reward Activity Type, F (2, 782) = 14.651, $p < 0.001$, $\eta^2p = .036$, where Sensory activities had higher reward response ratings than both Hobby and Social activities (all t (391) ≥ 4.651, all $p_{\text{Tukey}} < .001$), with no difference in reward response ratings between Hobby and Social activities ($t(391) = .045$, $p_{\text{Tukey}} = .999$). A main effect of Reward Response Domain was also found, F (2, 782) = 131.846, $p < 0.001$, $\eta^2p = .252$, where Wanting ratings were higher than Liking ($t(391) = 9.646$, $p_{\text{Tukey}} < .001$) and Seeking ($t(391) = 14.621$, $p_{\text{Tukey}} < .001$) ratings, and Liking ratings were higher than Seeking ratings ($t(391) = 8.148$, $p_{\text{Tukey}} < .001$). Importantly, no main effect of Instruction Condition was found, F (2, 391) = .440, $p = .644$, $\eta^2p = .002$, and there were no significant two-way or three-way interactions involving Instruction Condition with Reward Response Activity Type and Activity Domain, all F (4, 782) ≤ 2.208, all $p \geq .066$, all $\eta^2p \leq .011$. Since the relationship between Instruction Condition and I-RRS scores did not differ as a function of I-RRS task Activity Type and Rating Domain, subsequent analyses used total I-RRS for parsimony.

Results thus indicate that variation in self-reported liking, wanting, and seeking of reward activities, as measured on the I-RRS, was not moderated by Instruction Condition.

Descriptive statistics and zero-order association between study variables

Descriptive statistics, and zero-order correlations for I-RRS score, Depression Anhedonia and Non-anhedonia symptoms, Mental Imagery (Quantity and Quality) and Anticipatory Pleasure ratings are reported in Appendix 3 Supplementary Tables 1 and 2, respectively. Consistent with H1, while higher Imagery Quantity and Quality were moderately associated with higher I-RRS scores, Imagery Quantity was not associated with anhedonia or non-anhedonia depression scores. Small negative associations were found between Imagery Quality and anhedonia and non-anhedonia depression scores. While a moderate to strong positive association between Anticipatory Pleasure and I-RRS scores was found, small negative correlations were found between Anticipatory Pleasure and anhedonia and non-anhedonia scores.

Table 1. Study 1 Participant demographic and baseline characteristics.

	Instruction condition															
	Imagine $n = 128$					No instruction $n = 134$					Estimate frequency $n = 132$					
Variable	*M / n*	*Median /%*	*SD*	*Min*	*Max*	*M / n*	*Median /%*	*SD*	*Min*	*Max*	*M / n*	*Median /%*	*SD*	*Min*	*Max*	*Test*
Age	29.867	24	14.382	18	73	31.142	25	14.547	18	74	30.508	26	13.24	18	70	$X^2 = 1.600$
Gender (% Female)	97	75.80%				106	79.10%				94	71.20%				$X^2 = 3.710$
Nationality	128					134					132					$X^2 = 2.451$
British	5	4%				2	1%				3	2%				
German	75	59%				73	54%				74	56%				
Other	48	38%				59	44%				55	42%				
Education	128					134					132					$X^2 = 14.208$
Bachelor's degree	29	23%				33	25%				22	17%				
Doctorate	2	2%				6	4%				5	4%				
High School	62	48%				51	38%				50	38%				
Master's degree	12	9%				24	18%				30	23%				
None	6	5%				6	4%				6	5%				
Vocational college	17	13%				14	10%				19	14%				
Language	128					134					132					$X^2 = 0.127$
English	51	40%				56	42%				55	42%				
German	77	60%				78	58%				77	58%				
Employment	2.703	2	1.082	1	5	2.851	2	1.087	1	5	2.886	2	1.046	1	5	$X^2 = 7.880$
Employed	52	39%				33	26%				49	37%				
Retired	3	2%				7	5%				5	4%				
Self-employed	8	6%				10	8%				7	5%				
Student	65	49%				71	55%				67	50%				
Unemployed	4	3%				7	5%				6	4%				
DASS21.Anx	4.406	4	3.331	0	14	4.172	4	3.547	0	15	3.947	3	3.197	0	15	$X^2 = 1.360$
DASS21.Dep	5.672	4	4.716	0	20	4.896	4	4.159	0	20	4.439	4	3.580	0	17	$X^2 = 3.340$
Non-anhedonia items	3.648	3	2.844	0	12	3.104	3	2.532	0	12	2.826	3	2.095	0	10	$X^2 = 3.900$
Anhedonia items	2.023	1	2.175	0	9	1.791	1	1.832	0	8	1.614	1	1.785	0	7	$X^2 = 1.820$

Notes: Statistical significance markers: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Group comparisons used the X^2 test of independence for categorical variables, and non-parametric Kruskal-Wallis one-way ANOVAs for continuous variables (due to normality violation).

H1. Relationship between imagery use and I-RRS reward response score

Originally, we had planned to examine the relationship between Imagery Use and I-RRS reward responses score while completing the I-RRS under naturalistic conditions (i.e. within the no instruction group only). However, given that mental imagery use was similar across instruction conditions, the relationship between mental imagery use and I-RRS ratings was examined across the whole sample, with Instruction Condition still included as a factor to explore whether instruction type moderated the nature of the relationship between Imagery Use and I-RRS ratings. An Analysis of Covariance (ANCOVA) was conducted with I-RRS total reward response score as outcome variable and Imagery Use (Quantity) and Instruction Condition as interactive predictors. The overall model was statistically significant, F (5, 388) = 6.689, $p < .001$.There was no main effect of Instruction Condition, F (2, 388) = .060, $p = .942$, $\eta^2p = .000$. However, a main effect of Imagery Use (Quantity) was found, F (1, 388) = 29.869, $p = .001$, $\eta^2p = .071$.. This main effect was not further qualified by Instruction Condition, F (2, 388) = 1.943, $p = .145$, $\eta^2p = .010$.

Partially consistent with hypothesis 1, greater mental imagery use when completing the I-RRS task was independently associated with higher self-reported reward response, although unexpectedly the degree of mental imagery use did not differ across imagery generation instruction conditions.

H2. Imagery Use as a moderator of the relationship between I-RRS reward response score and DASS-21 anhedonia score

To explore whether Imagery Use (Quantity) moderated the congruence between I-RRS reward response score and anhedonia symptoms as measured via the DASS-21 Depression subscale, an ANCOVA was conducted with I-RRS total reward response score as outcome variable, Depression Anhedonia score and Imagery Use (Quantity) as interactive predictors, and Instruction Condition as co-variate.[7] The overall model was statistically significant, F (5, 388) = 13.524, $p < .001$. A main effect of Depression Anhedonia score was found, F (1, 388) = 22.232, $p < .001$, $\eta^2p = .054$. In addition, a main effect of Imagery Use (Quantity) was found, F (1, 388) = 26.741, $p < .001$, $\eta^2p = .064$.. Critically, these main effects were further qualified by a two-way interaction between them,

Table 2. Study 1 summary statistics for Instructed Reward Response Scale (I-RRS) ratings by Instruction Condition, Activity Type, and Response Domain.

		Instruction Condition																	
		Imagine						No instruction						Estimate Frequency					
		Enjoyment		Interest		Seek		Enjoyment		Interest		Seek		Enjoyment		Interest		Seek	
	Response domain	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Activity type	Hobby	4.453	0.822	4.305	0.901	3.945	1.037	4.44	0.741	4.172	0.906	3.993	0.992	4.394	0.707	4.258	0.913	4.03	0.819
	Sensory	4.648	0.671	4.438	0.849	4.07	1.051	4.694	0.685	4.47	0.801	4.269	0.86	4.561	0.68	4.417	0.865	4.144	0.934
	Social	4.359	0.876	4.156	0.9	3.867	1.139	4.478	0.856	4.239	0.99	4.127	1.051	4.462	0.703	4.25	0.877	4.068	0.951

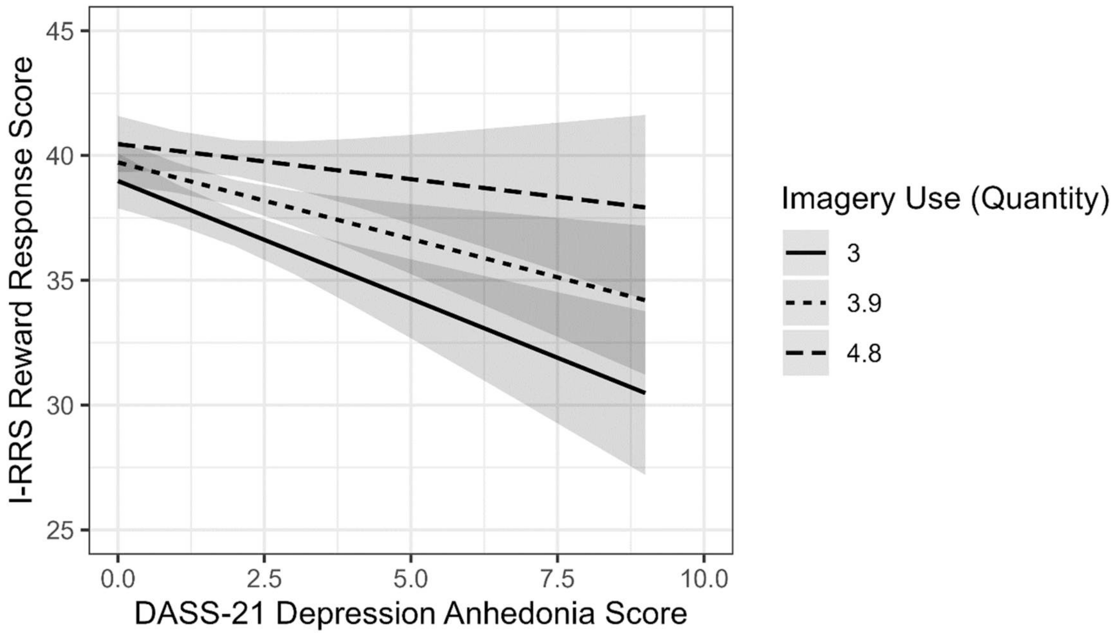

Figure 1. The relationship between DASS-21 Anhedonia Score and Instructed-RRS (I-RRS) Reward Response Score as a function of Imagery Use (Quantity) in Study 1.

F (1, 388) = 7.147, p = .008,, $\eta^2 p$ = .018.[8] As illustrated in Figure 1, post-hoc simple slopes analyses (fitted using the R package "Interactions" (Long & Long, 2019)) showed that the negative relationship between Depression Anhedonia score and I-RRS reward response score was present at average levels of Imagery Use (Quantity) at the mean (3.909/5), b = −.068, 95%C.I.[−.114:−.023], p = .003, and at lower levels of Imagery Use (Quantity) at 1 SD below the mean (3.008/5), b = −.105, 95%C.I.[−.155:−.055], p < .001, but the relationship was not statistically significant for those reporting higher Imagery Use (Quantity), at 1 SD above the mean (4.809/5), b = −.032, 95%C.I.[−.088:.024], p = .266.

As such, results indicate that the congruence between reward response measured on the I-RRS and anhedonia symptoms measured via the DASS-21 is lower for individuals reporting higher levels of mental imagery when completing the I-RRS.

Exploring the association between imagery quality, anticipatory pleasure, and reward response ratings

In addition to reporting the degree of imagery use (quantity), participants in the Imagine (instructed imagery generation) group were asked to rate the quality of their imagery (vividness and detail composite score), and anticipatory pleasure (sense of enjoyment while imagining the activity) in order to explore imagery quality as a moderator of the relationship between imagery quantity and reward response score. As shown in Appendix Supplementary Table 1, there was a medium association between Imagery Use (Quantity) and Imagery Quality, as well as strong associations between Anticipatory Pleasure and both Imagery Use (Quantity) and Imagery Quality. Consistent with H1, small to moderate associations between I-RRS score and Imagery Use (Quantity) and Imagery Quality, were found, as well as a strong association between I-RRS score and Anticipatory Pleasure score.

A hierarchical linear regression model was fitted with I-RRS Reward Response score as outcome variable, and Imagery Use (Quantity) and Imagery Quality as independent predictors in Step 1, and Anticipatory Pleasure as independent predictor in Step 2. The overall model was significant, F (3, 124) = 23.712, p < .001, R^2_{adjusted} = 34.92%. Results show that in Step 1 (R^2_{adjusted} = 18.46%), higher Imagery Quality was associated with higher I-RRS score (b = 2.517, p < .001), but not Imagery Use (Quantity; b = −.137, p = .826), when Anticipatory Pleasure was included in Step 2, neither Imagery Quality nor Imagery Use (Quantity) independently predicted I-

RRS score (all $b \leq .146$, all $p \geq .817$). Anticipatory Pleasure accounted for an additional $R^2_{\Delta} = 16.71\%$ of variance in I-RRS scores,. Based on the hierarchical regression results, an exploratory mediation analysis was conducted to assess whether the associations between Imagery Use (Quantity) and Imagery Quality and I-RRS score were mediated by Anticipatory Pleasure. As shown in Supplementary Figure 2 in Appendix 3, Imagery Quality was indirectly positively associated with I-RRS scores via their mutual positive association with Anticipatory Pleasure ratings.

As such, exploratory analyses within the Imagine group showed that, when deliberately instructed to imagine reward activity engagement, higher imagery quality, but not greater imagery use, is indirectly associated with higher reward response ratings via their joint association with higher anticipatory pleasure ratings.

Discussion

Study 1 found that when completing the I-RRS, individuals tended to imagine themselves engaging in the reward activities to similar levels irrespective of whether they were instructed to generate mental imagery or not. The instruction to generate mental imagery did not lead to any difference in reward response score. Importantly, greater experience of mental imagery while completing the I-RRS, irrespective whether imagery generation was instructed or not, was associated with higher reward response scores, even after accounting for depression symptoms. Critically, the strength of association between reward response score and anhedonia as measured by the DASS-21 depression questionnaire was lower for individuals reporting higher levels of mental imagery while completing the I-RRS.

The present results indicate that variation in spontaneous mental imagery use when completing reward response scales may be related to variation in reward response score but may also be related to variation in the degree of convergence between reward response scales and clinical questionnaires that also measure anhedonia. Of course, the present findings are preliminary, and interpretation is constrained by differences in task instructions, as well as the relatively small sample sizes within each instruction condition. We therefore conducted a second study to replicate the findings of Study 1 with respect to spontaneous (uninstructed) mental imagery use during the completion of reward response questionnaires.

Study 2

Study 2 aimed to replicate Study 1's results by examining spontaneous imagery generation using an uninstructed version of the Reward Response Scale (U-RRS) task in a larger sample. It was hypothesised that greater generation of mental imagery while completing the U-RRS would be associated with higher reward response scores, and the strength of association between reward response (U-RRS score) and anhedonia symptom level (as measured by the DASS-21 depression questionnaire) would be lower for individuals reporting higher levels of mental imagery use relative to those reporting lower levels of mental imagery use while completing the U-RRS. Study 2 also conducted a test of replication of the exploratory findings from Study 1 concerning the role of imagery quality in participants who were instructed to generate mental imagery, which suggested that imagery quality may be more strongly related to reward response score than imagery quantity when both are considered.

Method

Participants

Participants were recruited as part of a large multi-site online research project (the Cognition and Emotion Research Collaboration Initiative – CERCI) across four institutions (the University of Western Australia, Curtin University, University of Sydney, and the University of Sussex) from October 2022 to June 2023. $N = 600$ participants were recruited. Sample size was guided by simulations power estimates using the InteractionPowerR Shiny app (Finsaas et al., 2021), where approximately 600 participants were needed to detect a small interaction effect between continuous variables using multiple regression with 80% power and $\alpha = .05$.[9] Sixteen participants completed the study more than once and were removed from the dataset. The final sample of $N = 586$ participants comprised $n = 111$ from the University of Western Australia, $n = 172$ from Curtin University, $n = 142$ from the University of Sydney, and $n = 161$ from the University of Sussex. Participants were university students and received course credit for their participation in the study. The study was approved by the University of Western Australia Human Research Ethics Office (approval number 2021ET000074), with reciprocal approval from Curtin, Sydney Universities. The University of Sussex Sciences and Technology

Cross-Schools Research Ethics Committee had separately assessed and approved the study (approval code: ER/FMM28/18). All participants consented to participating in the study.

Mean age of the sample was $M = 20.50$, $SD = 4.01$, range = 17–51. For gender, 69.30% identified as female, 28.80% as male, 1.20% as non-binary, and 0.50% as other or prefer not to say. For ethnicity, 62.80% of participants were of European descent, 19.60% were of North or South-East Asia descent, 6.30% were of Southern or Central Asia descent, 2.70% were of African or Caribbean descent, 2.50% were of North African or Middle Eastern descent, 2.30% were of mixed ethnicity, and the rest (3.8%) were of other ethnicities. For education, 84.60% of participants were undergraduates who have completed secondary school, 12.10% had already completed a bachelor's degree, 0.30% had completed a master's degree, and 2.90% had completed another advanced degree. For language,75.10% of the participants were native English speakers, 17.30% were fluent, and 7.6% were proficient. For employment, 72% of participants were full-time students, 5.50% were part-time students,14% were part-time employed, 3.20% were full-time employed, 4.6% were unemployed, and the rest (.70%) indicated employment as "other/not applicable".

Materials

Questionnaires

Anhedonia and non-anhedonia depression symptoms. As per Study 1, anhedonia and non-anhedonia depression symptoms were assessed using the Depression subscale of the 21-item Depression, Anxiety, and Stress Scale (DASS-21; Lovibond & Lovibond, 1996). Internal consistency of the DASS-21 depression subscale was good: Depression subscale total score: α = .917; anhedonia items of the Depression subscale: α = .843, non-anhedonia symptoms within the Depression subscale: α = .871.

Reward Response Task

Uninstructed Reward Response Scale (U-RRS). All aspects were the same as the No Instruction condition in Study 1, i.e. there was no instruction for imagery generation or estimating frequency, and all participants were asked to rate their experience of mental imagery during the task at the end of the task, in response to the question "While answering the questions about all the different activities/experiences, to what extent did you imagine yourself engaging in the activities/experiences?". Responses were provided on a 5-point Likert scale ranging from "1 - Not at all" to "5 - All of the time". Participants providing a response of 2 or above were then asked to rate: (a) *anticipatory pleasure* ("I felt a sense of enjoyment while imagining the activities/experiences"); (b) *vividness* ("The images were as vivid as reality"); and (c) *detail* ("The scenes in my mind's eye were as detailed as scenes in reality"), all rated on a scale from 1 (*Not at all*) to 5 (*Very much*). Internal reliability for the U-RRS task was good, Cronbach's α = .866.

Results

Summary statistics for uninstructed reward response scale (U-RRS) score

Summary statistics for the Uninstructed Reward Response Scale (U-RRS) score by Reward Response domain and Reward Activity Type are shown in Table 3. A repeated measures ANOVA was conducted to assess U-RSS score as a function of Reward Activity Type and Reward Response Domain. Consistent with Study 1, results revealed a main effect of Reward Activity Type, $F(2, 1170) = 20.278$, $p < 0.001$, $\eta^2p = .034$, where Sensory activities had higher reward response ratings than both Hobby and Social activities, all $t(585) \geq 4.514$, all $p_{\text{Tukey}} < .001$., and no difference in reward response ratings was observed between Hobby and Social activities, $t(585) = .1.494$, $p_{\text{Tukey}} = .295$. Consistent with Study 1, a main effect of Reward Response Domain was also found, $F(2, 1170) = 81.629$, $p < 0.001$, $\eta^2p = .123$, but in contrast to Study 1, Liking ratings were higher than both Wanting and Seeking ratings, all $t(391) \geq 9.148$, all $p_{\text{Tukey}} < .001$, and Wanting ratings were higher than Seeking ratings, $t(585) = 5.769$, $p_{\text{Tukey}} < .001$. No two-way interaction involving Activity Type and Response Domain was found, $F(2, 2340) = 1.230$, $p = 0.269$, $\eta^2p = .002$.

Descriptive statistics and zero-order associations between study variables

A violin plot of Imagery Quantity score distributions is shown in Appendix 3 Supplementary Figure 3. Descriptive statistics and zero-order correlations between U-RRS score, Depression Anhedonia and Non-anhedonia symptoms, Mental Imagery (Quantity and Quality) and Anticipatory Pleasure ratings are reported in Appendix 3 Supplementary Table 3. While higher Imagery Quantity and Quality were moderately associated with higher U-RRS scores, they were not associated with anhedonia or non-anhedonia depression scores. While higher Anticipatory Pleasure was moderately to strongly associated with higher U-RRS scores, it was weakly associated with lower anhedonia and non-anhedonia depression symptoms.

H1. Relationship between U-RRS reward response score and mental imagery (quantity and quality) and anticipatory pleasure ratings

As shown in Supplementary Table 2, small to moderate associations were found between U-RRS score and Imagery Quantity and Quality, and a moderate association was found between U-RRS score and Anticipatory Pleasure ratings. Moderate associations were found between Imagery Quantity, Quality, and Anticipatory Pleasure ratings.

As per Study 1, a two-step hierarchical regression model was fitted with U-RRS total reward response score as outcome variable, Imagery Use (Quantity) and Imagery Quality (composite score of Vividness and Detail) as independent predictors in Step 1, and Anticipatory Pleasure (sense of enjoyment while imagining reward activity engagement) as a predictor in Step 2. The overall model was statistically significant and explained 26.73% of variance in U-RRS scores, $F(3, 582) = 72.140$, $p < .001$, R^2 adjusted = 26.73%. In Step 1, both Imagery Quantity ($b = 1.763$, $p < .001$) and Imagery Quality ($b = .344$, $p = .001$) were independent predictors of U-RRS score, accounting for 12.77% of variance in U-RRS score, R^2 adjusted = 12.77, However, when Anticipatory Pleasure was entered in Step 2, Imagery Quality no longer predicted U-RRS score ($b = -.118$, $p = .275$), while Imagery Quantity remained a significant predictor ($b = .918$, $p = .001$). Anticipatory Pleasure accounted for 14.34% additional variance in U-RRS score over and above Imagery Quantity and Imagery Quality ($b = 2.668$, $p < .001$, $R^2_\Delta = 14.34$)..

As per Study 1, mediation analysis was conducted to assess whether the associations between Imagery Quantity and Imagery Quality and U-RRS score were mediated by Anticipatory Pleasure. As depicted in Appendix 3 Supplementary Figure 4, significant indirect positive associations were found between both Imagery Quantity and Imagery Quality and U-RRS scores, via their mutual association with higher Anticipatory Pleasure ratings.

Results indicate that under naturalistic conditions, higher tendency to use mental imagery and higher imagery quality (vividness, detail) when completing the U-RRS reward response task were both indirectly associated with higher self-reported reward response via their mutual relationship with higher anticipatory pleasure.

Table 3. Study 2 summary statistics for Uninstructed Reward Response Scale (U-RRS) task scores by Activity Type and Response Domain.

	Response domain					
	Enjoyment		Interest		Seek	
Activity type	*M*	*SD*	*M*	*SD*	*M*	*SD*
Hobby	4.350	0.803	4.183	0.880	4.101	0.964
Social	4.393	0.829	4.270	0.892	4.137	1.029
Sensory	4.538	0.694	4.437	0.749	4.287	0.869

H2. Imagery Use as a moderator of the relationship between U-RRS reward response score and DASS-21 repression anhedonia score

We sought to replicate the finding from Study 1 and examine whether the negative relationship between I-RRS reward response score and DASS-21 depression anhedonia score was smaller in individuals reporting higher levels of imagery use would replicate under naturalistic conditions of uninstructed imagery generation. A linear regression model was fitted with U-RRS total reward response score as outcome variable, and DASS-21 Depression Anhedonia score, Imagery Use (Quantity), and Imagery Quality as interactive predictors. The overall model was statistically significant and explained a moderate proportion of variance, $F(7, 578) = 28.483$, $p < .001$, R^2 adjusted = 24.75%. Regression coefficients and model outputs are reported in Table 4.

A main effect of Depression Anhedonia score was found, $F(1, 578) = 48.853$, $p < .001$, were found, where higher anhedonia symptoms were both independently associated with lower U-RRS reward response score. Further, main effects of Imagery Use (Quantity), $F(1, 578) = 37.840$, $p > .001$, and Imagery Quality, $F(1, 578) = 10.055$, $p = .002$ were found, where higher imagery use and imagery quality were independently associated with higher U-RRS reward response score. Critically, a two-way interaction between Depression Anhedonia score and Imagery Use (Quantity) was found, $F(1, 578) = 13.730$, $p < .001$.[10] No other effects were found, all $F \leq 2.664$, all $p \geq .103$. Post-hoc simple slopes decomposition of the two-way interaction between Depression Anhedonia score and Imagery Use (Quantity) found that, and as depicted in Figure 2, the negative relationship between Depression Anhedonia Score and U-RRS Reward

Table 4. Study 2 linear regression model outputs for Imagery Use (Quantity) and Imagery Quality as predictors of Uninstructed-RRS Reward Response Scores.

			95% Confidence interval				
Predictor	*b*	*SE*	*Lower*	*Upper*	*t*	*p*	*β*
Intercept	38.641	0.214	38.221	39.061	180.790	< .001	
DASS Depression Anhedonia	−0.502	0.072	−0.643	−0.361	−6.989	< .001	−0.286
Imagery Use (Quantity)	1.734	0.282	1.180	2.288	6.151	< .001	0.259
Imagery Quality	0.321	0.101	0.122	0.520	3.171	0.002	0.133
DASS Depression Anhedonia * Imagery Use (Quantity)	0.346	0.093	0.162	0.529	3.705	< .001	0.159
DASS Depression Anhedonia * Imagery Quality	0.013	0.033	−0.051	0.078	0.405	0.685	0.017
Imagery Use (Quantity) * Imagery Quality	0.086	0.101	−0.113	0.285	0.852	0.394	0.029
DASS Depression Anhedonia * Imagery Use (Quantity) * Imagery Quality	−0.055	0.034	−0.121	0.011	−1.632	0.103	−0.056

Response score was significant and greatest for individuals reporting low Imagery Use (Quantity) (1 SD below the mean, rating = 3.247/5), $b = -.780$, 95%C.I. [−.993: −.567], $p < .001$, followed by those reporting average Imagery Use (Quantity) (mean rating = 4.053/5), $b = -.502$, 95% C.I. [−.642: −.361], $p < .0001$, with the lowest association for those reporting high imagery use (1 SD above the mean, rating = 4.858/5, $b = -.223$, 95%C.I. [−.418:−.028], $p = .025$).

As such, consistent with Study 1, the negative relationship between reward response as measured by the U-RRS and anhedonia level as measured by DASS-21 depression questionnaires was smaller at higher levels of mental imagery use, irrespective of the quality of imagery, and the relationship between reward response score and anhedonia level was not moderated by imagery quality.

Discussion

Study 2 investigated spontaneous imagery generation (i.e. Study 1's uninstructed condition) during reward response questionnaire completion. Using a larger sample, Study 2 found that, consistent with

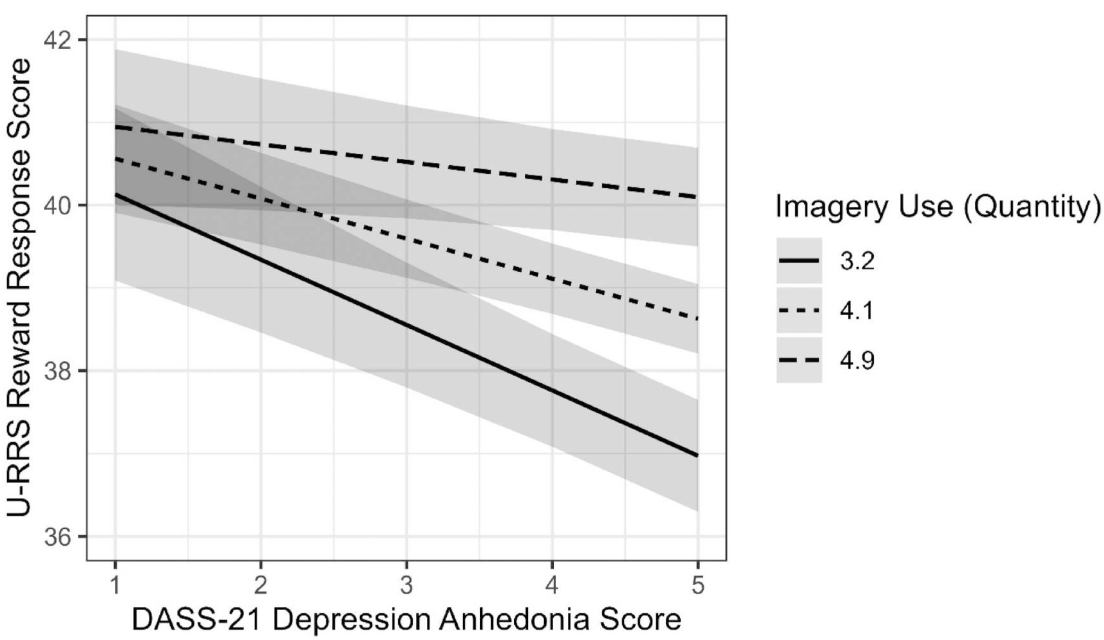

Figure 2. The relationship between DASS-21 Anhedonia Score and Uninstructed-RRS (U-RRS) Reward Response Score as a function of Imagery Use (Quantity) in Study 2.

Study 1, individuals who reported a greater degree of mental imagery use during reward response questionnaire completion also reported higher reward response scores, even when controlling for depression symptom level. Study 2 also sought to replicate the exploratory findings from Study 1's uninstructed condition concerning imagery quality vividness and detail (quality) and anticipatory pleasure. While Study 1 found that, when instructed to generate mental imagery, higher imagery quality, but not quantity, was indirectly associated with I-RRS scores via higher anticipatory pleasure, Study 2 found that when not instructed to generate mental imagery, both greater imagery quantity and quality were indirectly associated with higher U-RRS score via higher anticipatory pleasure. Critically, consistent with Study 1, Study 2 found that the association between reward response score and depression questionnaire anhedonia score was lower in individuals reporting greater mental imagery use when completing the reward response scale relative to those reporting lower mental imagery use.

General discussion

The present research aimed to investigate the role of mental imagery use on self-reported reward responses via reward response questionnaires, and the relationship between reward response questionnaire score and anhedonia levels measured via depression questionnaires. Study 1 found that, when individuals were asked to report what their "in-the-moment" levels of liking, wanting, and motivation to seek reward activities would be, mental imagery generation was common and engaged-in to a similar extent irrespective of whether mental imagery was generated spontaneously or under instructions to deliberately do so. Importantly, consistent with hypothesis, results from both studies show that those who imagined themselves engaging in reward activities to a greater extent also reported higher reward response scores, even when controlling for depression symptom level. As expected, the degree of mental imagery use during the reward response task was positively associated with in-the-moment ratings of reward activity reward response, but not with retrospective estimates of anhedonia symptoms, as assessed by the DASS-21 depression questionnaire. Critically, across both studies, the association between reward response score and anhedonia score as assessed via the DASS-21 depression questionnaire was lower in individuals reporting greater levels of mental imagery use when completing the reward response scale.

Theoretical implications

The present findings indicate that mental imagery generation influences self-reported reward response. When asked to report one's hypothetical "in-the-moment" hedonic responses to reward activities in daily life, individuals reporting greater use of mental imagery (imagining themselves engaging in the activity) reported higher levels of hedonic response than those with lower use of mental imagery. There was evidence that the positive relationship between mental imagery and reward response ratings was mediated by anticipatory pleasure, such that higher imagery quantity (Study 2 only) and quality (vividness and detail; Study 1 and 2) were found to be associated with higher anticipatory pleasure (sense of enjoyment while imagining activity engagement), which was in turn associated with higher levels of reward response ratings. Importantly. Further, the degree to which reward response scores inversely correlates with anhedonia symptoms reported via a depression questionnaire was also lower in those reporting greater mental imagery use.

The present findings are consistent with prior research indicating that the motivational amplification effect of reward-focused mental imagery is mediated by the degree to which imagery evokes anticipatory pleasure (Ji et al., 2021). Given that reward response measures of anhedonia, asks individuals to report how much they *would* enjoy reward activities and how much they *would* be motivated to seek such activities, scores on such scales in part reflect affective and motivational forecasts for future events, i.e. anticipated pleasure and motivational states. Prior research has shown that anticipatory pleasure and anticipated pleasure are strongly correlated with each other (Hallford et al., 2022; Ji et al., 2021), with increases in anticipatory pleasure having a stronger impact on reward activity engagement motivation than increases in anticipated pleasure (Hallford et al., 2022), and anticipatory pleasure may be more affected in depression than anticipated pleasure (Clayton McClure et al., 2024). Further, consistent with basic research on mental imagery's unique capacity to evoke state emotional responses (for a review see Ji et al., 2016), reward-focused mental imagery has unique capacity to promote anticipatory pleasure, while anticipated pleasure is enhanced by both reward-focused imagery and reasoning (Ji et al., 2021).

Applied implications

The present findings have implications for the assessment of anhedonia. Reward activity engagement imagery may influence affective and motivational forecasts via its influence on anticipatory emotion, As such, variation in mental imagery use is likely to influence affective and motivational forecasts via its influence on ratings on state emotion, and thus may be contributing to score variation on reward response scores on scales such as the Snaith – Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), Temporal Experience of Pleasure Scale (TEPS; Gard et al., 2006), and the Dimensional Anhedonia Rating Scale (Rizvi et al., 2015). Findings from the present research suggest that spontaneous generation of mental imagery may be prevalent during a reward response task modelled on the DARS (Rizvi et al., 2015). When not instructed to generate imagery, participants across both studies reported mean levels of mental imagery use at 4 out of 5, indicating that they imagined themselves engaging in the activities/experiences "Most of the time" when completing task. At the same time, in Study 1, instructing people to deliberately imagine engaging in the reward activities did not lead to in greater levels of mental imagery use as compared to providing no instructions, or to asking people to focus on estimating the frequency of activity engagement. This suggests that spontaneous mental imagery generation may be common during reward response questionnaire completion and independent from instructions. Importantly, as shown in Appendix 3 Supplementary Figures 1 and 2, there is also substantial variation in imagery use across individuals. Thus, when assessing hedonic response using "in-the-moment" reward activity response scales, it may be important to assess individual variation in mental imagery use.

Limitations and future directions

The present studies have several limitations. First, experimental instructions employed in Study 1 did not serve to induce systematic variation in mental imagery use during reward response scale completion, suggesting that simply instructing individuals to imagine reward activity engagement or to evaluate its frequency may be insufficient in boosting or dampening mental imagery use relative to uninstructed scale completion. However, we note that participants in the uninstructed imagery generation condition in Study 1, and across Study 2, reported high levels of imagery use on average, indicating potential ceiling effects in the study sample. Future research should investigate more effective ways to manipulate mental imagery quantity or quality during reward response questionnaire online and/or offline completion, e.g. via cognitive training to boost the vividness of positive mental imagery (Renner et al., 2017), more detailed instructions as to which aspects of the reward activity to focus on (e.g. process or outcome), or via sensory scaffolding (Ji et al., 2020) to boost imagery, or to dampen imagery via concurrent visuo-spatial working memory interference.

Relatedly, the correlational nature of the present research prevents conclusions regarding the causal influence of mental imagery on self-reported "in-the-moment" reward responses. On one hand, it is plausible that individuals first imagine themselves engaging in the reward activities to estimate how they would respond "in-the-moment" (or to evaluate the frequency of engagement in reward activities, as in Study 1's instructed frequency estimation condition), and as such greater mental imagery use leads to more positive reward response ratings. If this is the case, then experimental manipulations that successfully attenuate imagery use during reward response scale completion (e.g. via concurrent visuo-spatial working memory interference) would be expected to result in greater congruence between reward response scale and depression questionnaire anhedonia score. However, it is also possible that the mental imagery is generated as a spontaneous by-product of estimating one's in-the-moment response to reward activities, in that individuals who can access representations of reward responses to activities more readily will also tend to simultaneously retrieve image-based memories and simulate "in-the-moment" engagement in such activities spontaneously. That is, if mental imagery is epiphenomenal to reward response scale completion and plays no causal role, then it is expected that experimental procedures that attenuate mental imagery generation will not impact the convergence between reward response scale and depression questionnaire anhedonia score.

Beyond the need to manipulate mental imagery use for the purposes of testing the causal nature of the present findings, the present finding that higher quantity and quality of reward mental imagery is associated with greater reward response via greater anticipatory pleasure is of relevance for future clinical research on depression. Previous research has found dysphoria to be associated with lower spontaneous tendency to generate future positive mental imagery under controlled laboratory conditions (Ji et al., 2019). Although spontaneous imagery generation was not found to be associated with overall depression symptom severity in either Study 1 (unstructed condition, $r = -.107$, $p = .219$) or Study 2 ($r = -.011$, $p = .783$), further research is needed to test the extent to which this holds in individuals with more severe depression. In terms of imagery quality, depression symptom severity was associated with lower imagery vividness/detail in Study 1 (instructed imagery condition only) but not in Study 2, consistent with prior research showing impoverished detail/vividness of deliberately generated positive mental imagery in prior research (Anderson et al., 2023; Gamble et al., 2021; Hallford et al., 2020; for a review of earlier studies see Holmes et al., 2016). Finally, the degree to which reward mental imagery can be enhanced may also hinge on the extent to which individuals are willing or motivated to do so, as motivated devaluation and avoidance/dampening of reward experiences is postulated to play an integral role in the etiology and maintenance of depression (Dunn, 2012; Gallagher et al., 2023; Werner-Seidler et al., 2013; Winer & Salem, 2016). Thus, additional instructions or psychoeducation, for example on reward devaluation, may be required to reduce avoidance and increase motivation to generate vivid/detailed mental imagery of reward activity engagement in a manner that boosts anticipatory pleasure and motivation.

Finally, the present studies were not designed to assess the accuracy of either type of self-report measures of anhedonia and therefore it cannot draw conclusions about the role of mental imagery in inflating reward response scores relative to reality. Future research should also seek to assess the accuracy of both reward response questionnaire and depression questionnaire assessments of anhedonia, such as through real-time experience sampling of reward responses in daily life, and/or through lab-based reward response measurements. Future research should also investigate whether controlling for mental imagery use during reward response scale completion increases the predictive utility of reward response scales such as the DARS. That is, studies could either instruct and train all participants to engage in mental imagery during reward response scale completion, or to attenuate mental imagery use (e.g. via concurrent visuo-spatial working memory interference), and assess whether such reward response scores better predict future anhedonia symptom progression and treatment response (e.g. for depression).

Conclusion

The present research demonstrates the importance of assessing mental imagery use during self-report assessments of anhedonia. Variation in people's ability and tendency to generate mental imagery when answering questions about their hypothetical "in-the-moment" reward responses, such as via the DARS (Rizvi et al., 2015), may contribute to variation in the degree of convergence between such measures and depression questionnaire measures of anhedonia symptoms, with greater convergence associated with lower mental imagery use when reward response scale completion. Future research is required to further understand the causal impact of mental imagery use in reward response scale measures of anhedonia, both in terms of its accuracy and predictive utility.

Notes

1. We also pre-registered hypotheses about moderation of the effect of the imagery instruction on interest/enjoyment ratings. As these do not relate to closely to the main research questions, they are not presented in this manuscript.
2. See section 7 of the pre-registered study protocol document.
3. While the original DARS assessed eight activities across four activity types, to reduce participant burden, the I-RRS assessed six activities across three activity types by merging the favourite "foods or drinks" category with the "sensory experiences" category.
4. I-RRS reward response ratings were simplified from the DARS, where a) all rating question wordings were identical across activity types (unlike the DARS, which used slight variations in wording for questions across activity types); and b) three questions were asked instead of four or five questions for each activity type.
5. Baseline depression score was not included as a covariate as there were no associations between baseline depression score (anhedonia or non-anhedonia score) and Imagery Use (Quantity), as shown in Supplementary Table 2 in Appendix 3.
6. Language (English speaker vs. German speaker) was not included in the model as a separate 3×3×3×2 mixed-ANOVA model with Language as additional factor showed no main or 2-way, 3-way, and 4-way interactions involving Language, except for a 2-way interaction

between Language and Response Domain (with German speakers reporting lower Seeking scores, but not Liking or Wanting scores, than English speakers). We did not include this in the model reported in the manuscript as it was not pertinent to the research question. Subsequent analyses did not include Language as a moderator as any Language group differences in Seeking scores would simply be reflected in total I-RRS scores. See Appendix 3 for model outputs.

7. A separate model with Instruction Condition as an additional interactive predictor found no two-way, three-way, or three-way interactions involving Instruction Condition, and did not result in improved model fit as compared to the reported simpler model, $F = 1.247$, $p = .282$, therefore the model with only the interaction of interest fitted is presented for parsimony.
8. This two-way interaction was significant even when Depression Non-anhedonia score was statistically controlled for as a covariate, $F\ (1,\ 387) = 7.140$, $p = .008$, $\eta^2 p = .018$.
9. Simulation parameters were 1000 iterations with 1 cluster. Strength of associations were conservatively estimated relative to those observed in Study 1: interaction term association with outcome $r = .15$, predictor terms association with outcome $r = .20$, predictor association with each other $r = .55$.
10. This two-way interaction was significant even when Depression Non-anhedonia score was statistically controlled for as a covariate, $F\ (1,\ 577) = 15.003$, $p < .001$.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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