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## Altered interaction with environmental reinforcers in major depressive disorder: Relationship to anhedonia

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### Abstract

Anhedonia—defined as loss of interest or pleasure—is one of two core symptoms of major depressive disorder (MDD). Anhedonia may involve decreased enjoyment of potentially rewarding activities and decreased motivation to engage in such activities. Increased engagement with reinforcers—activities with the potential to be positive experiences—is a frequent target of cognitive-behavioral therapies. Nevertheless, how environmental reinforcers are perceived, and how decisions to approach or avoid them are made by individuals with MDD, is largely unknown. We developed an experimental Behavioral Approach Motivation Paradigm to study how activities are evaluated and approached in MDD. Twenty-one MDD participants and 23 healthy controls performed an experimental task that rated activity words for their hedonic value, then engaged in an approach-avoidance joystick task with each individual's unique set of 'liked' and 'disliked' activity words. A negative correlation was observed between anhedonia and the number of 'liked' activities across participants. No significant difference between approach and avoidance behavior was found in direct comparisons between healthy controls and MDD participants; however, weaker avoidance and greater approach toward 'disliked' activities was found in MDD participants. This suggests negative bias in selecting environmental opportunities, potentially further compromising access to hedonic experiences in MDD.

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#### Conflict of interest

Dr. Zarate is listed as a coinventor on a patent for the use of ketamine and its metabolites in major depression and suicidal ideation. Dr. Zarate is listed as a co-inventor on a patent for the use of (2*R*,6*R*)-hydroxynorketamine, (5*S*)-dehydronorketamine, and other stereoisomeric dehydro and hydroxylated metabolites of (2*R*,6*R*)-ketamine metabolites in the treatment of depression and neuropathic pain. Dr. Zarate is listed as co-inventor on a patent application for the use of (2*R*,6*R*)-hydroxynorketamine and (2*S*,6*S*)-hydroxynorketamine in the treatment of depression, anxiety, anhedonia, suicidal ideation, and post-traumatic stress disorders; he has assigned his patent rights to the U.S. government but will share a percentage of any royalties that may be received by the government. The NIMH has filed a use patent for the use of scopolamine in the treatment of depression, and Dr. Furey is identified as a co-inventor on this pending patent application in the US and an existing patent in Europe. Dr. Furey is a full-time employee at Janssen Pharmaceuticals, Neuroscience Research and Development, La Jolla, CA. All other authors have no conflict of interest to disclose, financial or otherwise.

#### Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.brat.2017.08.003>.

## Keywords

Anhedonia; Approach; Avoidance; Behavioral activation; Major depressive disorder; Reinforcement

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Anhedonia, which is a core symptom of major depressive disorder (MDD), is defined by the DSM-IV (American Psychiatric Association, 1994) and DSM-5 (American Psychiatric Association, 2013) as an impaired capacity to experience or anticipate pleasure. Behaviors associated with anhedonia include lack of engagement in previously pleasurable activities, social withdrawal, lassitude, and avoidance. Higher levels of anhedonia in depressed patients have been associated with a more severe course of illness, increased suicide risk, greater functional impairment, and greater resistance to treatment (Lally et al., 2015; McMakin et al., 2012; Uher et al., 2012; Vrieze et al., 2014). Given its importance, efforts are underway to develop interventions that specifically target anhedonia as a clinical symptom (Craske, Meuret, Ritz, Treanor, & Dour, 2016).

Conceptually, anhedonia refers to the internal experience of an individual and their recall of the feeling of pleasure upon questioning by a clinician or when responding to a questionnaire (Franken, Rassin, & Muris, 2007; Gorwood, 2008). Clinically, no distinction is made between decreased motivation and reduction in experienced pleasure (Treadway & Zald, 2011). Because these behaviors are also associated with lack of action, with regard to the standard diagnosis of MDD, it is difficult to conclude whether an individual endorsing ‘lack of interest or pleasure’ is experiencing an inability to enjoy an activity in general versus a reluctance to approach and take part in pleasurable activities. Thus, as a symptom, experiential anhedonia—historically associated with melancholic depression—may differ from lack of motivation (Treadway & Zald, 2013) and may have a distinct neurobiology (Berridge & Kringelbach, 2008; Berridge, Robinson, & Aldridge, 2009).

To understand why an individual might not engage in a reinforcing activity and thereby potentially miss out on pleasure, the steps that precede actual engagement—specifically, the motivation to take action and the resulting approach of an opportunity—must be considered. Evidence suggests that hedonic deficit and approach motivation are related (Germans & Kring, 2000), and that severity of anhedonia influences task performance in different ways than severity of depression, most notably by slowing reward learning (Chase et al., 2010). Higher levels of anhedonia have also been associated with decreased willingness to exert the effort necessary to obtain rewards (Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009). Another deficit that contributes to anhedonia in MDD is the reduced ability to *sustain* positive emotion, rather than an inability to *experience* positive emotion (Heller et al., 2009). Thus, emerging research into the nature of hedonic deficits in MDD suggests the involvement of related but distinct processes that may all underlie anhedonia. Understanding these distinct processes could lead to better therapeutic interventions by targeting motivation and hedonic expectation, or facilitating the ability to remain engaged with reinforcers in therapy, as appropriate for an individual patient. The biological distinction between hedonic experience and motivation for reward was formulated based on both animal and human studies (Berridge & Kringelbach, 2008; Berridge et al., 2009) and is often referred to as

‘liking’ versus ‘wanting’. Neurobiological correlates of anhedonia in individuals with MDD could inform biology-based treatments (Lally et al., 2015). Both approach behavior and anhedonia have been identified as research targets based on Research Domain Criteria (RDoC) (Cuthbert & Insel, 2013; Insel et al., 2010).

This study sought to assess the ‘liking’ and ‘wanting’ components of anhedonia in MDD participants and healthy controls. Towards this end, we developed a Behavioral Approach Motivation Paradigm (BAMP) as an experimental assessment. First, we asked participants how much they ‘liked’ particular activities in order to establish each individual’s capacity to enjoy various activities and to identify individual reinforcers. We subsequently used participant-identified ‘liked’ activities to study how ‘wanting’ of activities might differ as they were approached by healthy and MDD participants. Our hypothesis was that, in contrast to healthy controls, individuals with MDD would be less likely to recognize (that is, ‘like’) potentially reinforcing activities and also be less likely to approach (that is, ‘want’) activities that they had previously identified as ‘liked’. The study also sought to evaluate the BAMP task as a potential tool—both behaviorally and in combination with neuroimaging studies—for studying MDD in general and anhedonia in particular.

## 1. Methods

### 1.1. Participants

Participants in the current study were a subset of individuals recruited for research studies (NCT00397111) at the National Institute of Mental Health (NIMH) by means of community and internet advertising (including the ClinicalTrials.gov website). All participants were between the ages of 18 and 50 and physically healthy as determined by medical history, laboratory testing, drug screening, and physical examination. The psychiatric diagnosis of MDD participants currently experiencing a major depressive episode was established using the Structured Clinical Interview for DSM-IV (SCID-IV) (First, Spitzer, Gibbon, & Williams, 2002) as well as a semi-structured clinical interview with a psychiatrist. MDD participants were excluded if they had serious suicidal ideation or behavior, major medical or neurological disorders, a history of drug or alcohol abuse within the past year, or a lifetime history of drug or alcohol dependence. Lack of psychiatric diagnosis for healthy controls was assessed via the Structured Clinical Interview for DSM-IV-Non-Patient Edition (SCID-NP) (SCID-I/NP) (First et al., 2002). In addition, healthy controls were excluded if there was any history of psychiatric disorder including alcohol or drug addiction or the presence of a first-degree relative with an Axis I diagnosis. All of the participants were fluent in English (either native speakers or educated in English beyond high school). After signing an informed consent form, participants completed a 2-h testing session that included self-ratings (described below), questionnaires, two computerized tasks, and a debriefing.

A final sample of 44 participants (21 with MDD (13M/8F) and 23 healthy controls (14M/9F)) was included in the study. All MDD participants were medication-free for at least 14 days at the time of testing but were not taken off medications to participate in this study. Demographic information is provided in Table 1.

## 1.2. Assessment measures

Measures of mood, anhedonia, and approach/avoidance tendencies were administered as part of the study (see Table 1). Mood was assessed using the self-reported Beck Depression Inventory-II (BDI-II) (Beck, Steer, Ball, & Ranieri, 1996), which estimates the level of current depressive symptoms in both clinical and non-clinical populations. Anhedonia was assessed via the widely used Chapman scales, specifically the Physical Anhedonia Scale/Social Anhedonia Scale (CPAS/CSAS) (Chapman, Chapman, & Raulin, 1976); both measure trait-level hedonic capacity. To assess current (state-level) hedonic capacity, the Snaith Hamilton Pleasure Scale (SHAPS) with modified scoring was included (Snaith et al., 1995). The psychological processes underlying the tendency to approach or avoid activities and social situations were assessed using the Behavior Inhibition/Behavior Activation Scales (BIS/BAS) (Carver & White, 1994; Smillie & Jackson, 2005). The Jackson Appetitive Motivation Scale (JAMS) was included to measure established trait levels of reward motivation (Jackson & Smillie, 2004; Smillie & Jackson, 2005).

## 1.3. The Behavioral Approach Motivation Paradigm (BAMP): word rating and lexical decision tasks

The BAMP paradigm comprised two tasks: rating of activity words (the Word Rating Task (WRT)) and a reaction time joystick task (the Lexical Decision Reaction Time Task (LDT)) (Fig. 1). The WRT required each participant to rate 150 two-to four-syllable verbs representing activities such as ‘bowling’, ‘hiking’, or ‘cooking’ on a five-point Likert scale (0–4) ranging from ‘can’t stand’ to ‘like a lot’ (see Appendix 1 for the complete list of words). We chose the most negative anchor to promote a possible active rejection of a ‘disliked’ activity, thereby strengthening the disparity between an activity that participants would potentially approach or avoid. Each word thus acquired a number representing an individually assessed appetitive value; scores of 0 and 1 represented ‘disliked’ items, scores of 2 represented neutral items, and scores of 3 or 4 represented ‘liked’ items. The participants used a mouse to click a button on the screen representing the choices and had an option to skip up to 10 words if they could not relate to an activity or if they did not wish to rate it for any other reason. The task was self-paced, and time to decision was not measured. The selection of words was loosely based on the Pleasant Events Schedule (Lewinsohn & Graf, 1973), but was expanded and supplemented to include potentially neutral and aversive actions in order to enable a wide variety of ratings. From this task, data were generated for how the words were rated by each participant. Furthermore, the words from each rating category (‘can’t stand’/‘disliked’, neutral, ‘liked’/‘liked a lot’) served as a pool from which stimuli for the LDT were randomly selected.

In the LDT, participants performed a reaction time joystick task that required pulling the joystick towards themselves or pushing it away from themselves in response to the previously rated activity words. The stimulus set was unique to each participant. Specifically, the stimulus words in the second task were generated from the output of the first task (the WRT) by randomly selecting five words from each rating category—that is, five words previously rated by the participant as representing ‘liked’ activities, five words previously rated as representing neutral activities, and five words previously rated as representing ‘disliked’ activities, resulting in a total of 15 unique stimulus words for each

participant. The words for the 'liked' category were randomly selected from items rated with a 4 ('like a lot'); however, if a participant rated fewer than five items with a 4, items rated with a 3 ('like') were randomly selected and included to complete the category. Similarly, for 'disliked' items, the random selection was made from items rated with a 0 ('can't stand') and randomly supplemented if necessary by words rated with a 1 ('don't like'). Notably, the push or pull response to the stimulus word did not depend on the word's meaning, nor its appetitive value, but on the lexical decision (word versus non-word).

In the LDT, the non-words were created by scrambling the target words (eg, gardening to daegnrnig); it should be noted here that each participant had a unique set of words, but also a unique set of non-words. During task administration, 15 words ('liked', neutral, and 'disliked') were each shown three times per block. The 15 non-word stimuli appeared once per block in each push and pull condition. Hence, the non-words constituted 25% of the stimuli and were matched to the stimulus words by sensory properties, number, size, and shape of letters. The word or non-word stimuli stayed on the screen until a response was initiated, or until 3 s elapsed. The fixation cross (+) appeared on the screen between the trials for 5 s. Each block of the task took approximately 8 min to complete. Two blocks of the LDT were administered randomly. One of the blocks required pushing away on the joystick when presented with words and pulling in on the joystick when presented with non-words; the second block had opposite instructions. This manipulation created the experimental conditions of interest: pushing away when presented with a word represented either pushing away a 'disliked' word (that is, avoiding 'disliked' words) or pushing away a 'liked' word (that is, avoiding 'liked' words); conversely, pulling in represented either pulling in a 'disliked' word (that is, approaching 'disliked' words) or pulling in 'liked' words (that is, approaching 'liked' words). The conditions were balanced with the push/pull non-word conditions so that each participant completed two blocks, one of each condition. Fig. 1 summarizes the task procedures.

It is important to note that, in terms of our ability to characterize and differentiate the dimensions of 'liking' and 'wanting', we considered the evaluation of activity words in the WRT for their hedonic potential as an expression of 'liking'. Thus, the number of words rated as 'liked' and 'liked a lot' was assumed to reflect greater potential for consummatory pleasure. Along these lines, the joystick movement toward stimulus words in the LDT was thought to reflect the motivational strength to approach an incentive (Tibboel, De Houwer, & Van Bockstaele, 2015) and was thus considered to reflect the 'wanting' dimension in this part of the experiment; under these circumstances, faster movement would indicate enhanced approach and wanting, and slower movement would indicate the opposite.

#### 1.4. Study procedures

Each session was held in a quiet room and began with participants performing the WRT. The computerized version was programmed in Visual Basic 6.0, with the output directed to Microsoft Access. For stimulus presentation, white lower case words were presented in 32-point font on a black background. Prior to the task, participants were given a brief training with examples on how to rate the words using the mouse. After the WRT, participants

completed self-report measures and questionnaires (previously described) that took on average 20 min.

The LDT was then administered. Participants used their dominant hand and were instructed to move the Logitech ATK3 Joystick (Logitech, Inc. Newark, CA) away or towards themselves as quickly and as accurately as possible in response to words versus non-words presented one at a time on the computer screen. A few examples were presented and participants were given an opportunity to ask questions. The emphasis was placed on directionality in relation to self rather than on a simple instruction to push or pull, since it had previously been found that manipulating task instructions could lead to re-categorization of approach and avoidance responses (Seibt, Neumann, Nussinson, & Strack, 2008).

### 1.5. Data analysis

Descriptive statistics were calculated to characterize the sample, and between group differences in demographic variables were assessed by *t*-tests or Mann-Whitney U-tests as appropriate. The number of words in the 'liked' and 'disliked' categories in the WRT were compared between MDD participants and healthy controls using one-way ANOVA to assess hedonic capacity, represented by the number of 'liked' ratings assigned to a common set of activity words. This was followed by *post-hoc* independent sample *t*-tests to describe specific differences in the ratings. The significance level was set at  $p < 0.05$ . The numbers of words in the 'liked' and 'disliked' categories were correlated with mood and anhedonia measures across all participants using Pearson correlations in order to verify the relevance of 'liked'/'disliked' word selection and six measures of clinical constructs of interest (anhedonia, appetitive motivation, behavioral activation and inhibition, and depressive symptoms). A Bonferroni correction was applied to set correlation significance at  $p < 0.004$ .

For the LDT, three measures of interest were collected: 1) accuracy in identifying words vs. non-words; 2) reaction time; and 3) response duration. Both reaction time and response duration were the primary outcome measures of interest. Consistent with previous research on approach and avoidance, only correct responses were included in the reaction time-related analyses (Bargh, Chaiken, Govender, & Pratto, 1992; Fazio, 1986).

Briefly, reaction time was defined as the time of initiating movement of the joystick in response to word and non-word stimuli. While reaction time is the most established measure of cognitive processing efficiency (Whelan, 2008), it does not reflect the whole movement, just its onset. In contrast, response duration reflected the entire process of active approach and avoidance of 'liked'/'disliked' stimulus words. Response duration was computed by subtracting the time necessary to initiate a response (initial reaction time) from the time at which movement of the joystick was complete, corresponding to release of the joystick when it reached the maximum extension allowed by the device or when the participant terminated movement and released pressure. Response duration, which can also be conceptualized as response force, is thought to reflect important psychological processes and provides a more complete picture of approach and avoidance motor behavior (Puca, Rinkenauer, & Breidenstein, 2006); some studies have referred to this variable as 'movement time' (Roelofs, Elzinga, & Rotteveel, 2005). Response duration was of central interest because we wanted to measure the complete movement toward or away from the stimulus.



To minimize the impact of individual variables such as physical strength and experience with video games, all analyses related to the timing of response were done on log<sub>10</sub> transformed values.

Data were inspected for outliers by examining initial reaction time and removing responses faster than 200 ms (to ensure adequate processing of the stimulus) and slower than 3000 ms (at which time the stimulus was no longer present). Response times in that broadly acceptable range were then log<sub>10</sub> transformed. Incorrect responses were removed because the movement direction that determined a correct response was considered a separate variable. The final steps in calculating response duration for each participant and each stimulus required converting the time of termination of the response to log<sub>10</sub> value, then subtracting the converted reaction time value from the log<sub>10</sub> response termination time. All analyses were conducted on both the initial measure of reaction time as well as on response duration values using SPSS 20 software.

The principal analysis was a repeated measures analysis of variance (ANOVA) to investigate the effects of group (MDD versus healthy controls), movement direction (pulling in vs pushing away), and valence ('liked' or 'disliked' words) on performance. *Post-hoc t*-tests were conducted to investigate significant interaction effects. The analyses did not include the neutral condition and are presented here for 'liked' and 'disliked' conditions only, specifically because previous research has shown that the neutral condition may assume either appetitive or aversive stimulus properties and because the perception of a neutral stimulus may be subject to bias (Leppanen, Milders, Bell, Terriere, & Hietanen, 2004).

## 2. Results

### 2.1. Word Rating Task

With regard to the WRT, both groups rated more activities as 'liked' than 'disliked' ( $p < 0.001$ ; Fig. 2). However, healthy controls rated more activities as 'liked' than MDD participants ( $p = 0.001$ ), and MDD participants rated more activities as 'disliked' ( $p = 0.004$ ).

Correlational analyses across groups demonstrated significant relationships between the number of activities rated as 'liked' and greater appetitive motivation (as measured by the JAMS,  $r = 0.58$ ,  $p < 0.001$ ), higher level of activation (as measured by the BAS,  $r = 0.55$ ,  $p < 0.001$ ), lower levels of anhedonia (as rated by the SHAPS,  $r = -0.53$ ,  $p < 0.001$  and Chapman scales  $r = -0.67$ ,  $p < 0.001$ ), and fewer depressive symptoms (as assessed by the BDI-II,  $r = -0.50$ ,  $p < 0.001$ ). The number of activities rated as 'disliked' correlated positively with increases in anhedonia (as measured by the SHAPS,  $r = 0.48$ ,  $p < 0.01$  and Chapman scales,  $r = 0.53$ ,  $p < 0.001$ ) and in depressive symptoms (as measured by the BDI-II,  $r = 0.51$ ,  $p < 0.001$ ); the number of activities rated as 'disliked' also correlated negatively with appetitive motivation (as assessed by the JAMS,  $r = -0.48$ ,  $p < 0.01$ ) and with behavioral activation (as measured by the BAS,  $r = -0.47$ ,  $p < 0.01$ ).

## 2.2. Lexical Decision Reaction Time Task

**2.2.1. Stimuli**—Each participant's stimulus set of 'liked', neutral, and 'disliked' words was unique, randomly selected from their WRT output. In 12 of 23 healthy controls and seven of 21 MDD participants, the extreme ratings of 'can't stand' and/or 'like a lot' were randomly supplemented by items from the 'don't like' or 'like' categories. The average ratings for 'dislike' and 'like' did not differ between groups ( $p > 0.13$ , summarized in Table 2).

**2.2.2. Accuracy**—The accuracy of the LDT was high across both groups and all conditions for both word and non-word trials; of the 5280 total responses, only 124 (2.3%) were incorrect. The proportion of errors with regard to approach and avoidance conditions did not significantly differ between healthy controls and individuals with MDD ( $p > 0.07$ ), nor did performance on non-word trials ( $p > 0.05$ ).

**2.2.3. Reaction time**—Six responses were excluded from the analysis for exceeding the defined outlier limits. The analysis of initial reaction time for the four experimental conditions (pushing away a 'disliked' word, pulling in a 'liked' word, pushing away a 'liked' word, and pulling in a 'disliked' word) found a three-way interaction (valence by direction by group) [ $F(1,42) = 4.608, p = 0.04, \eta_p^2 = 0.1$ ]. However, no significant difference was found in direct comparisons between or within groups ( $p > 0.1$ ); thus, this interaction was not further interpreted.

The analysis of the primary experimental outcome of response duration showed a significant three-way interaction (valence by direction by group) [ $F(1,42) = 8.714, p < 0.01, \eta_p^2 = 0.17$ ]. Follow-up *t*-tests found no difference between healthy controls and individuals with MDD with regard to performance on any of the four conditions ( $p > 0.10$ ). Within-group paired comparisons found a significant difference on response duration in approaching versus avoiding 'disliked' stimulus words in MDD participants ( $t = 2.410, p = 0.03$ ). The response was shorter (stronger movement) towards 'disliked' rather than away from 'disliked' stimulus words. A faster approach towards 'disliked' than 'liked' stimulus words in MDD participants did not meet the threshold for significance ( $t = -1.83, p = 0.08$ ; Fig. 3). No within group differences were observed in the healthy controls ( $p > 0.13$ ).

## 3. Discussion

The current study developed and tested a behavioral paradigm (the BAMP) to examine how individuals with MDD select and interact with environmental reinforcers, defined as any activity that has the potential to be a positive experience. We found that MDD participants identified fewer activities as enjoyable than healthy controls. No differences were observed in a direct comparison of approach and avoidance task performance between healthy controls and MDD participants; however, we found that in individuals with MDD, weaker avoidance and greater approach behavior was directed towards activities that participants 'disliked', suggesting a negative bias.

With regard to the finding of fewer reinforcers identified by MDD participants, the current results—based on stimulus words individually selected as 'liked'/'disliked' by participants



—suggests that the hedonic range of MDD participants is narrower than that of healthy controls, as fewer activities were regarded as potentially reinforcing, and more activities were regarded as aversive. One issue of interest is whether the ‘liked’ ratings had the same hedonic value for MDD participants and healthy controls. The BAMP task relied on subjective ratings, and while this did not allow us to determine the equivalence of the ratings for the two groups, we nevertheless believe this investigation has an advantage over most studies, which use stimuli generally accepted as ‘liked’ or ‘disliked’ (for example, positive or negative facial expressions, normative pictures or words) (Canli et al., 2005; Derntl et al., 2011; Mitterschiffthaler et al., 2003; Surguladze et al., 2004) or assume motivational salience as positive or negative (for instance, gaining versus losing money) (Dichter et al., 2009; Knutson, Fong, Adams, Varner, & Hommer, 2001; Pizzagalli et al., 2009).

With regard to the second finding of altered approach behavior in MDD, we found that pattern approach and avoidance behaviors differed between MDD participants and healthy controls in terms of how they related to representations of ‘liked’ and ‘disliked’ activities. No distinct pattern emerged in terms of how healthy controls approached or avoided ‘liked’ and ‘disliked’ activities. Surprisingly—and contrary to our hypothesis—the manner in which individuals with MDD approached ‘liked’ activities on our task did not differ from that of healthy controls. Instead, the primary difference was an automated preference towards ‘*disliked*’ stimulus words in the MDD participants, as indicated by stronger and faster approach movement in this condition. This result may indicate that in the initial stages of evaluating a potential reinforcer, individuals with MDD are drawn to the negative. Such behavior could jeopardize their chances of engaging in ‘liked’ activities, even if their capacity to approach ‘liked’ experience is not compromised. Second, the finding might suggest that MDD participants have a decreased ability to avoid what they themselves identify as unpleasant (slower movement away from ‘disliked’ stimulus words), possibly because of a deficit in negative reinforcement or because of punishment learning at the automated level of response. Overall, we observed a processing tendency consistent with the negative bias demonstrated in multiple domains in MDD (Bradley, Mogg, & Williams, 1995; Erickson et al., 2005; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Leppänen, 2006).

In this context, seeking out experiences not likely to bring pleasure may contribute to a generalized negative view of the environment. Evidence does suggest that individuals with MDD have a tendency to engage in depression-perpetuating ruminations (Nolen-Hoeksema, 1991) and to selectively attend to, remember, and interpret events in a way that is congruent with negative mood states (Williams, Mathews, & MacLeod, 1996; Wray, Freund, & Dougher, 2009). Given these cognitive biases, cognitive resources would thus be misdirected towards experiences that are non-reinforcing or punishing, thereby decreasing an individual’s chance of experiencing pleasure even if they are capable of doing so.

Our findings have implications for cognitive-behavioral interventions such as Behavioral Activation Treatment for Depression (BATD) (Lejuez, Hopko, Acierno, Daughters, & Pagoto, 2011), which directly targets re-engagement. Given that our study found that individuals with MDD were slower to avoid ‘disliked’ stimulus words than ‘liked’ stimulus words, therapy could focus on not only selecting activity goals to engage in, but also setting appropriate avoidance goals to allow for better resource allocation, i.e. to reduce time spent

in unproductive, detrimental, or less valued activities, improve time management skills, and redirect resources towards desired and identified goals. When examining barriers to pleasure, a patient's relationship to negative, undesirable activities could be explored for its role in possibly interfering with efforts to engage in positive activities. A study of cognitive resource allocation under conditions of high interference found that higher levels of rumination correlated with poor performance on a cognitive task that required high but not low levels of engagement (Levens, Muhtadie, & Gotlib, 2009), suggesting that MDD participants performed attentional tasks less efficiently, and that their goal-directed behavior may be compromised by negative interference (Kaiser et al., 2015). In our study, MDD participants were not faster to approach 'disliked' over 'liked' stimuli, but the effect did approach significance and could be explored in future studies.

The study has several strengths. First, we operationalized the important concepts of 'liking' and 'wanting'—both drawn from the reward processing and motivation literature—and applied them to the study of anhedonia in MDD. Second, the WRT part of the study enabled us to directly assess 'liked' activities and, thus, to validate the process of selecting a 'liked' stimulus word pool by delegating this task to the participants themselves; this made the stimulus words personally relevant, which in turn closely approximated what individual participants were interested in and what was potentially pleasurable. Correlations of ratings with clinical measures of anhedonia suggest that this is a potentially useful experimental assessment of hedonic capacity. Third, the 'wanting' aspect was studied as movement toward self (approach) in response to the stimulus words. Previous studies have sought to separate 'liking' and 'wanting' processes in experimental paradigms (for example, in relation to food (Piqueras-Fiszman, Kraus, & Spence, 2014)), used individually-rated stimuli in approach/avoidance experiments (for example, faces rated for attractiveness (Chelnokova et al., 2014)), and examined social approach and avoidance in MDD using emotional faces (Radke, Güths, André, Müller, & de Bruijn, 2014). However, our task is, to our knowledge, the first laboratory experiment that attempts to precisely model individual selection of reinforcers and action towards 'liked' activities in MDD, and to conceptually link these preferences with the clinical symptoms of anhedonia. Fourth, this study was conducted with a medication-free MDD sample as well as a rigorously screened group of healthy controls, allowing us to limit variability related to medication in MDD and to familial depression risk in healthy controls. Finally, the high accuracy of performance indicates that the task did not place excessive cognitive demands on MDD participants, which could have compromised the assessment of the constructs of interest. Our paradigm can be further refined and applied in future studies of depression or other conditions where reinforcement behavior and anhedonia are of interest.

Nevertheless, the study also had several limitations. First is the sensitivity of the apparatus, as the standard ATK3 joystick did not only limit movement towards and away. Second, we could not control for lexical frequency as the words used to elicit approach and avoidance movement differed for each participant. While we observed a robust between-group difference on the WRT, we only observed within-group pattern differences in MDD in the approach/avoidance task, possibly because the study was underpowered due to the smaller than planned sample size.

Taken together, the results of this study identified several behavioral changes in individuals with MDD that may contribute to their inadequate engagement with reinforcing activities in their everyday lives. ‘Liking’ was compromised in terms of finding hedonic potential in fewer opportunities, and ‘wanting’ appeared to be misdirected towards what the MDD participants themselves rated as undesirable. With regard to explaining ‘lack of interest or pleasure’ as a core symptom of MDD, it appears that the tendency to be slower at avoiding unpleasant activities coupled with the tendency to approach ‘disliked’ activities observed in MDD participants may expand negative processes rather than limit positive environmental interactions. In this sense, the hedonic principle—that is, repeating behaviors that can lead to pleasure—may be replaced by the ‘anti-hedonic’ principle—repeating behaviors likely to result in a negative experience in order to maintain a negative view of self, the world, and the environment.

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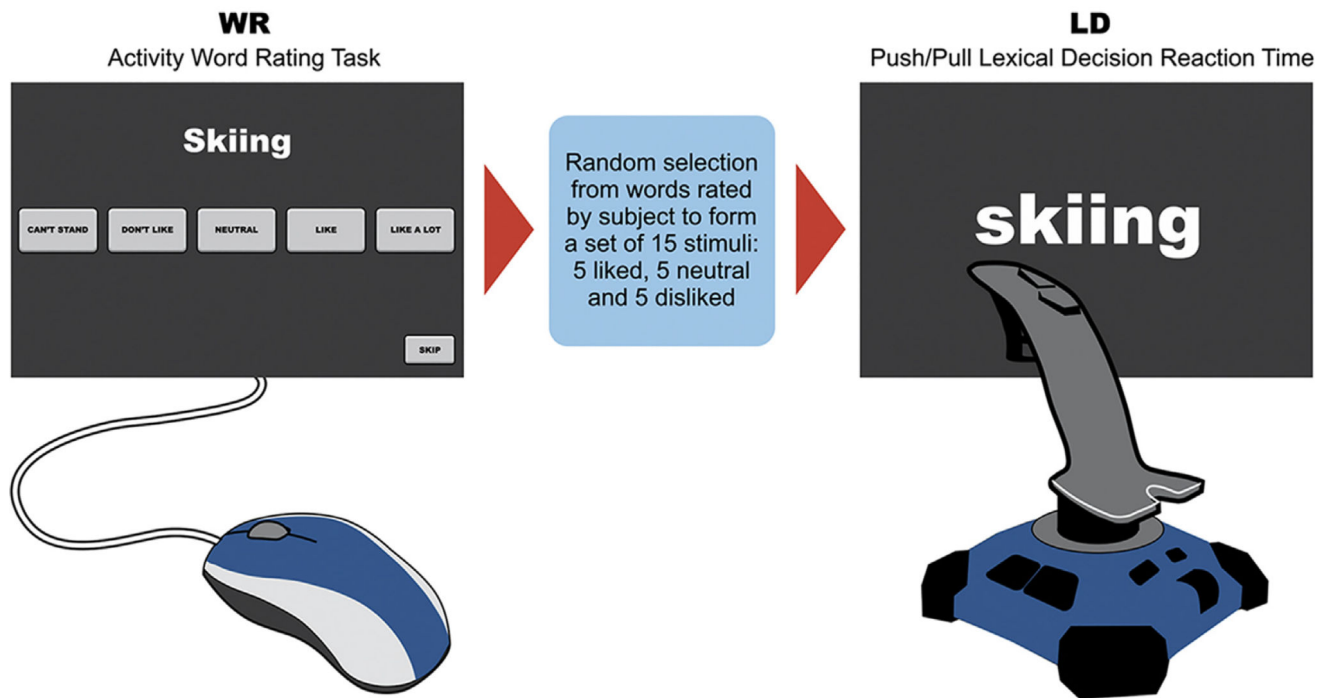
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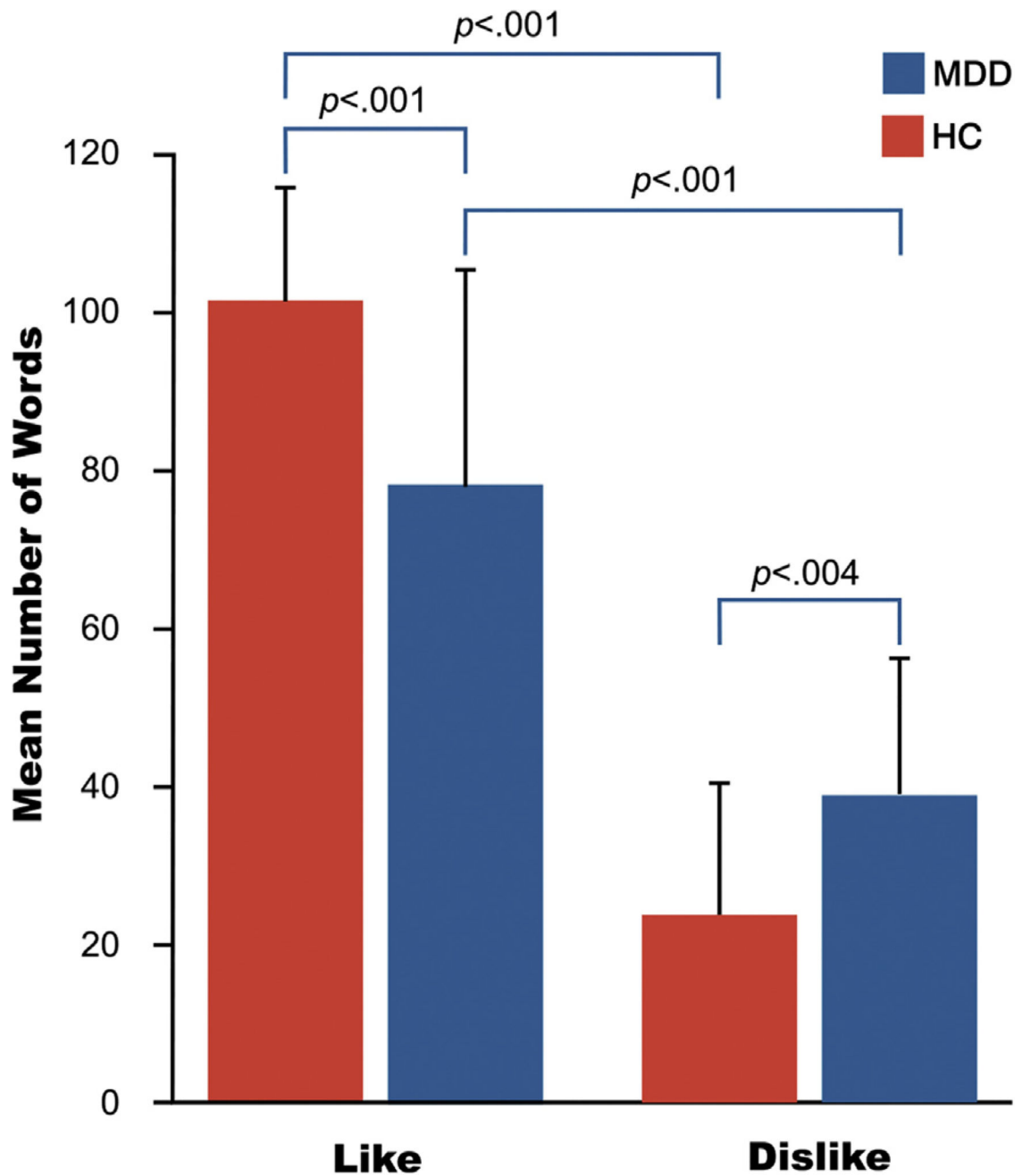
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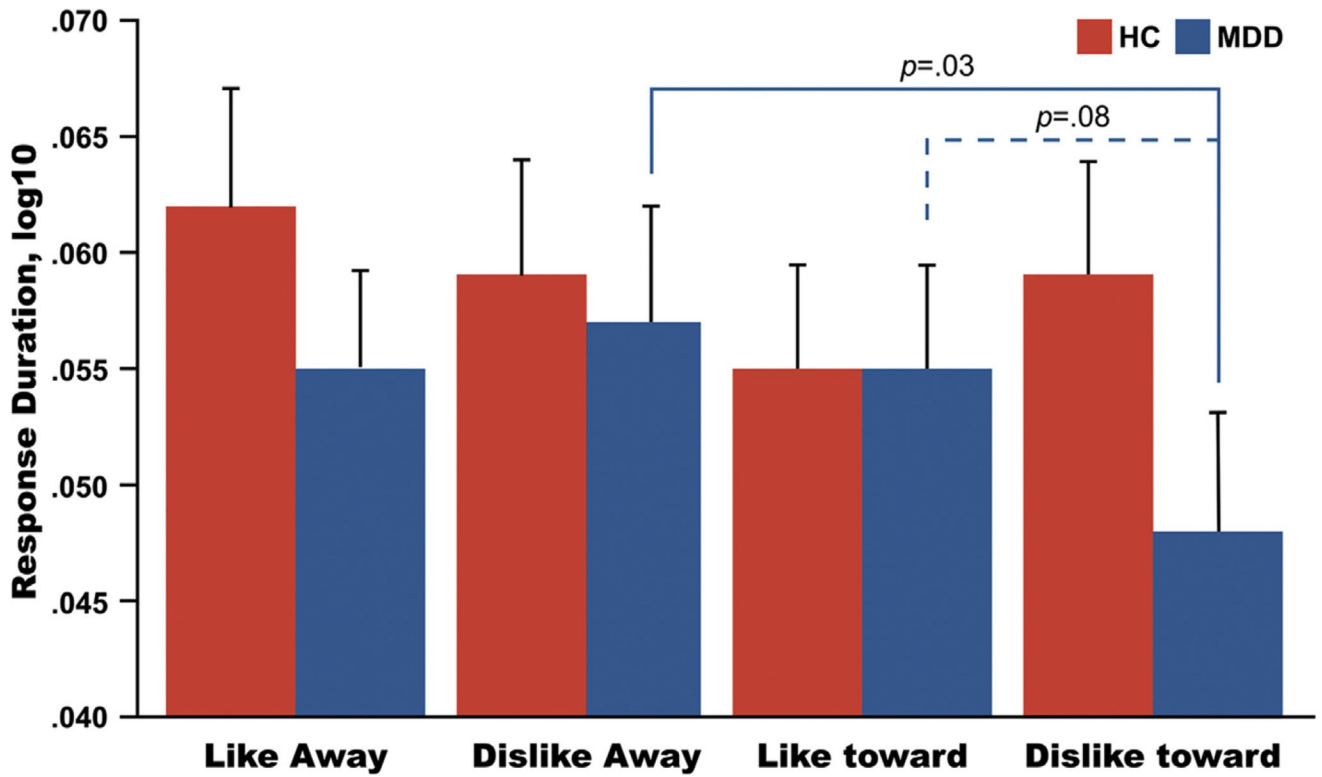
## 2 Components of BAMP



**Fig. 1.** An illustration of the Behavioral Approach Motivation Paradigm (BAMP). In the Word Rating Task (WRT), participants rated how much they ‘liked’ 150 words on a scale from 0 to 4, with 0 and 1 representing ‘disliked’, 2 being ‘neutral’, and 3 or 4 representing ‘liked’. They were allowed to skip up to 10 words and the cursor reset after each item. Next, 15 words were randomly selected and subsequently used in the Lexical Decision Reaction Time Task (LDT), where participants were required to decide whether an item was a word or a non-word (scrambled target words), and push or pull the joystick depending on the item category.



**Fig. 2.** Results of the activity Word Rating Task (WRT), mean, SD. Healthy controls rated more words as 'liked' and fewer as 'disliked' than participants with major depressive disorder (MDD). Both groups rated more words as 'liked' than 'disliked'.



**Fig. 3.** Approach and avoidance of ‘liked’ and ‘disliked’ stimulus words, mean, SEM. Response duration: group  $\times$  direction  $\times$  valence,  $p < 0.01$ . MDD: major depressive disorder; HC: healthy control.

**Table 1**

Demographic information for MDD participants and healthy controls.

	<b>Overall (n = 44)</b>	<b>HC (n = 23)</b>	<b>MDD (n = 21)</b>	<b>p value</b>
<b>Demographics</b>				
Age, mean (SD)	33.6 (7.9)	31.8 (8.0)	35.5 (7.5)	0.12
Gender				
Male, %	61.4	56.5	61.9	0.94 <sup>#</sup>
Female, %	38.6	43.5	38.1	
Education, years	16.7 (2.3)	17.1 (1.8)	16.3 (2.8)	0.31
Ethnicity	W = 32, AA = 5 API = 5, H = 2	W = 15, AA = 3 API = 3, H = 2	W = 17, AA = 2 API = 2	
<b>Assessments</b>				
BDI-II	16.5 (17.0)	1.7 (2.8)	32.7 (9.5)	0.00
SHAPS	28.3 (10.5)	19.6 (5.0)	37.8 (5.6)	0.00
JAMS	12.7 (3.8)	15.3 (2.5)	9.9 (2.8)	0.00
BAS-drive	9.8 (3.1)	11.3 (2.6)	8.1 (2.7)	0.00
BAS-reward	15.8 (3.6)	18.0 (1.9)	13.5 (3.5)	0.00
BAS-fun	10.3 (2.9)	11.8 (2.1)	8.7 (2.8)	0.00
BAS total	36.0 (8.2)	41.1 (5.2)	30.3 (7.1)	0.00
BIS	21.4 (5.0)	18.4 (4.2)	24.6 (3.7)	0.00
Chapman Social Anhedonia	13.3 (10.1)	6.7 (4.8)	20.6 (9.3)	0.00
Chapman Physical Anhedonia	15.3 (11.8)	9.1 (6.4)	22.0 (12.7)	0.00
Chapman Anhedonia Total	28.4 (21.0)	15.5 (9.8)	42.6 (21.1)	0.00

<sup>#</sup>Mann -Whitney U; Abbreviations: W: White (of European descent); AA: African American; API: Asian/Pacific Islander; H: Hispanic; BDI-II: Beck Depression Inventory; SHAPS: Snaith Hamilton Pleasure Scale; JAMS: Jackson Appetitive Motivation Scale; BAS: Behavior Activation Scale; BIS: Behavior Inhibition Scale; MDD: major depressive disorder; HC: healthy control.

**Table 2**

Summary of LDT results for healthy control and MDD participants.

	HC (n = 23)	MDD (n = 21)	Two tail <i>t</i> -test <i>p</i> value
<b>Word ratings for stimuli used in LDT, mean, SD</b>			
'Liked' (3–4)	4.0 (0.0)	3.9 (0.3)	0.16
'Disliked' (0–1)	0.44 (0.54)	0.23 (0.35)	0.17
<b>Reaction time, mean, SD</b>			
'Like' away	2.80 (0.073)	2.84 (0.106)	0.14
'Dislike' away	2.81 (0.069)	2.84 (0.107)	0.30
'Like' toward	2.81 (0.076)	2.83 (0.089)	0.31
'Dislike' toward	2.80 (0.072)	2.84 (0.105)	0.15
<b>Response duration, mean, SD</b>			
'Like' away	0.0619 (0.024)	0.0556 (0.016)	0.32
'Dislike' away	0.0585 (0.025)	0.0575 (0.017)	0.89
'Like' toward	0.0553 (0.020)	0.0549 (0.021)	0.94
'Dislike' toward	0.0585 (0.025)	0.0489 (0.013)	0.13

Abbreviations: HC: healthy control; MDD: major depressive disorder; LDT: Lexical Decision Reaction Time Task.