Affective Predictors of Disrupted Reward-Seeking in Depression

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THESIS

Submitted as partial fulfillment of the requirements
for the degree of Master of Arts in Psychology
in the Graduate College of the
University of Illinois at Chicago, 2015

Chicago, Illinois

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ACKNOWLEDGMENTS

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LIST OF ABBREVIATIONS

a-MDD   Active MDD

AMW   Amount of Money Won

BA   Behavioral Activation

BAS   Behavioral Activation Scale

BAS-RR   Behavioral Activation Scale Reward-Responsiveness

BAS-D   Behavioral Activation Scale Drive

BI   Behavioral Inhibition

BIS   Behavioral Inhibition Scale

fMRI   Functional Magnetic Resonance Imaging

HAM-A   Hamilton Rating Scale for Anxiety

HAM-D   Hamilton Rating Scale for Depression

HC   Healthy Control

MDD   Major Depressive Disorder

MIDT   Monetary Incentive Delay Task

mMIDT   Modified Monetary Incentive Delay Task

r-MDD   Remitted Major Depressive Disorder

RT   Reaction Time

SD   Standard Deviation

SUMMARY

Individuals with MDD approach and pursue reward differently from healthy individuals because of increased anhedonia, or the lack of motivation to seek out reward and blunted reward responsiveness, and increased behavioral inhibition (BI), which manifests as heightened sensitivity to loss and punishment. Trait behavioral activation (BA), as a proxy for anhedonia, and BI may moderate the relationship between depression and reward pursuit. The present studies investigated the differential and predictive roles of BA and BI in reward pursuit behavior in active (Study 1) and remitted (Study 2) MDD individuals, compared to healthy controls. BA and BI were operationalized as scores on the Behavioral Inhibition System and Behavioral Activation System Scale. Reward pursuit was assessed by performance on the modified Monetary Incentive Delay Task (mMIDT), a measure of reward sensitivity that was individually adjusted to theoretically elicit 50%-80% accuracy in all participants. Despite the individualized adjustment of task parameters that aimed to equate accuracy between groups, active MDD participants performed worse than healthy controls. The performance of the MDD group was predicted by Reward-Responsiveness, a component of BA. Study 2 aimed to clarify trait predictors of reward learning that may co-occur with history of depression. Study 2 recruited individuals with remitted MDD in a narrower and younger age range, to eliminate the possible confounds of age and chronicity of illness. In Study 2, remitted MDD participants performed similarly to healthy participants, and neither BA nor BI predicted performance. Study 2 results suggest that reward processing deficits co-occur with active MDD symptoms, and are predicted by increased anhedonia, as measured by the BA scale. Delineating deficits in reward pursuit may lead to a greater understanding of the behavioral activation and inhibition systems, and may inform intervention plans for select MDD patients.

A.   <u>Introduction</u>

Depression is the second leading cause of disability in the world (Ferrari et al., 2013) and carries a 16.5% lifetime prevalence rate in American adults (NIMH, 2013). Such high rates of occurrence nationally and globally demonstrate the critical need for continuing research into the etiology and treatment of this disorder. Anhedonia, the reduced anticipation of pleasurable stimuli and blunted responsiveness to reward, is one of the core symptoms of major depressive disorder (MDD) in the DSM-5 (American Psychiatric Association, 2013) and has been shown to be a predictor of antidepressant efficacy (Keedwell et al., 2005). Anhedonia contributes to reward-processing deficits in depression (Treadway & Zald, 2011) and can be studied using paradigms that assess both anticipatory and consummatory processes.

It is not yet clear whether anhedonia in MDD is a trait that can be exacerbated during active states of illness, or whether it is a transient marker associated with acute disease. One way to probe this particular question is to determine whether trait personality markers of reward anticipation and pursuit are lowered in active and remitted states of MDD. The Behavioral Activation Scale (BAS) is a personality trait scale that probes the stability of desire for and pursuit of hedonic goals. The BAS measures traits related to feelings of elation and desire through incentivized pursuit of rewards, and has three subcomponents: Reward-Responsiveness, Drive, and Fun-Seeking. We focused specifically on Reward-Responsiveness and Drive, which are more specifically related to anhedonia. The BAS also has a parallel scale, the Behavioral Inhibition Scale (BIS), measuring anxiety and over-reactive inhibition due to sensitivity to threat cues and punishment (Carver & White, 1994; Johnson et al., 2003).   The authors of the questionnaire have demonstrated divergence of the two scales, claiming that BAS and BIS are distinct constructs (Carver & White, 1994). Notably, BAS and BIS correlate with

the related personality constructs positive affect and neuroticism, respectively (Campbell-Sills et al., 2004).

Individuals with MDD have lowered BA Reward-Responsiveness and Drive, which may impair functioning in reward pursuit and may predict symptom change over time (Kasch et al., 2002). Lowered BA may result in a decreased advantageous response bias, in that those with MDD may have difficulty modulating their behavior to respond positively to ambiguous cues in the context of reward contingencies (Pizzagalli et al., 2009a). This diminished responsiveness to reinforcement may lead to decreased drive towards, learning of, and engagement in pleasurable activities and rewards (Pizzagalli et al., 2009a). Indeed, participants with MDD exhibit reduced reward responsiveness by failing to modify their responding in order to maximize gains during a behavioral reward-seeking task (Henriques & Davidson, 2000). These deficits could be due to difficulty incorporating internal feedback (perceived error or discrepancy between desired goal and actual attainment), or affective interference with goal pursuit. It may also be a response to external feedback (failed goal attainment), interfering with learning and behavior modification (Holmes & Pizzagalli, 2007). These disruptions in individuals with depression could be a result of BA dysfunction resulting in low motivation and pursuit and/or increased BI over-function interfering with such processes.

Particularly when considering BI, patients with MDD seem to perceive punishment more readily and intensely than non-MDD individuals, which could trigger negative thoughts, strengthen BI, and interfere with the successful pursuit of reward (Eshel & Roiser, 2010). Task paradigms that include punishment trials in addition to reward trials attempt to tease apart hypoactive BA functioning from hyperactive BI functioning, with the consideration that the BI may suppress BA in punishment trials. In support of this supposition, individuals with subthreshold MDD are more willing to classify ambiguous stimuli as cues for punishment rather than reward, demonstrating increased sensitivity to

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aversive stimuli and decreased reward-responsiveness (Henriques et al., 1994). Similarly, MDD patients are more likely to classify ambiguous facial expressions as negative versus positive (Bouhuys et al., 1999), providing further evidence that individuals with MDD systematically interpret ambiguous stimuli with a negative bias. Furthermore, the degree to which r-MDD patients (currently euthymic individuals who have experienced one or more episodes of depression) perceive negative emotions in ambiguous faces predicts relapse (Bouhuys et al., 1999). It is important to better understand this negative bias in MDD, whether it is related to BI, and how it may interfere with MDD individuals pursuing and attaining pleasure. This may be particularly true in contexts where there are potential rewards to be gained but the cues are ambiguous or certainty of reward is unclear.

In addition to impaired reward pursuit, individuals with MDD commonly experience psychomotor slowing (Buyukdura et al., 2011). In fact, anhedonia and psychomotor retardation may share an underlying neurobiology, specifically the mesolimbic and mesostriatal dopaminergic pathways (Stein, 2008). Several studies have found that as compared to healthy controls, depressed participants had slower decision and motor response times (Sobin & Sackeim, 1997). Psychomotor slowing may confound measurements where reaction time is key. When using tasks that depend on reaction time but where reaction time is not the variable of interest, it is important to make task adjustments that address psychomotor slowing in MDD individuals.

The present investigation sought to evaluate differences in reward pursuit between individuals with active MDD (a-MDD) and never-depressed individuals (healthy controls). Additionally, we investigated whether BAS and BIS scores predict performance on a reward pursuit task. BI was operationalized as the BIS score and BA was characterized as BAS Drive and BAS Reward-Responsiveness scores (Carver & White, 1994). Reward pursuit and attainment was assessed using the modified Monetary Incentive Delay Task (mMIDT).

In Study 1, we first hypothesized that a-MDD participants, relative to never-depressed participants (healthy controls; HC), would have lower accuracy (win less money), than in the baseline portion of the behavioral mMIDT. To help participants perform between 50% and 80% accuracy as well as address the psychomotor retardation that is potentially inherent to MDD (Buyukdura et al., 2011), we modified the MIDT (Knutson et al., 2000) by adding within-run modulation of response time. This was accomplished by individually adjusting response time windows. Response time windows were lengthened to accommodate participants with slower responses and shortened to challenge those with faster responses. As a result of this titration procedure, our second hypothesis was that performance differences between groups would decrease, and no longer be significant by runs 3 and 4. Third, we hypothesized that for a-MDD individuals, the BIS/BAS scales, especially BAS Reward-Responsiveness, would predict performance on the baseline and titrated mMIDT. We predicted that the BIS/BAS scales would predict the titrated mMIDT performance more strongly because response time variance was reduced.

B.   Methods

    1.   Participants

        Participants were 18-55 years old and were free of any chronic or serious medical condition. Participants with MDD met DSM-IV criteria for current MDD, were free of psychotropic medication in the past three months. Anxiety disorders were allowed. HC participants had no personal or family history of any psychiatric disorder. Exclusionary criteria included current or past psychotic symptoms, a family history of psychosis, a history of suicidal attempts or ideation in the past six months, regular tobacco use (more than 10 cigarettes per week), and presence of alcohol or substance abuse in the last six months. See Table I for demographic information.

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2. <u>Measures</u>

      a.   <u>Behavioral Inhibition Scale/Behavioral Activation Scale (BIS/BAS)</u>

The BIS/BAS is a 20-item self-report measure that assesses trait inhibition and appetitive motivation (Carver & White, 1994). We used two of the three BAS subscales: Drive (BAS-D) and Reward-Responsiveness (BAS-RR). The BAS-D assessed the degree to which an individual will persistently pursue a desired goal ("I go out of my way to get things I want"). The BAS-RR probed positive responses to the anticipation or occurrence of reward ("When I get something I want, I feel excited and energized"). The third BAS subscale, Fun Seeking, measured the desire for novelty-seeking and impulsivity. Because Fun Seeking is less relevant to the construct of diminished reward pursuit and attainment being tested here, it was not included as a predictor variable. In contrast, the BIS measured punishment anticipation, sensitivity to anxiety-provoking circumstances ("Criticism or scolding hurts me quite a bit"), and conflict generation and resolution (McNaughton & Gray, 2000). Items are rated on a Likert scale (1 = strongly disagree; 4 = strongly agree). The BIS/BAS has appropriate divergent and convergent validity, test-retest correlations ranging from .59 to .69 (Carver & White, 1994), good psychometric properties, high internal consistency, moderate intercorrelation of the BAS subscales, modest inverse correlation of the BAS and BIS scales, and high long-term reliability in assessing stable characteristics in a depressed sample (Kasch et al., 2002).

      b.   <u>Modified Monetary Incentive Delay Task (mMIDT)</u>

The mMIDT was a 24-minute task in which participants responded to a simple visual stimulus (target) with an index-finger button-press within a predefined response window. The task was completed during fMRI. There were three types of trials: win, neutral, and loss trials. At the beginning of each trial, the type of trial upcoming and amount of money at stake was indicated by a cue: "win $5" or "win $0.20" in a red circle, "don't lose $5" or "don't lose $0.20" in a blue square, or

"no money at stake" in a green triangle. The cue then disappeared and, after a variable delay, a white square (the target) flashed on the screen. Upon seeing the target, participants had to press the button within the response window in order to win $0.20 or $5 (on win trials) or avoid losing $0.20 or $5 (on loss trials). On neutral trials, no money was at stake, no matter how quickly participants respond. After the target disappeared, they received feedback as to whether they won or lost money. The three types of trials yielded nine possible outcomes: small win ($0.20/none), big win ($5/none), small loss (none/-$0.20), big loss (none/-$5), or no money at stake ($0). The inter-trial interval was jittered, resulting in an average trial duration of 2000ms. Each run contained 25 trials (5 per type) and lasted about 6 minutes.

Before completing runs 1 – 4, participants completed a 25-trial baseline run. Besides acquainting participants with the task, the purpose of the baseline task (with a fixed 250 ms response time) was to measure each participant's reaction time to the target stimulus and then titrate the actual task to that individualized response window. For example, if a participant's average reaction time to the target during the baseline is 220 ms with a standard deviation of 30 ms, the initial response window is set to 265 ms for run one (mean plus 1.5*SD). If performance in the next run is lower than 50%, we make the task slower; if subsequent performance is better than 80% we make the task faster, in increments of .5 SD. The individual titration process should result in each participant making a correct response above 50% and less than 80% of the time. Titration adjustments were also made after the first and second runs of the fMRI task based upon performance, which was tracked by the experimenter and kept blind to the participant. Participants were told that only their performance on runs three and four would count towards their total earnings (up to $52 more than the base compensation) and that no money would be taken away if their final performance was below $0. The titration procedure adapts the task to the participant's advantage so they can win a majority of the

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trials. Titration also standardizes the task by removing the effect of each participant's individual

psychomotor ability.

Baseline psychomotor speed and working memory differences were evaluated using Digit

Symbol and Digit Span WAIS subtests (Wechsler, 1997), Go response time and accuracy for level 1 of

the Parametric Go/No-go test (Langenecker et al., 2007), and the Purdue Pegboard test (Tiffin &

Asher, 1948; to assess dominant hand dexterity/speed; see Table I).

Computerized tasks were presented in E-Prime (Version 2.0, Psychology Software Tools Inc.,

Pittsburgh PA, USA).

Table I
Participant Characteristics, Neuropsychological Variables, and Predictors in Study 1

Measure	a-MDD (n = 27) M (SD)	HC (n = 27) M (SD)	t	p
Gender (% female)	74.1	77.8	$\chi^2 = .101$	.75
Age	27.07 (6.73)	30.96 (10.17)	1.66*	.11
Education[a]	15.80 (1.63)	15.31 (1.74)	-1.04	.30
Shipley Estimated IQ[a]	111.58 (6.31)	102.28 (23.98)	-1.63	.11
HAM-D[a]	18.48 (4.24)	.15 (.46)	-21.48*	<.001
HAM-A[a]	18.55 (7.69)	.16 (.50)	-11.19*	<.001
No. of Depressive Episodes[b]	4.30 (6.67)	0.00 (0.00)	-2.89*	.009
BAS-RR[c]	15.38 (2.97)	17.00 (1.59)	2.13*	.04
BIS[c]	23.90 (3.85)	17.19 (3.02)	-5.76	<.001
BAS-D[c]	8.76 (2.33)	11.31 (1.40)	3.85	<.001
Go Target Reaction Time (ms)[b]	438.79 (47.19)	409.54 (32.12)	-1.96	.06
Go Target Accuracy (%)[b]	.95 (.06)	.98 (.03)	1.65*	.12
Digit Span (scaled)[a]	10.86 (2.64)	11.0 (3.02)	.15	.88
Digit Symbol (scaled)[a]	11.35 (3.30)	13.44 (2.89)	2.07	.05
Purdue Pegboard (right hand) (s)[a]	14.55 (4.110)	15.50 (2.33)	.61	.55

* Levene's test indicated equal variances not assumed.
[a]Missing data for up to 9 participants per group.
[b]Missing data for 13 a-MDD participants.
[c] Sample size reduced because not all participants completed the BIS/BAS (a-MDD = 21, HC = 16)

2.   Procedures

Participants were recruited from the community and initially screened over the phone by a trained research assistant. All study procedures were approved by the University of Michigan IRB, and participants provided informed consent consistent with the Declaration of Helsinki. A trained doctoral-level interviewer conducted the Structured Clinical Interview for DSM-IV (SCID) to confirm a diagnosis of MDD, as well as the Hamilton Anxiety Rating Scale (HAM-A), and Hamilton Depression Rating Scale 17 (HAM-D). The present study was part of a larger protocol that included a comprehensive battery of neuropsychological tests, self-report measures (Behavioral Inhibition System/Behavioral Activation System Scales [BIS/BAS]), and structural and functional magnetic resonance imaging (fMRI), which will be reported elsewhere. Participants were compensated $30 for the SCID intake, and $100 for the fMRI session, with an additional $0-52 for their performance on the final two runs of the mMIDT.

3.   Statistical Analyses

In SPSS (IBM SPSS Statistics for Macintosh, Version 22.0), repeated measures ANOVA was used to compare groups on the net amount of money won (AMW), with AMW in the baseline task and AMW in the titrated task (runs 3 and 4) as the repeated dependent variable. Hierarchical linear multiple regressions were used to predict AMW in runs 3 and 4 using diagnostic group, BAS-RR, BAS-D, and BIS as predictors. One regression was run with the entire sample, and a second was computed with the a-MDD group only. In the first regression, we entered diagnostic group in the first block, BAS-RR, BAS-D, and BIS in the second block, interaction terms for the BIS/BAS in the third block, and age as a covariate in the fourth block. Non-significant variables were then removed and a reduced model with only diagnostic group and the BIS/BAS variables was run. In the second regression with a-MDD only, we entered the BIS/BAS variables in one block. HAM-A, HAM-

D, and number of depressive episodes violated assumptions of equal variance and were not used for the first regression, but were included in an additional regression with a-MDD only. Each variable was grand mean centered for Study 1 and for Study 2. All predictor variables were normally distributed.

C.   Results

Group means of the predictor variables, as well as measures of reaction time, target accuracy, working memory, attention, and motor dexterity were compared to determine whether a-MDD and healthy control groups were comparable in baseline performance (Table I). The a-MDD group performed significantly poorer in one measure of processing speed, Digit Symbol.

A repeated measures ANOVA revealed that a-MDD participants won less money than HC participants overall, $F(1, 52) = 11.42$, $p = .001$. There was also a significant interaction of diagnosis and time, $F(1, 52) = 12.08$, $p = .001$, such that groups were equivalent at baseline, $F(1, 52) = .64$, $p > .05$, but then HC participants gradually won more money while a-MDDs lost money or broke even throughout the task, $F(1, 52) = 14.42$, $p < .001$ (see Figure 1). In posthoc paired t tests, both groups had greater accuracy in win relative to null and loss trials (p's $< .05$), and in loss trials relative to null trials (p's $< .01$).
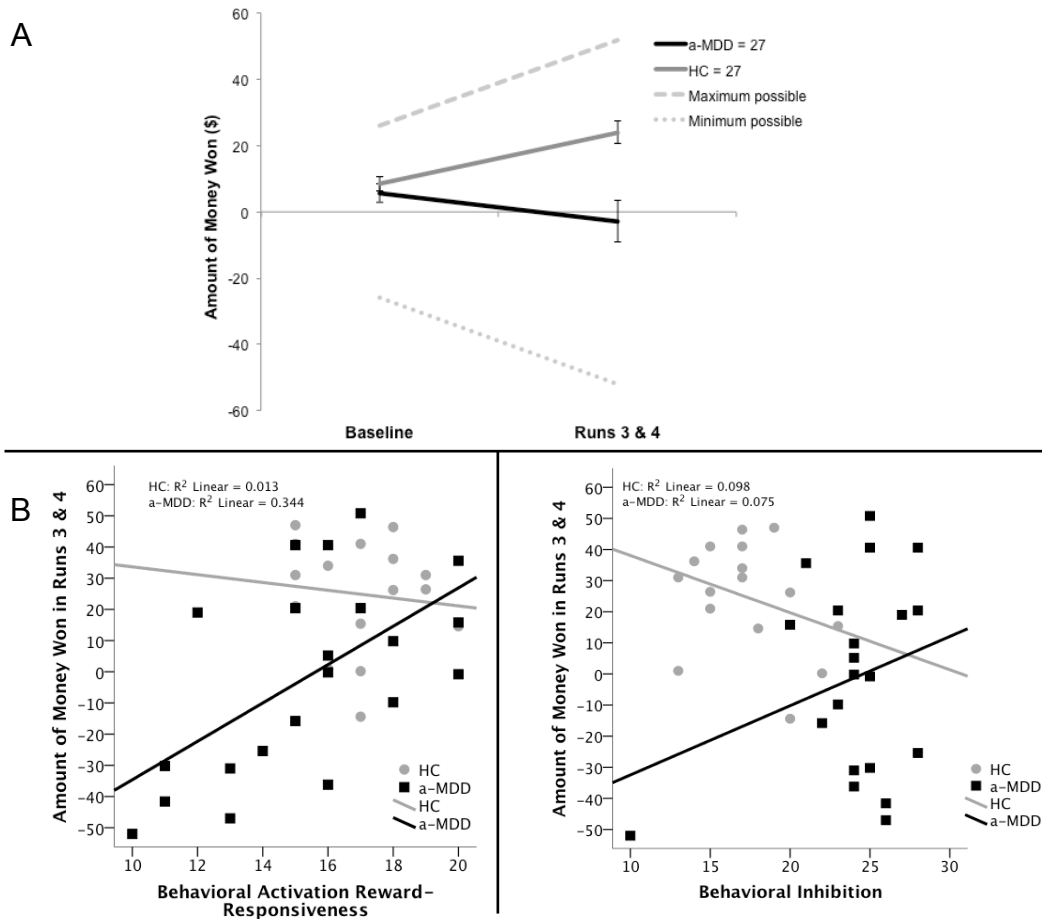
Fig. 1. Panel A: Amount of money won in both groups during baseline and in titrated runs 3 and 4 of the mMIDT. Error bars represent standard error of the mean. Panel B: Scatterplots illustrating amount of money won in runs 3 and 4 in relation to BA Reward-Responsiveness and BI in a-MDD and HC groups.

Two hierarchical multiple linear regressions were computed. The first was used to establish group differences in the relationship between the dimensional measures of BA and BI with AMW. Each of these was then run using a reduced model, i.e. excluding non-significant variables. For the entire sample in the full and reduced models, diagnostic group and the BAS Reward-Responsiveness scale predicted AMW (see Table II). The sample sizes are slightly lower in the regression analysis than the ANOVA because some participants completed the mMIDT but not the BIS/BAS. In a posthoc analysis, we removed BIS from the model to evaluate whether potential colinearity between

the BIS and BAS scales might mask an interaction between diagnosis and BAS-RR. In this posthoc

regression, diagnostic group and BAS-RR separately were significant, but not the interaction term.

The second regression examined individual differences in the a-MDD group only. In the

second full model analysis with the a-MDD group only, BAS-RR predicted AMW (see Table II). This

analysis included HAM-D, HAM-A, and number of depressive episodes as covariates, but none were

significant and were excluded in a reduced model that was run subsequently. The relationship between

BAS-RR and BIS with AMW in the titrated task is displayed in scatterplots (Figure 1).

Table II
Predicting Amount of Money Won in Runs 3 and 4 in Study 1

A	Both Groups			a-MDD Only		
Predictor	**Stand. β**	**t**	**p**	**Stand. β**	**t**	**p**
Intercept	-	2.88	<.01	-	-.38	.71
Diagnostic Group	-.48	-2.25	*.03*	-	-	-
BAS-RR	.51	3.01	*<.01*	.65	2.89	*.01*
BIS	.11	.58	.57	.25	1.33	.20
BAS-D	-.19	-.99	.33	-.13	-.57	.58
Interactions						
BAS-RR*aMDD	.48	1.38	.18	-	-	-
BIS*aMDD	.44	1.62	.12	-	-	-
BAS-D*aMDD	.25	.76	.45	-	-	-
Age	-.14	-.78	.44	-.12	-.35	.73
HAM-D	-	-	-	.08	.22	.83
HAM-A	-	-	-	.16	.59	.57
No. Depressive Episodes	-	-	-	.28	1.38	.19

As a follow-up analysis, we looked to determine whether the baseline difference in Digit

Symbol was related to AMW, finding that Digit Symbol and AMW were not correlated in the entire

sample or in the a-MDD group alone ($r = .28$, $p = .09$; $r = .14$, $p = .55$, respectively).

To assess whether the differences in AMW could be explained by differing mean RTs between

groups (overall slowing in MDD, slowing over time in MDD due to fatigue), we ran a posthoc

repeated measures ANOVA with mean RT in run 1, run 2, run 3, and run 4 as the timepoints. Both

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groups responded faster as the task went on ($p < .001$) and there was no interaction of RT and diagnostic group. To assess whether differing mean standard deviations affected performance (speed variability as an index of intermittent lapses in effort or attention), we ran a posthoc repeated measures ANOVA with mean SD in run 1, run 2, run 3, and run 4 as the timepoints. There were no differences in mean SD between runs over the course of the task, no differences between groups, and no interaction between run and group for SDs (p's $> .05$).

D.   Discussion

The main goal of Study 1 was to evaluate the sensitivity of individuals with MDD to reward-based tasks and whether measures of BA and BI were predictive of performance. We hypothesized that the a-MDD group would win less money in the baseline mMIDT than the HC group, and that a-MDD and HC groups would win equivalent amounts of money in the titrated condition. Contrary to both hypotheses, performance accuracy for the HC and a-MDD groups did not differ significantly in the baseline mMIDT but did differ in the titrated portion. We also hypothesized that the BIS/BAS scale (especially BAS-RR) would predict the mMIDT performance, and our results did support this hypothesis. The primary finding was that although titration appeared to help the HCs improve performance, the a-MDD group did not benefit from titration and failed to earn and avoid losing money, thus earning less than HCs in the titrated portion of the task.

Groups were not significantly different on most neuropsychological tests, suggesting that group differences on the mMIDT cannot be attributed to baseline differences in attention, working memory, and psychomotor ability. Active MDD and HC differed only on Digit Symbol, a measure of attention, processing speed, and working memory, which is consistent with the literature (Gotlib & Joorman, 2010; Snyder, 2013). Follow-up analyses suggested that the difference in Digit Symbol did not affect the titrated mMIDT results.

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Surprisingly, even though the task was titrated to optimize performance and indeed equalize task performance between groups, the a-MDD participants performed at the low end of the accuracy range. In spite of group differences in the titrated task, there were no significant group differences in accuracy in the baseline portion, possibly suggesting that the a-MDD group grew fatigued or disheartened as the task went on. Also possible is that HCs are more attentive and responsive to environmental changes (i.e., task parameter titration). The a-MDD group may also have had trouble sustaining engagement with the task, both sustained neural processing resources and psychomotor ability. We indirectly assessed fatigue by looking at reaction time across runs over the course of the task, and whether it varied differentially between groups. We also assessed sustained engagement by inspecting response time standard deviation across runs and between groups. There were no interactions between diagnostic group and RT or SD, meaning that these variables did not change differentially between groups over the course of the task. Notably, though, there was significant missing data for reaction time because response time was not captured if participants responded after the cue had disappeared from the screen. Given the missing data we can only speculate that fatigue and sustained attention are not alternate explanations for the findings.

Inability to earn money as the task progressed may reflect an inability to sustain positive emotion over time (Heller et al., 2009). In another study using an emotion regulation task, in which depressed participants were instructed to up-regulate their response to positive images, nucleus accumbens activation decreased over time, suggesting that individuals with MDD may have difficulty sustaining positive affect and reward-related neural activity (Heller et al, 2009).

Given the differences after titration, we investigated whether BA and BI trait factors moderated the effect of the titration procedure differently for each group. In support of our third hypothesis, a-MDD participants' BAS Reward-Responsiveness scores predicted AMW in the titrated condition,

whereas this was not the case in the baseline condition. BAS-RR scores capture an inclination of attention toward and enjoyment of positive experiences. Although it is possible that this trait characteristic is unrelated to psychomotor speed and pursuit of reward, controlling for psychomotor speed (in the titrated task runs) made the relationship between Reward-Responsiveness scores and task performance stronger. The BAS Drive scale did not predict total amount won, possibly because the mMIDT does not involve a voluntary initiation of the pursuit of reward and participants are told that a set amount of money is available to them to earn.

The BIS scale also did not predict total amount won. Nonetheless, because people with MDD tend to be hypersensitive to punishment (Henrique et al., 1994; Eshel & Roiser, 2010), losses early in the task could have triggered rumination and feelings of hopelessness about doing well on the rest of the task. This cognitive-emotional interference with motivation (Papageorgiou & Siegle, 2003) could result in slower reaction times and less money won in the a-MDD group. Failing to win money and increased loss of money could confirm depressed participants' pathologically negative self-image and interfere with their ability to achieve and sustain good performance (Eshel & Roiser, 2010). In contrast, in the context of reward HC participants may be more resilient to initial difficulty and persist in learning and adapting.

II. STUDY 2

A.   <u>Introduction</u>

Although previous research has suggested that depressed patients are able to recover select neuropsychological functions in remission (Lin et al., 2014), few studies have looked at reward pursuit and attainment in r-MDD individuals. Studying reward-processing in remitted MDD allows for better focus on trait or scar effects of illness, given the minimal effects of depressive symptoms. In one study of remitted depressed (r-MDD) individuals, participants exhibited neural hyperactivation and slowed responses during the anticipation of reward and hypoactivation when receiving feedback, relative to HC (Dichter et al., 2012). Remitted MDD individuals may need to over-recruit neural resources to attain rewards (Dichter et al., 2012). Despite being euthymic, r-MDD participants may engage in excessive rumination about the prior trial, which could interfere with anticipation and preparation for the upcoming trial, disrupting the motoric component of reward pursuit and resulting in slower behavioral responses (Dichter et al., 2012). It is also possible that cognitive interference between anticipation of reward and estimation of success may result in slower responses. In contrast, another study found hypoactivation of reward- and error-related brain regions in response to primary rewarding stimuli in an r-MDD sample (McCabe et al., 2009). Additionally, as compared to healthy individuals, r-MDD participants failed to develop a response bias towards a more frequently rewarded stimulus, even when controlling for residual anhedonic symptoms (Pechtel et al., 2013). Together, r-MDD individuals seem to experience reward-seeking deficits due to underlying neural or cognitive trait vulnerabilities that persist in remission. Alternatively, these differences in reward pursuit could be scar effects of previous episodes.

The results of Study 1 highlighted three important limitations that needed to be addressed to clarify the role of BA reward-responsiveness in MDD individuals. First, because trait BA and BI can

be altered in the context of active MDD, current MDD symptoms may have interfered with performance and estimation of trait-performance relationships. Put another way, it is unclear whether the observed differences in reward-seeking were driven by trait or state factors. Second, it is possible that chronic recurrent MDD results in diminished reward learning and pursuit due to scar effects of multiple episodes (Kerestes et al., 2012). Younger, remitted MDD individuals without significant recurrence of illness might not exhibit similar deficits to older participants with a longer MDD history. Further, examining reward-related deficits earlier in the course of illness may also help us predict the recurrence of MDEs in early adulthood. Third, the distracting fMRI scanner environment may have contributed to greater heterogeneity of performance by inducing psychomotor slowing (Gutchess & Park, 2006), preventing the a-MDD group from optimizing their performance. This third limitation could be addressed by running the task outside the scanner. Each of these limitations was addressed in the design of Study 2.

Study 2 aimed to test whether disrupted reward pursuit and attainment persist independent of active MDD symptoms and if BAS-RR is predictive. First we hypothesized that the r-MDD and HCs would perform equally on the baseline mMIDT, similar to the results with the a-MDD group. Second, we expected that after titration the HC but not r-MDD group would optimize performance, which would suggest trait reward-seeking deficits in remitted MDD. Third, we hypothesized that the BIS/BAS scales would predict performance on the titrated mMIDT in r-MDD individuals, similar to that observed in a-MDD.

B.   Methods

    1.   Participants

        Participants (ages 17-23) were enrolled under very similar inclusionary and the same exclusionary criteria as Study 1. No participants in Study 1 participated in Study 2. Remitted MDD

participants had between one and three prior episodes of MDD but no major depressive episode within the last month. Remitted MDD participants could have a family history of depression or anxiety, could have a comorbid anxiety diagnosis, and were free of psychotropic medication use in the past three months. See Table III for demographics.

2.   <u>Measures</u>

The administration of the mMIDT (including titration procedures) and BIS/BAS were identical in Study 2 compared to Study 1. To avoid any diagnosis-by-magnet interactions, the mMIDT was not administered during fMRI. Baseline psychomotor speed, attention, and working memory differences were evaluated using the Digit Symbol WAIS subtest (Wechsler, 1997), Go response time and accuracy for level 1 of the Parametric Go/No-go test (Langenecker et al., 2007), and the Purdue Pegboard test (Tiffin & Asher, 1948).

3.   <u>Procedures</u>

Participants were recruited from the community and initially phone screened by a trained research assistant. Participants gave informed consent consistent with the Declaration of Helsinki. A trained doctoral-level interviewer conducted the Diagnostic Interview for Genetic Studies, HAM-A, and HAM-D. Participants completed a neuropsychological testing battery that assessed memory, visuospatial and motor skills, inhibitory control, attention, and reward processing (the mMIDT). Participants completed the BIS/BAS and other self-report questionnaires. Participants were compensated $120 for completion of the neuropsychological battery, and had the opportunity to earn an additional $52 for the titrated portion of the mMIDT. All study procedures were approved by the University of Illinois at Chicago IRB.

Statistical analyses were identical to those used in Study 1, now with r-MDD instead of a-MDD.

C.   Results

We present the group means of the predictor variables in Table III. Groups did not differ on measures of reaction time, target accuracy, working memory, attention, or motor dexterity (see Table III).

Table III
Participant Characteristics, Neuropsychological Variables, and Predictors in Study 2

Measure	r-MDD (n = 37) M (SD)	HC (n = 23) M (SD)	t	p
Gender (% female)	70.3	52.2	$\chi^2 = 2.00$	.16
Age	21.19 (1.79)	21.34 (1.82)	.33	.74
Education	14.30 (1.58)	14.83 (1.53)	1.28	.21
Verbal IQ[a]	104.29 (9.01)	102.82 (9.37)	-.59	.56
HAM-D	2.62 (2.94)	.43 (1.04)	-4.13*	<.001
HAM-A	2.92 (3.02)	.83 (1.80)	-3.36*	.001
No. of Depressive Episodes[a]	2.24 (2.11)	0.00 (0.00)	-6.11*	<.001
BAS-RR[b]	16.85 (2.24)	16.94 (1.89)	.14	.89
BIS[b]	20.12 (3.37)	19.71 (2.47)	-.45	.66
BAS-D[b]	10.62 (2.00)	10.82 (1.47)	.38	.71
Go Target Reaction Time (ms)[a]	443.82 (38.97)	427.62 (31.76)	-1.57	.12
Go Target Accuracy (%)[a]	.96 (.04)	.98 (.03)	1.36	.18
Digit Symbol (scaled)[a]	10.92 (1.98)	10.90 (2.95)	-.03	.98
Purdue Pegboard (Dominant hand)[a]	14.95 (1.76)	15.25 (1.74)	.62	.54

* Levene's test indicated equal variances not assumed.
[a] Missing up to 4 participants per group.
[b] Sample size reduced because not all participants completed the BIS/BAS (rMDD = 34, HC = 17)

A repeated measures ANOVA revealed that r-MDD participants won equivalent amounts of money to HC participants overall, $F(1, 58) = 1.83$, $p > .05$, supporting our first hypothesis of equal performance before titration. There was an effect of time, such that both groups won more money as the task went on, $F(1, 58) = 119.70$, $p < .001$ (see Figure 2). There was no diagnosis-by-task interaction ($F(1, 58) = .142$, $p > .05$), thus failing to support our second hypothesis that HCs would show better adaptation to titration relative to the r-MDD group.

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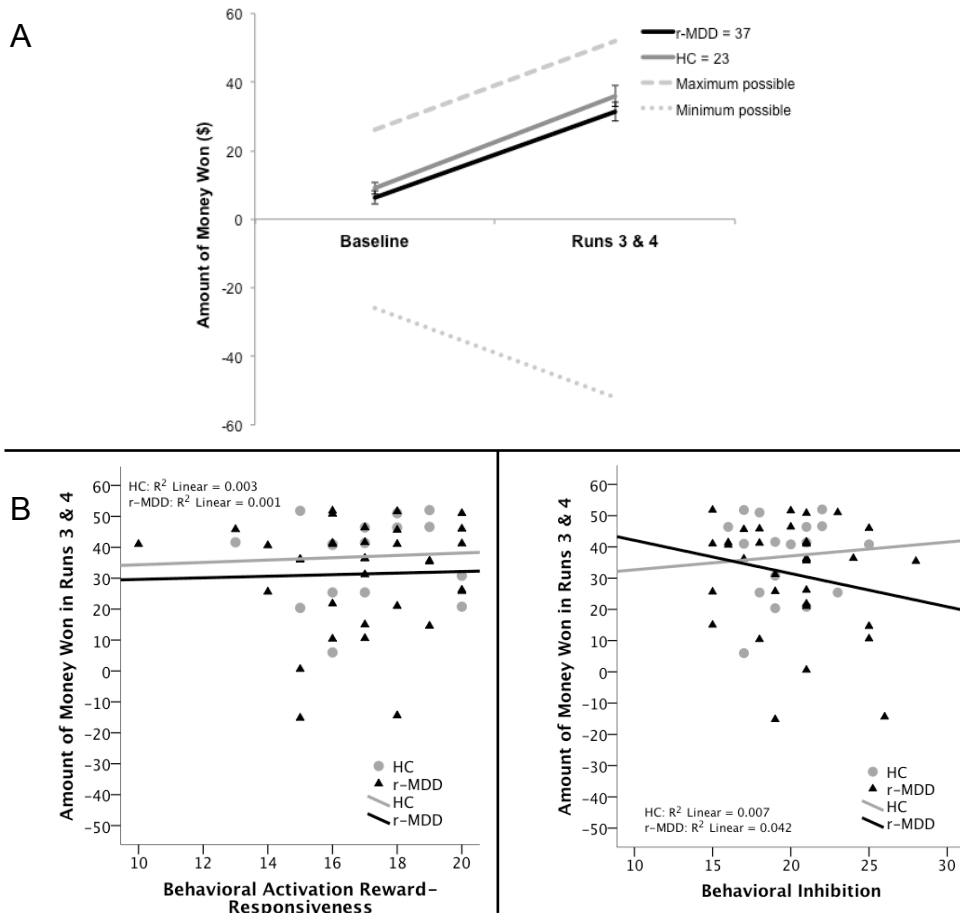
Fig 2. Panel A: Amount of money won in both groups during baseline and in titrated runs 3 and 4 of the mMIDT. Error bars represent standard error of the mean. Panel B: Scatterplots illustrating amount of money won in runs 3 and 4 in relation to BA Reward-Responsiveness and BI in r-MDD and HC groups.

Hierarchical multiple linear regressions were used to test the third hypothesis, that BAS-RR and BIS would predict AMW. In a between-groups model and an r-MDD group only model, BIS and BAS scores did not predict AMW in the baseline or titrated mMIDT, failing to support our hypothesis (see Figure 2). Table IV displays these results, with the intercept, diagnosis, and BIS/BAS beta coefficients coming from reduced models with non-significant covariates removed.

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Table IV

Predicting Amount of Money Won in Runs 3 and 4 in Study 2

Predictor	Both Groups			r-MDD Only		
	Stand. β	**t**	**p**	**Stand. β**	**t**	**p**
Intercept	-	4.75	<.001	-	9.73	<.001
Diagnostic Group	-.15	-1.03	.31	-	-	-
BAS-RR	.10	.60	.55	.22	.90	.37
BIS	-.19	-1.09	.28	-.33	-1.40	.17
BAS-D	.06	.38	.71	-.03	-.15	.89
Interactions						
BAS-RR*rMDD	-.03	-.08	.94	-	-	-
BIS*rMDD	.05	.15	.88	-	-	-
BAS-D*rMDD	.18	.51	.61	-	-	-
HAM-D	-	-	-	.36	1.22	.24
HAM-A	-	-	-	-.12	-.39	.70
No. of Depressive Episodes	-	-	-	-.04	-.22	.83

III. GENERAL DISCUSSION

This is the only study to our knowledge to evaluate the behavioral MIDT performance of a currently depressed sample contrasted with a remitted depressed sample. We found that the r-MDD group performed as well as HCs on the titrated mMIDT, whereas the a-MDD did not. This suggests that depressive symptoms significantly interfered with performance on the task, whereas remission from MDD eliminated group differences on task accuracy. However, there may be alternative explanations for the current findings. For instance, the r-MDD group may have performed better than the a-MDD group because the r-MDD participants were younger. In fact, the HC group in Study 2 performed significantly better on runs 3 and 4 than the HCs in Study 1. Younger participants may have been quicker to learn computer tasks and game contingencies than slightly older adults. They may have also been more responsive to changes in task parameters. Moreover, reward pursuit deficits in the a-MDD group could have been exacerbated by the scanner environment, which was not present in Study 2. Furthermore, the young age range of the r-MDD could mean that each individual has had fewer episodes of MDD than the older MDD participants. In other words, the a-MDD group could have been at a disadvantage due to scar effects of multiple major depressive episodes.

A key finding of Study 2 was that BIS and BAS scores of the r-MDD participants did not differ from HCs and were unrelated to the amount of money won during the task. The BIS/BAS scale may be measure of affective state in addition to trait affect, thus failing to predict reward pursuit behavior in a euthymic group. In other words, impaired reward pursuit may be a state effect of MDD and not a trait or risk factor. Negative mood state could have also affected the range of BIS/BAS scores. These results contrast previous research that has found disrupted reward learning in remitted MDD (Dichter et al., 2012; Pechtel et al., 2013), as compared to healthy controls. We may have failed to find similar

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results due to the titration procedure, which could have helped r-MDD participants perform similarly to the HCs.

Alternatively, it is possible that our data in Study 2 reflect a restricted range of scores on the BIS and BAS scales, especially BAS Reward-Responsiveness. While BAS-RR scores were equivalent between HCs in both studies, the a-MDD group's BAS-RR was significantly lower and more distributed than the r-MDD group's. This restricted range of BAS-RR for r-MDD in Study 2 could have attenuated our ability to see effects of BAS-RR on AMW. BIS scores were significantly lower in the Study 1 HCs than in Study 2 but were significantly higher in the a-MDD group than r-MDD, further suggesting that the range of scores in Study 2 may have been restricted.

Overall, our major finding was that MDD individuals perform worse on a behavioral measure of reward pursuit and attainment than healthy individuals, and that r-MDD individuals perform equally well as controls. This finding has important clinical implications in that it suggests that the group differences on a reward pursuit task may be due to state effects of illness, such as interfering cognitive deficits such as poor task concentration and enhanced concentration on negative self-focused thoughts (Gotlib & Joormann, 2010). Although frustration tolerance, fatigue, and rumination were not directly assessed, these factors could have confounded or negatively influenced performance in the a-MDD group. Fatigue and ruminative thinking are common symptoms of MDD and could have been exacerbated by the 24-minute task that frequently gave participants rumination-enhancing negative feedback. Additionally, participants with low frustration tolerance may have experienced feelings of discouragement and hopelessness, which could interfere with their performance, deepen their frustration, and continue in such a cycle. The influence of BA on reward pursuit behavior suggests that assessing and remediating anhedonic symptoms in MDD may be essential to symptom improvement and recovery of normal reward learning and pursuit processes, possibly through

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behavioral activation (Dichter et al., 2010). MDD patients with reward pursuit abnormalities may benefit from specific interventions such as cognitive restructuring to increase the salience of rewards.

There are several limitations to the present studies. First, the age range in Study 2 is narrower than in Study 2, limiting generalizability and the validity of comparison between studies. Future studies should better control for age differences and history of illness across groups. Second, the a-MDD group's performance may have been negatively influenced by the scanner environment, as even the Study 1 HCs won less money in runs 3 and 4 than Study 2 HCs. Although our results suggest that impaired reward pursuit is a consequence of active MDD rather than a trait, these limitations from Study 1 weakened our ability to dissociate state and trait effects because of confounding variables such as age, disease burden, and the magnet. Lastly, the sample sizes were relatively small. In addition, some of the individuals who completed the mMIDT did not complete BA and BI measures.

Further research should examine the functional neural correlates of this phenomenon. Many studies have found that when anticipating reward, HCs show increased activation in the nucleus accumbens and medial caudate, whereas MDD individuals show deactivation in the nucleus accumbens and increased activation in the dorsal anterior cingulate cortex (dACC) (Knutson, et al., 2001; Knutson et al., 2008; McCabe et al., 2009; Pizzagalli et al., 2009b). When anticipating non-reward or punishment, HCs show increased activation in the medial caudate (Knutson et al., 2001) and dACC (Knutson et al., 2008). The basal ganglia may also play a role in consummatory reward processes (Pizzagalli et al., 2009b). Delineating functional differences between MDD and healthy individuals could provide a way to predict first onset or risk of relapse.

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VITA

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Education

Bachelor of Arts   Stony Brook University
05/2011   Psychology (Cum. GPA: 3.95, Major GPA: 4.00)

Honors and Awards

10/2014   Young Investigator Award, National Network of Depression
                              Centers

05/2011   Graduated summa cum laude, Stony Brook University

09/2010 – 05/2011   Honors Program in Psychology, Stony Brook University

2008 – 2011   Academic Achievement Award, Stony Brook University

2007 – 2011   Dean's List (all semesters), Stony Brook University

2007 – 2011   Provost's Out-of-State Scholarship, Stony Brook University

Research Experience

Graduate Student   *Clinical Psychology Doctoral Program*
09/2013 – present   *MENDD Laboratory, Cognitive Neuroscience Center*
                              University of Illinois, Chicago, IL
                              Advisor and PI: Scott Langenecker, Ph.D.

- Develop and program fMRI tasks
- Conduct the semi-structured clinical Longitudinal Interview for Follow-Up Evaluation,
  structured Diagnostic Interview for Genetic Studies, and psychodiagnostic assessments of
  depression, suicidal ideation history, anxiety, social phobia, OCD with study participants
- Score neuropsychological assessments and preprocess fMRI data
- Screen potential participants for a study of remitted depression

Clinical Research Assistant   *McLean Hospital, Belmont, MA*
06/2011 – 07/2013   *Social, Cognitive, & Affective Neuroscience Laboratory*
                                     PIs: William Killgore, Ph.D., Scott Rauch, M.D.

- Prepare and submit IRB documents; manage regulatory requirements
- Compile grant proposals to Department of Defense funding mechanisms
- Run subjects through study protocols, including cognitive and neuropsychological testing (i.e. Repeatable Battery for the Assessment of Neuropsychological Status), structured clinical interviews (i.e. Mini International Neuropsychiatric Interview), and functional neuroimaging (fMRI) data acquisition
- Analyze behavioral and fMRI data for presentation at professional conferences

Research Assistant   *Stony Brook University, Stony Brook, NY*
09/2008 – 05/2011   *Cognitive and Affective Psychophysiology Laboratory*
                                     PI: Greg Hajcak, Ph.D.

- Collected EEG data using Biosemi 64-channel active electrode system, including sensor preparation and placement, and data monitoring
- Ran participants through reward learning, mood induction, affective processing, and cognitive ERP paradigms
- Measured startle reflex and other peripheral psychophysiological in fear conditioning paradigms, using the Contact Precision Instruments System
- Performed artifact rejection procedures on EMG startle response data
- Interacted with a range of populations, including adolescents and psychiatric outpatients

Student Volunteer   *McLean Hospital, Belmont, MA*
01/2011   *Laboratory for Affective and Translational Neuroscience*
                                     PI: Diego Pizzagalli, Ph.D.

- Performed scoring and artifact rejection on EEG data using eegscore in MATLAB
- Assisted with maintaining contact with participants enrolled in a longitudinal study
- Prepared analysis of structural and functional MRI data

Research Assistant   *Tufts University, Medford, MA*
06/2010 – 08/2010   *Emotion, Brain, and Behavior Laboratory*
                                     PI: Heather Urry, Ph.D.

- Conducted clinical screening interviews with participants over the phone
- Applied ECG, EMG, and EDA electrodes and monitored physiological data collection during an emotion regulation paradigm in participants with remitted depression
- Processed ECG and EMG data using ANS Lab in MATLAB
- Assisted with preparation of IRB documents

Independent Honors Research

09/2010 – 05/2011	Honors Thesis, Psychology Department, Stony Brook University Title: *The impact of threat of shock on the defensive startle reflex* Advisor: Greg Hajcak, Ph.D.

Supervised Clinical Experience

09/2014 – present	*Office of Applied Psychological Services* *University of Illinois, Chicago, IL* Supervisors: Gloria Balague, Ph.D., Amanda Lorenz, Ph.D., Nancy Dassoff, Ph.D.

- Conduct intake interviews with potential therapy clients
- Administer and score neuropsychological assessment batteries and write integrated reports
- Provide cognitive behavioral therapy or another appropriate evidence-based therapy

07/2011 – 07/2013	*McLean Hospital, Belmont, MA* Supervisor: Melissa Kaufman, M.D., Ph.D.

- Assessed current and past psychiatric history using the Mini International Neuropsychiatric Interview (M.I.N.I.) with nonclinical community populations and mild traumatic brain injury research subjects

Workshops and Training

01/2015	*fMRI Image Acquisition and Analysis Course* *The Mind Research Network & University of Colorado - Boulder* Instructors: Kent Kiehl, Ph.D., Vince Calhoun, Ph.D., Tor Wager, Ph.D.

- Received in-depth instruction about fMRI data acquisition, image processing, statistical analysis, experimental design, and independent component analysis (ICA)
- Implemented fMRI data processing and analysis using SPM8 and GIFT (Group ICA of fMRI Toolbox) software packages

04/2014	*Motivational Interviewing Workshop* *University of Illinois, Chicago, IL* Presenter: Kelly Lowry, Ph.D.

- Participated in 8 hours of training in motivational interviewing, covering topics such as conceptual framework, language and listening skills, agenda-setting, and action plan development

- Practiced skills through role-playing and critique of example videos

Other Experience

Resident Assistant   *Stony Brook University, Stony Brook, NY*
08/2008 – 05/2011   *Campus Residences*

- Built community in the residence hall through educational and social programming
- Addressed and resolved students' concerns through one-on-one discussions and group mediation
- Provided advice and resources for academic, physical, social, and personal well-being

Clinical Research Intern   *Aspect Medical Systems, Inc., Norwood, MA*
05/2008 – 01/2009   *Clinical Research Department*

- Processed and presented surgical and physiological data at weekly department meetings
- Compiled an instruction manual for clinical case data processing
- Maintained and monitored regulatory compliance with clinical trial site institutions
- Implemented department-wide computerized filing system

Volunteer Experience

Mental Health Screener   *McLean Hospital, Belmont, MA*
10/2012   *National Depression Screening Day*

- Conducted structured clinical interviews assessing depressive and anxious symptoms for individuals seeking depression screening and mental health care referral

Skills

- Intermediate statistical analyses in Excel and SPSS
- Intermediate programming in E-Prime
- Proficiency in pre-processing and first-level analyses of fMRI and voxel-based morphometry data in SPM 8

Society Membership

Society for a Science of Clinical Psychology (10/2014 – present)
Phi Beta Kappa (05/2011 – present)
Psi Chi (09/2009 – present)

Manuscripts

1. **DelDonno, SR**, Weldon, AL, Crane, NA, Passarotti, AM, Pruitt, PJ, Gabriel, LB, Yau, W, Meyers, KK, Hsu, DT, Taylor, SF, Heitzeg, MM, Herbener, E, Shankman, SA, Mickey, BJ,

Zubieta, JK, & Langenecker, SA. (2015). Affective personality predictors of disrupted reward learning and pursuit in major depressive disorder. *Under review.*

2. Webb, CA, **DelDonno, S**, & Killgore, WD. (2014). The role of cognitive versus emotional intelligence in Iowa Gambling Task performance: What's emotion got to do with it?. *Intelligence*, *44*, 112-119.

3. Dunning, JP, **DelDonno, S**, & Hajcak, G. (2013). The effects of contextual threat and anxiety on affective startle modulation. *Biological Psychology, 94*(1), 130-135.

4. Killgore WD, Schwab ZJ, Kipman M, **DelDonno SR**, & Weber M. (2013). Insomnia-related complaints correlate with functional connectivity between sensory-motor regions. *Neuroreport, 24*(5), 233-240.

5. Killgore WD, Schwab ZJ, Weber M, Kipman M, **DelDonno SR**, Weiner MR, & Rauch SL. (2013). Daytime sleepiness affects prefrontal regulation of food intake. *Neuroimage, 71*(1), 216-223.

6. Killgore, WDS, Schwab, ZJ, Tkachenko, O, Webb, CA, **DelDonno, SR**, Kipman, M, Rauch, SL, & Weber, M. Emotional intelligence correlates with functional responses to dynamic changes in facial trustworthiness (2013). *Social Neuroscience, 8*(4), 334-346.

7. Killgore, WD, Weber, M, Schwab, ZJ, Kipman, M, **DelDonno, S**, Webb, CA, & Rauch, SL. (2013). Cortico-limbic responsiveness to high-calorie foods predicts weight status among women. *International Journal of Obesity, 37*, 1435-1442.

8. Webb, CA, Schwab, ZJ, Weber, M, **DelDonno, S**, Kipman, M, Weiner, MR, & Killgore, WD. (2013). Convergent and divergent validity of integrative versus mixed model measure of emotional intelligence. *Intelligence, 41*(3), 149-156.

9. Weber, M, Webb, CA, **DelDonno, SR**, Kipman, M, Schwab, ZJ, Weiner, MW, & Killgore, WDS. (2013). Habitual 'sleep credit' is associated with greater grey matter volume of the medial prefrontal cortex, higher emotional intelligence and better mental health. *J of Sleep Research, 22*(5), 527-534.

10. Killgore, WD, Weber, M, Schwab, ZJ, **DelDonno, SR**, Kipman, M, Weiner, MR, & Rauch, SL. (2012). Grey matter correlates of trait and ability models of emotional intelligence. *Neuroreport, 23*, 551-555.

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12. Kipman, M, Weber, M, Schwab, ZJ, **DelDonno, SR**, & Killgore, WD. (2012). A funny thing happened on the way to the scanner: Humor detection correlates with gray matter volume. *Neuroreport, 23*, 1059-1064.

Oral Presentations at Professional Meetings

1. Reward-processing deficits in active but not remitted depression. Presented at the Annual National Network of Depression Centers Conference, Chicago, IL, October 24, 2014.

Poster Presentations at Professional Meetings

1. **DelDonno, SR**, Jenkins, LM, Skerrett, K, Hymen, E, Kreutzer, K, Broussard, NG, Passarotti, AM, Jacobs, RH, Langenecker, SA. Impaired recognition of subliminal happy faces in remitted mood disorders. To be presented at the 70th Annual Meeting of the Society of Biological Psychiatry, Toronto, Ontario, May 14-16, 2015.

2. **DelDonno, SR**, Weldon, AL, Passarotti, AM, Mickey, BJ, Pruitt, PJ, Crane, NA, Gabriel, L, Yau, W, Meyers, KK, Hsu, DT, Taylor, SF, Heitzeg, MM, Shankman, S, Zubieta, JK, & Langenecker, SA. Reward-processing deficits in active but not remitted depression. Poster presented at the Annual National Network of Depression Centers Conference, Chicago, IL, October 22-24, 2014.

3. **DelDonno, S**, Mickey, B, Weldon, A, Nagel, C, Pruitt, P, Yau, W, Zubieta, J, & Langenecker, S. Sex differential effects in psychomotor speed related to reward seeking and attainment. Poster presented at the 28th Annual Meeting of the Society for Research in Psychopathology, Evanston, IL, September 18-21, 2014.

4. **DelDonno, SR**, Weldon, AL, Meyers, KK, Gabriel, LB, Pester, B, Kassel, MT, Crane, N, Hsu, DT, Mickey, BJ, Zubieta, J, & Langenecker, SA. Behavioral activation predicts reward-seeking in depression. Poster presented at the 69th Annual Scientific Meeting and Convention of the Society of Biological Psychiatry, New York, NY, May 8-10, 2014.

5. **DelDonno, S**, Kipman, M, Schwab, ZJ, & Killgore, WDS. The contributions of emotional intelligence and facial perception to social intuition. Poster presented at the Annual McLean Research Day, Belmont, MA, January 16, 2013.

6. **DelDonno, S**, Weber, M, Kipman M, Schwab, ZJ, & Killgore, WD. Resistance to insufficient sleep correlates with olfactory cortex gray matter. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

7. **DelDonno, S**, Schwab, ZJ, Kipman, M, Weber, M, & Killgore, WD. Weekend sleep is related to greater coping and resilience capacities. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

8. **DelDonno, S**, Schwab, ZJ, Kipman, M, Rauch, SL, & Killgore, WD. The influence of cognitive and emotional intelligence on performance on the Iowa Gambling Task. Poster presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

9. **DelDonno, S** & Hajcak, G. The impact of threat of shock on the defensive startle reflex. Poster and paper presented at the Stony Brook Undergraduate Research and Creative Activities Conference, Stony Brook, NY, April 27, 2011.

10. Crane, NA, Jenkins, LM, Gowins, JR, Barba, AM, Gabriel, LB, Kassel, MT, Weldon, AL, Baker, AM, **DelDonno, SR**, Zubieta, JK, Mermelstein, RJ, & Langenecker, SA. *History of Substance Use Disorder Modulates Neural Emotional Processing in Individuals with Remitted Major Depression.* To be presented at the 70th Annual Meeting of the Society of Biological Psychiatry, Toronto, Ontario, May 14-16, 2015.

11. Crane, NA, Gowins, JR, Barba, AM, **DelDonno, SR**, Jenkins, LM, Meyers, KK, Hazlett, KE, Tsu, DT, Mickey, BJ, Zubieta, JK, & Langenecker, SA. Independent component analysis of cognitive control as treatment predictors for major depressive disorder. To be presented at the 43rd Annual Meeting of the International Neuropsychological Society, Denver, CO, February 4-7, 2015.

12. Crane, NA, Gowins, JR, Barba, AM, **DelDonno, SR**, Jenkins, LM, Meyers, KK, Hazlett, KE, Hsu, DT, Mickey, BJ, Zubieta, JK, & Langenecker, SA. Cognitive control neural markers of treatment response for depression using independent component analysis. Poster presented at the Annual National Network of Depression Centers Conference, Chicago, IL, October 22-24, 2014.

13. Jenkins, LM, **DelDonno, SR**, Meyers, KK, Zubieta, JK, Starkman, MN, & Langenecker, SA. Effects of music on reward task performance during functional brain imaging. Poster presented at the Fifth Annual UIC Psychiatry Research Extravaganza, October 21, 2014.

14. Langenecker, SA, **DelDonno, SR**, Jacobs, RH, Barba, A, Ryan, KA, Gowins, JR, Jenkins, LM, Crane, NA, Zubieta, JK, Nusslock, R, Phan, KL, & Shankman, S. Diminished learning and pursuit of reward and disrupted resting state connectivity of reward networks in remitted major depressive disorder. Poster presented at the Fifth Annual UIC Psychiatry Research Extravaganza, October 21, 2014.

15. Dunning, JP, **DelDonno, S**, & Hajcak, G. The intersection of threat, anxiety, and affective startle modulation. Poster presented at the 52nd Annual Meeting of the Society for Psychophysiological Research, New Orleans, LA, September 19-23, 2012.

16. Kipman, M, Schwab ZJ, Weiner, MR, **DelDonno, S**, Rauch SL, & Killgore WD. The insightful yet bitter comedian: The role of emotional versus cognitive intelligence in humor appreciation. Poster presented at the Annual McLean Research Day, Belmont, MA, January 11, 2012.

17. Kipman, M, Schwab, ZJ, **DelDonno, S**, & Killgore, WD. Gender differences in the contribution of cognitive and emotional intelligence to the left visual field bias for facial perception. Poster presented at the 40th Annual Meeting of the International

Neuropsychological Society, Montreal, CA, February 15-18, 2012.

18. Kipman, M., Schwab, ZJ, Weiner, MR, **DelDonno, S**, Rauch, SL, & Killgore, WD. Contributions of emotional versus cognitive intelligence in humor appreciation. Poster presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

19. Killgore, WD, Schwab, ZJ, Weiner, MR, Kipman, M, **DelDonno, S**, & Rauch SL. Overeating is associated with altered cortico-limbic responses to images of high calorie foods. Poster presented at the 40th Annual Meeting of the International Neuropsychological Society, Montreal, CA, February 15-18, 2012.

20. Weber, M, **DelDonno, S**, Kipman M, Schwab, ZJ, & Killgore WD. Grey matter correlates of self-reported sleep duration. Poster presented at the Harvard Medical School Research Day, Boston, MA, March 28, 2012.

21. Kipman, M, Weber, M, **DelDonno, S**, Schwab, ZJ, & Killgore, WD. Morningness-Eveningness correlates with orbitofrontal gray matter volume. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

22. Kipman, M, Schwab, ZJ, Weber, M, **DelDonno, S**, & Killgore, WD. Yawning frequency is correlated with reduced medial thalamic volume. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

23. Weber, M, **DelDonno, S**, Kipman M, Schwab, ZJ, & Killgore WD. Grey matter correlates of daytime sleepiness. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

24. Weber, M, **DelDonno, S**, Kipman M, Schwab, ZJ, & Killgore WD. Grey matter correlates of self-reported sleep duration. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

25. Schwab, ZJ, **DelDonno, S**, Weber, M, Kipman M, & Killgore, WD. Habitual caffeine consumption and cerebral gray matter volume. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

26. Killgore, WD, Schwab, ZJ, **DelDonno S**, Kipman, M, Weber M, & Rauch, SL. Greater nocturnal sleep time is associated with increased default mode functional connectivity. Poster presented at the 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012.

27. Weber, M, **DelDonno, S**, Kipman M, Schwab, ZJ, & Killgore WD. Grey matter correlates of self-reported sleep duration. Poster presented at the Harvard Division of Sleep Medicine Annual Poster Session, Boston, MA, September 27, 2012.