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Longitudinal Examination of Decision-Making Performance in Anorexia Nervosa: Before and After Weight Restoration

Lindsay P. Bodell, M.S.¹, Pamela K. Keel, Ph.D.¹, Michael C. Brumm, B.S.², Ashley Akubuiro, M.S.³, Joseph Caballero, B.S.⁴, Daniel Tranel, Ph.D.⁵, Brendan Hodis, M.S.⁴, and Laurie M. McCormick, M.D.^{2,6,7}

¹Florida State University, Department of Psychology ²University of Iowa Carver College of Medicine, Department of Psychiatry ³University of Iowa, Department of Neuroscience ⁴University of Iowa Carver College of Medicine ⁵University of Iowa Carver College of Medicine, Division of Behavioral Neurology and Cognitive Neuroscience and Department of Psychology. ⁶University of Iowa Carver College of Medicine, Department of Psychiatry ⁷University of the Virgin Islands ⁷Roy Lester Schneider Hospital

Abstract

Background—This study aimed to extend previous work on decision-making deficits in anorexia nervosa (AN) by using a longitudinal design to examine decision-making before and after weight restoration.

Methods—Participants were 22 women with AN and 20 healthy comparison participants who completed the Iowa Gambling Task (IGT). Decision-making was assessed both before and after weight restoration in a subset of 14 AN patients. Self-report and interview assessments were used to measure psychological correlates of decision-making performance including depression, anxiety, and eating disorder symptoms, and magnetic resonance imaging (MRI) scans were conducted to explore associations between brain volume in the orbitofrontal cortex (OFC) and decision-making in individuals with AN.

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Address correspondence to: Laurie M. McCormick, Roy Lester Schneider Hospital, 9048 Sugar Estate #5103, St. Thomas, VI, 00801. Phone: (340)-244-9658. Fax: (340)-714-6467. laurie-mccormick@uiowa.edu.

Conflict of Interest

None.

Contributors

Dr. McCormick designed the original study from which data were used. Ms. Bodell wrote the first draft of the manuscript. Dr. Keel participated in the writing and preparation of the manuscript. All authors contributed to and have approved the final manuscript.

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Results—Currently ill AN patients performed worse on the IGT compared to the control group. Although decision-making performance did not improve significantly with weight restoration in the full AN sample, AN patients who were poor performers at baseline did improve task performance with weight-restoration. When actively ill, lower body mass index (BMI) and decreased left medial OFC volume were significantly associated with worse IGT performance, and these associations were no longer significant after weight restoration.

Conclusions—Findings suggest that decision-making deficits in AN in the acute phase of illness are associated with low weight and decreased left medial OFC volume, but increases in brain volume and BMI may not have been sufficient to improve decision-making in all patients. Findings contribute to a model for understanding how some patients may sustain self-starvation, and future work should examine whether decision-making deficits predict relapse.

Keywords

anorexia nervosa; decision-making; cognitive impairment; Iowa Gambling Task; neuropsychology; orbitofrontal cortex

1. Introduction

Anorexia nervosa (AN) is a serious psychiatric illness associated with neuropsychological impairments that may be implicated in the etiology of the disorder (Tchanturia et al., 2005). In particular, research has begun investigating the role of decision-making in AN using the Iowa Gambling Task (IGT; Bechara et al., 1994) (e.g., Cavedini et al., 2006; Danner et al., 2012; Fagundo et al., 2012; Guillaume et al., 2010; Tchanturia et al., 2007). This task was developed to simulate decision-making under conditions of uncertainty, reward, and punishment and to capture deficits found in patients with known lesions in the ventromedial prefrontal cortex, a broad area that includes the orbitofrontal cortex. Poor decision-making performance in these patients reflects insensitivity to future negative consequences, despite intact general intelligence and problem-solving abilities (Bechara et al., 1994). Similarly, individuals with AN act in ways that may have positive short-term consequences (e.g., anxiety relief through food restriction) despite negative long-term consequences (e.g., health problems) (Brogan et al., 2010; Cavedini et al., 2004). Consistent with this idea, the majority of studies examining decision-making in AN using the IGT have documented worse performance in AN compared to healthy participants (e.g., Abbate-Daga et al., 2011; Cavedini et al., 2004; Cavedini et al., 2006; Danner et al., 2012; Garrido & Subirá, 2013; Tchanturia et al., 2007). This has led to models in which poor decision-making may contribute to the development and maintenance of symptoms in AN (Brogan et al., 2010; Cavedini et al., 2004; Chan et al., 2014).

Importantly, malnutrition causes cognitive impairment independent of the presence of an eating disorder (Keys, 1950). Thus, poor decision-making in patients actively ill with AN may reflect a consequence of illness rather than a premorbid underlying impairment in decision-making that contributes to vulnerability. Researchers have evaluated decision-making in weight-restored patients with AN in order to disentangle state versus trait impairments; however, mixed findings have emerged from such studies (Bosanac et al., 2007; Danner et al., 2012; Lindner et al., 2012; Tchanturia et al., 2007). Studies have found

poorer (Danner et al., 2012), similar (Bosanac et al., 2007; Tchanturia et al., 2007), and even superior performance (Lindner et al., 2012) in individuals recovered from AN compared to healthy comparison participants. Importantly, all studies were cross-sectional, thus it is unclear whether decision-making performance in individuals with AN actually improves with increased weight, given that differences may or may not have been present during the acute phase of illness.

Another way to examine whether decision-making deficits are state versus trait characteristics is to examine patients longitudinally. To our knowledge, only one study has examined IGT performance in individuals with AN using a longitudinal design (Cavedini et al., 2006). Cavedini and colleagues (2006) found that IGT performance in inpatients with AN did not improve significantly from intake to discharge. Importantly, average body mass index (BMI) at discharge ($BMI=15.9 \text{ kg/m}^2$) was below a minimally healthy threshold (18.5 kg/m^2), suggesting that most patients were still malnourished at discharge. Thus, it remains unclear whether poor IGT performance in AN is a consequence of low weight because no study has examined decision-making in AN patients longitudinally at the time of acute illness and again following weight restoration to a minimally healthy weight. The primary aim of this study was to examine changes in decision-making performance from intake to hospital discharge in patients restored to normal weight.

Importantly, decision-making deficits on the IGT have been identified in a range of mental illnesses (e.g., Cavedini et al., 2010; Jollant et al., 2007; LeGris et al., 2012); thus, in addition to examining associations between decision making and illness state, it is important to identify whether deficits found in AN may be explained by comorbid psychological factors rather than to AN. As such, a secondary aim of this study was to explore whether impaired decision-making is attributable to eating pathology or other psychological traits. Furthermore, the orbitofrontal cortex (OFC) is an important brain region for decision-making and the processing of rewards and punishments (e.g., Bechara et al., 1999; Bechara et al., 2000; Kringelbach & Rolls, 2004; Kringelbach, 2005) and deficits in this region have been linked to eating disorders (Cavedini et al., 2004; Frank et al., 2013; Kaye et al., 2009; Uher et al., 2004). For example, differences in OFC volume have been found in individuals with acute and recovered AN and bulimia nervosa compared to control participants, and these differences have been linked to self-reported reward sensitivity (Frank et al., 2013). However, no study, to our knowledge, has examined whether OFC volume is a specific correlate of decision-making behaviors in AN and whether this association is independent of BMI. Thus, another secondary aim of this study was to evaluate whether OFC volume is associated with decision-making performance in AN patients.

2. Methods

2.1 Participants

Participants with AN ($n=22$, female) were recruited from the inpatient eating disorder unit at the University of Iowa Hospitals and Clinics as part of a larger longitudinal study examining cognitive functioning. The AN diagnosis and subtype were determined by board certified psychiatrists using criteria from the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR; American Psychiatric Association, 2000).

Fifteen patients met criteria for the restrictive subtype, and seven met criteria for the binge-purge subtype. Patients with AN were excluded if they had a diagnosis of illicit drug or alcohol abuse/dependence within the past three months, had a concurrent diagnosis of a psychotic or bipolar disorder, had a history of DSM-IV diagnosis of bulimia nervosa prior to the onset of AN, had a history of significant brain damage or neurological problems, were currently pregnant, or had the presence of standard exclusionary criteria for magnetic resonance imaging (MRI) of metal objects in the body (e.g., a pacemaker). Healthy comparison participants (n=20) were matched to AN participants on gender, age, and education. This comparison group was recruited through advertisements in the Iowa City area and did not have current or lifetime histories of any major psychiatric diagnoses, including eating disorders, as established through the Structured Clinical Interview for DSM-IV (SCID; First et al., 1995).

2.2 Procedures

All participants signed consent forms prior to participation. The AN participants completed a battery of assessments including demographic information, self-report questionnaires, interviews, neuropsychological tests and MRI scans. The IGT and MRI scans were completed as part of intake assessments, approximately 10 days after hospital admission (range 6–15 days). Fourteen patients (63%) completed second IGT and MRI assessments after weight restoration (BMI = 18.5 kg/m²). At the time of the second assessments, patients had been weight-restored for at least one week. The healthy comparison group completed the demographic information and one IGT assessment. Height and weight were measured at the time of all IGT assessments in order to calculate BMI. All study procedures were approved by the university's Institutional Review Board.

MRI scans were obtained using a Siemens 3T Trio scanner (Siemens Medical Solutions, Erlangen, Germany). T1- and T2-weighted images were collected. T1 images were collected using a coronal 3D MP-RAGE sequence (slice thickness=1mm, TR=2530ms, TE=2.8ms, TI=1100ms, NEX=1, number of echoes = 1, flip angle = 10°, FOV=256×256×256mm, Matrix=256×256×256) whereas T2 scans were acquired using a coronal 2D TSE sequence (slice thickness=1.5mm, TR=9910ms, TE=12ms, NEX=1, number of echoes = 10, FOV=256×256mm, Matrix=256×256). Cortical reconstruction and volumetric segmentation was performed with the Freesurfer image analysis suite (v 5.1) (<http://surfer.nmr.mgh.harvard.edu/>). These procedures have demonstrated good test-retest reliability across scanner manufacturers and across field strengths (Han et al., 2006; Reuter et al., 2012).

The output of interest was total cerebral cortex gray matter volume and volume of predefined regions of interest (ROI), including the left and right medial and lateral OFC. The anatomical accuracy of each FreeSurfer ROI was visually inspected by independent reviewers who were blind to both diagnosis and IGT performance and modifications of abnormally parcellated scans were completed. Details of FreeSurfer parcellation, including reliability, validity and anatomical boundaries, are described elsewhere (Desikan et al., 2006). Manual editing of OFC labels included two types of modifications. If necessary, both medial and lateral OFC labels were revised such that they extended no farther posteriorly

than the caudal portions of the lateral orbital gyrus and medial orbital gyrus/gyrus rectus. The medial OFC label was edited in cases where a secondary (i.e., paracingulate) sulcus running parallel to the cingulate sulcus was evident within the rostral anterior cingulate cortex (ACC); in such cases, the paracingulate gyrus was re-labeled as part of the rostral ACC, not the medial OFC.

2.3 Measures

The computerized IGT (Bechara et al., 1997) was used to assess decision-making. Participants were presented with four decks of cards labeled A, B, C, and D and instructed to select one card at a time from a total of 100 cards that were dispersed evenly among five blocks (20 in each block). Participants were informed that each selection would result in winning some money, but that “every so often, when you click on a card, the computer will tell you that you won some money as usual, but then it will say that you lost some money as well.” The goal of the task is to accumulate as much money as possible by selecting cards from whichever card decks they choose during each block session (1–5). The overall outcome from choosing from decks A and B is a greater loss than gain of money and thus considered disadvantageous. The overall outcome of choosing from decks C and D more often than A and B is a gain of money, which makes decks C and D advantageous. During the second time point (weight restoration), the decks were labeled K, L, M, N instead of A, B, C, D, and the task was counterbalanced for which decks were advantageous and disadvantageous. Scoring for this measure is described below in Statistical Analyses.

Eating disorder symptoms were assessed in the AN patients by the Eating Attitudes Test (EAT-26; Garner et al., 1982), the Eating Disorder Inventory (EDI-3; Garner, 2004), and the Yale-Brown-Cornell Eating Disorder Scale (YBC-EDS; Mazure et al., 1994; Sunday et al., 1995), all of which are frequently used self-report measures of severity of eating pathology. In the current study, only the drive for thinness, bulimia, and body dissatisfaction subscales of the EDI-3 were used, given that they are most directly related to eating disorder symptoms.

Depression and anxiety were assessed with the 17-item Hamilton Depression Rating Scale (HDRS; Hamilton, 1960) and the 14-item Hamilton Anxiety Rating Scale (HARS; Hamilton, 1959). Mood and anxiety disorder diagnoses were also confirmed by board certified psychiatrists using the DSM-IV-TR (American Psychiatric Association, 2000).

Finally, the Wechsler Adult Intelligence Scale–IV (WAIS-IV; Wechsler, 2008) was administered during intake and the Full-Scale Intelligence Quotient (IQ) was used as an estimate of intellectual ability.

2.4 Statistical Analyses

All statistical analyses were conducted using SPSS version 18.0. Normality of the data was assessed for all variables. The EDI Bulimia subscale scores were transformed using square root transformation to correct for positive skew.

In order to quantify participants’ performance on the IGT, the 100 card selections were divided into five blocks of 20, and the number of selections from the advantageous and

disadvantageous decks was counted (Bechara et al., 1999). The number of disadvantageous card selections was subtracted from the number of advantageous card selections [i.e. $(C+D) - (A+B)$] to determine the net score for each block, as well as the overall net score. Overall performance was also dichotomized into “good” and “poor” based on cut points used by Cavedini and colleagues (2006). Poor performers included individuals whose overall net score on the IGT was less than zero, indicating greater selection (51 cards) from the disadvantageous decks.

Independent samples t-test was used to compare the AN and comparison groups on overall performance, and a chi-square analysis was used to compare the AN and comparison groups on percentage of good versus poor performers. A 5×2 repeated measures ANOVA was conducted with net scores from the five blocks as the within-subject repeated-measures variable and group (AN, comparison group) as the between-subjects variable. Additionally, a post-hoc 5×3 repeated measures ANOVA was conducted to explore differences in decision-making patterns among AN good, AN poor, and comparison groups.

A paired samples t-test was used to examine IGT net scores from baseline to weight restoration in the AN patients, and an independent samples t-test was conducted to compare weight-restored AN patients to the controls on overall IGT performance. We also conducted a 5×2 and 5×3 repeated measures ANOVA identical to those conducted at baseline to explore differences in decision-making patterns after weight restoration among AN and comparison groups. In order to ease comparison with findings from baseline (Time 1), AN status (good vs. poor) was based on their status at baseline.

Pearson correlations and regression analyses were conducted within individuals with AN to explore associations between demographic variables, psychological variables, and OFC brain volume and IGT performance at baseline and weight-restoration. Additionally, AN good and poor performers were compared on these variables using independent samples t-tests.

A Little’s chi-square test indicated that follow-up data were not missing completely at random, thus, expectation-maximization (EM) algorithm was used to obtain maximum likelihood estimators and impute missing data, consistent with recommendations from Schafer and Graham (2002). Results were unchanged when using listwise deletion for missing values.

3. Results

Clinical characteristics of the AN sample appear in Table 1. Six AN patients (27%) had at least one prior hospitalization, but the majority ($n=16$; 73%) were being hospitalized for their eating disorder for the first time. Ten patients were taking antidepressant medication during the first IGT assessment (baseline) and seven patients were taking antidepressant medication during the second IGT at weight restoration. Medication doses were stable for approximately one week prior to assessment, and no differences were found between medicated and unmedicated AN patients on IGT performance, brain volume, BMI, duration of illness, IQ, depression, anxiety, drive for thinness, bulimia scores, body dissatisfaction, or preoccupations and rituals related to their eating disorder at either baseline (during the acute

phase of illness) or after weight-restoration (all p -values $>.14$). However, individuals on medication at baseline were significantly older (28.8 ± 5.4 vs. 22.9 ± 4.9 years; $t = -2.7$, $p < .02$) and had higher education than individuals not on medication at baseline (15.7 ± 2 vs. 13.8 ± 2 years; $t = -2.16$, $p < .05$). Information at weight restoration was unavailable for eight patients because five patients discontinued treatment prematurely, two patients had scheduling constraints that could not be accommodated, and one patient began electroconvulsive therapy. Of the eight AN participants who did not complete procedures after weight restoration, seven were good IGT performers and one was a poor performer at baseline. There were no significant differences on any baseline variables between patients who completed both time points and those who only completed baseline procedures (all p -values $>.08$, Cohen's d range = $.05$ -. $.74$)

3.1 IGT Performance at Baseline (Time 1): Low-Weight AN Compared to Control Participants

Consistent with prior research, a significant group difference was found between the low-weight AN patients and comparison group on overall performance, such that women with AN performed significantly worse on the IGT compared to the comparison group (7.27 ± 35.12 vs. 28.30 ± 31.11 ; $t = -2.11$, $p < .05$, Cohen's $d = -0.63$). Additionally, a greater proportion of the AN patients (41%; $n = 9$) than controls (10%; $n = 2$) were categorized as poor performers on the task ($\chi^2 = 5.18$, $df = 1$, $p = .023$). The repeated measures ANOVA revealed a main effect for block such that net scores improved across groups, indicating learning occurred in both the AN and comparison participants ($F(3.15, 37) = 25.69$, $p < .001$, partial $\eta^2 = .39$) (Figure 1A). There was no significant group $\times$ block interaction ($F(3.15, 37) = 2.03$, $p > .10$, partial $\eta^2 = .05$). However, when AN good and poor performers were separated, there was a significant group $\times$ block interaction, such that net scores improved during the task in the AN good and control groups but not the AN poor group ($F(6.70, 36) = 5.02$, $p < .001$, partial $\eta^2 = .21$) (Figure 1B).

3.2 IGT Performance after Weight-Restoration (Time 2)

Although patients were weight restored (mean = 20.6 ± 0.9 ; range = 18.6 – 22.2), there was no significant difference on IGT performance from baseline (7.27 ± 35.1) to weight restoration (11.6 ± 21.0) ($t(21) = -.60$, $p = .56$, Cohen's $d = -0.18$) in the full sample of AN patients. Furthermore, weight-restored AN patients continued to score worse than the comparison participants on the IGT (11.6 ± 21.0 vs. 28.3 ± 31.1 , $t = -2.05$, $p < .05$, Cohen's $d = -0.63$). Chi-square analyses of performance at baseline and weight restoration indicated that performer status at baseline (good versus poor) was related to performer status at weight restoration ($\chi^2 = 4.17$, $df = 1$, $p = .04$). Specifically, 92% ($n = 12$ of 13) of the good performers at baseline remained good performers, and 44% of the poor performers at baseline ($n = 4$ of 9) remained poor performers after weight restoration. However, exploratory analyses indicate that overall performance did improve significantly from baseline (-29.56 ± 17.57) to weight restoration (5.93 ± 28.04) in the subset of AN patients who were poor performers at baseline ($t(8) = 4.01$, $p = .004$, Cohen's $d = 1.52$). Additionally, performance at weight restoration in this group did not differ significantly from controls (5.9 ± 28.0 vs. 28.3 ± 31.1 , $t(27) = -1.84$, $p < .08$). However, given the moderate to large effect size (Cohen's $d = .76$), this result may have been significant with a larger sample. Finally, the repeated measures ANOVA indicated a

significant effect of block ($F(3.27)=26.34$, $p<.001$, partial $\eta^2=.40$) and a significant group $\times$ block interaction ($F(3.27)=6.72$, $p<.001$, partial $\eta^2=.14$) such that both AN and control participants learned within the task, however, the pattern at which they learned differed across the groups (Figure 1C). Similarly, when the AN group was divided into good and poor based on their baseline performance, there was a significant group $\times$ block interaction such that net scores improved across the trials in the AN good and control groups but not the AN poor group ($F(6.50)=4.10$, $t<.01$, partial $\eta^2=.17$) (Figure 1D).

3.3 Correlates of IGT Performance in AN at Baseline and Weight Restoration

Mean volumes of the different brain regions before and after weight restoration appear in Table 2. Correlational analyses among individuals with AN indicate that baseline BMI, left lateral OFC volume, and left medial OFC volume were significantly associated with decision-making performance at baseline (Table 3). These associations remained significant, controlling for age, education level, IQ, and depression, such that higher BMI ($\beta=.55$, $p<.05$), and greater left medial OFC ($\beta=.72$, $p<.01$) and left lateral OFC ($\beta=.82$, $p<.05$) brain volumes were associated with better IGT scores. When including BMI as an additional covariate, left medial OFC volume remained a significant predictor of IGT scores ($\beta=.60$, $p=.02$); however, left lateral OFC volume did not ($\beta=.60$, $p=.07$). Similarly, results comparing AN poor versus AN good IGT performers at baseline indicate that poor performers had significantly lower mean BMI compared to good performers (14.6 ± 2.1 kg/m² vs. 16.6 ± 2.0 kg/m², $t=-2.22$, $df=20$, $p<.04$, Cohen's $d=-0.98$) and significantly decreased left medial OFC volume compared to good performers (4792.22 ± 585.32 mm³ vs. 5511.2 ± 829.1 mm³, $t=1.68$, $df=20$, $p<.04$, Cohen's $d=-1.00$). This difference in left medial OFC brain volume remained significant while controlling for BMI and intracranial volume ($F=8.34$, $p<.01$, partial $\eta^2=.31$). No other variables distinguished between good and poor performers at baseline, and no significant correlations were found between IGT performance and age, education, FSIQ, depression, anxiety, food related preoccupations or rituals, drive for thinness, bulimia scores, body dissatisfaction, or AN subtype at baseline or weight restoration (all p -values $>.05$).

Although baseline BMI and left medial OFC brain volume were associated with IGT performance at baseline, they were not significantly associated with performance after weight restoration, and there were no significant associations between IGT performance at weight restoration and brain volume or BMI at weight restoration. Furthermore, there was no significant association between change in left medial OFC brain volume and change in IGT scores from baseline to weight restoration ($r=-.10$, $p=.73$) or between change in BMI and change in IGT scores ($r=.36$, $p<.1$) in the full AN sample. However, the effect size for this latter association was moderate, suggesting that this association may be significant with a larger sample. In exploratory analyses within the subset of poor performers at baseline, there was a significant association between change in left medial OFC volume and change in IGT scores, however, this association was in the opposite direction of that expected with greater increases in brain volume associated with smaller improvements on the IGT ($r=-.78$, $p=.01$). Finally, changes in BMI were not associated with changes in IGT performance in the subset of poor performers ($r=-.10$, $p=.78$).

4. Discussion

The current study found that compared to control participants, low-weight women with AN have impaired decision-making, as measured by greater selection from disadvantageous decks on the IGT. This finding is consistent with previous research demonstrating poorer IGT performance in AN compared to healthy controls (Abbate-Daga et al., 2011; Bosanac et al., 2007; Brogan et al., 2010; Cavedini et al., 2004; Cavedini et al., 2006; Danner et al., 2012; Garrido & Subriá, 2013; Tchanturia et al., 2007). During baseline IGT administration, we did not find a significant group $\times$ block interaction, suggesting that AN patients learned about and understood the negative consequences across the trials. However, an exploratory analysis of decision-making patterns separating good and poor AN performers revealed a significant group $\times$ block interaction, with the poor AN group displaying a different pattern of decision-making compared to the good performers and controls. Specifically, the poor AN performers did not appear to learn about or be influenced by negative consequences, as they continued to pick from the disadvantageous decks throughout the trials. Taken together, these findings highlight that decision-making within AN is relatively heterogeneous and may be useful for classifying subtypes of AN.

In contrast to previous studies that have found improvements in other aspects of cognitive functioning such as attention, memory, and problem solving abilities (Lauer et al., 1999; Moser et al., 2003), the current study did not find significant improvements in decision-making performance with weight restoration in the overall AN sample. This finding suggests that decision-making in AN may represent a trait-like cognitive vulnerability that may influence eating behavior and the persistence of self-starvation. In support of this hypothesis, a recent study found moderate heritability of decision-making impairments, such that individuals with AN and their unaffected first-degree relatives performed worse on the IGT than healthy controls and their relatives (Galimberti et al., 2012). However, a lack of significant improvement from baseline to follow-up in the full AN sample may also be due to insufficient duration of weight restoration to facilitate neurocognitive changes in decision-making. In addition, although brain volume in the AN patients increased, we did not have brain volume data on the healthy comparison group to evaluate whether these changes represented fully normalized volume in weight-restored AN patients. Other studies have found individuals recovered from AN to have similar or better IGT performance than comparison participants (Lindner et al., 2012; Tchanturia et al., 2007). Thus, it is possible that decision-making deficits observed in the current study would improve with longer duration of follow-up.

Notably, previous studies examining decision-making in individuals recovered from AN are cross-sectional, so it is also possible that better decision-making ability facilitated recovery from AN. This interpretation is consistent with findings from Cavedini and colleagues (2006) who found decision-making ability to be associated with treatment outcome. Specifically, those with better IGT performance were more likely to have a significant gain in BMI after treatment. Given that patients in the current study were weight restored to a minimally acceptable healthy weight in an inpatient setting ($20.6 \pm 0.9 \text{ kg/m}^2$), we were unable to specifically examine and replicate findings of decision-making ability predicting treatment outcome (i.e., weight gain). If better decision-making does facilitate recovery,

then decision-making ability may be an important target for treatment in individuals with AN in order to decrease persistent self-starvation and potential risk of relapse.

Furthermore, even if poor decision-making found in AN does not represent a consequence of the acute stage of illness, then it could reflect a “scar” effect. In support of this hypothesis, our data indicate that poor performers who remained poor performers tended to be older and have a longer duration of illness compared to the poor performers whose performance improved after weight restoration. Finally, given that there was a subset of AN patients in the current study who performed as well as controls on the IGT at baseline, it is also possible that the lack of significant improvement found within the overall AN sample is being driven by the good performers not having room to improve. Indeed, in exploratory analyses of only poor performers, IGT scores did significantly improve with weight-restoration and performance at weight restoration did not differ significantly from controls, suggesting deficits may have been a consequence of acute malnutrition. Additional longitudinal studies with both larger samples and longer duration of follow-up with multiple time points are essential to examine these questions.

In order to evaluate whether impaired decision making in AN is attributable to eating pathology or other factors, the current study also explored potential correlates of decision-making in AN. Low BMI and decreased left OFC brain volume were the only significant correlates of poor decision-making among women in the acute phase of illness, which could reflect either the effect of poor decision-making on reaching extremely low weight or the effect of extremely low weight on cognitive function. Similar to patterns found for BMI, significant increases in OFC volume were not associated with improvements in IGT performance from baseline to weight restoration. However, given the limited duration of weight-restoration and absence of a control group against which to evaluate brain volume, it is possible that increases in brain volume were not sufficient to facilitate significant improvements in cognitive processes. Indeed, there is some evidence that despite increases in brain volume, the poor performers who remained poor ($n=4$) still had lower left medial OFC volume compared to the poor performers who improved after weight-restoration ($n=5$) (4788.50 ± 830.78 vs. 5382.92 ± 495.29 mm³, $t=-1.34$, Cohen's $d=-.87$), suggesting that brain volume may not be sufficiently normalized in all individuals. Furthermore, studies have indicated that impairments in decision-making performance arise from a broad network of brain regions including the amygdala and somatosensory/insular cortices (Bechera et al., 1999). Thus, involvement of other areas not evaluated in the current study may have influenced performance. Future studies should examine associations between decision-making performance in AN and other brain regions as well as neural activation associated with performance to further elucidate decision-making processes in AN.

The current study had several strengths and limitations to acknowledge. This is the first longitudinal study examining changes in IGT scores from intake to weight restoration, which represents an important advance for examining whether decision-making deficits in AN represent a state versus possible trait characteristic. Additionally, this was the first study to examine associations between brain volume and IGT performance in AN, which provides information on factors that may be linked to observed deficits. Furthermore, we explored a wide range of psychological traits to better understand factors that may or may not be

associated with IGT performance in AN. Importantly, this study is limited in that we had a small sample size, which contributes to low power and increased risk of both Type I and Type II errors. Further, we were not able to include a psychiatric comparison sample, and we did not have brain volume or psychological data or multiple time points from the comparison sample. As such, we could only compare data from weight-restored AN patients to baseline assessments of controls. Many studies have noted learning effects from multiple administrations of the IGT (Buelow & Suhr, 2009). Thus, it is possible that learning effects within the control group would offset similar improvements in the AN group. As such, the current study may underestimate decision-making deficits found in AN following weight restoration. Furthermore, the relatively short duration of follow up within the AN group may not have been adequate to capture significant neurocognitive changes. The current study consisted of inpatients with AN, thus results may not generalize to outpatient or non-treatment seeking samples. Additionally, some of the patients were being treated with psychotropic medication, which may have influenced findings. Finally, although we used standard instructions for the IGT, the wording may impact participants' expectations and task performance. Despite these limitations, results provide information on those most likely to follow a chronic course and have the highest treatment needs. In addition, results provide much needed data to support future larger and more resource-intensive investigations.

In summary, the current study found impaired decision-making in individuals with AN during the acute phase of illness, which was associated with both lower BMI and reduced left OFC volume. The majority of poor performing participants did improve task performance with weight restoration, suggesting that decision-making impairments may represent a consequence of acute malnutrition. However, for a small portion of individuals, poor decision-making may be a risk factor for AN, such that being less sensitive to the rewarding value of food or consequences of self-starvation may make it easier to establish a pattern of restricting food intake and weight loss. Indeed, Wagner and colleagues (2007) found that individuals recovered from AN do not differentiate between reward and punishment stimuli in anterior ventral striatum limbic circuits, suggesting that they may have problems distinguishing between positive and negative feedback. Alternatively, decision-making deficits may represent a "scar" of having had AN. As such, these consequences may serve as a maintenance factor or may contribute to risk for future relapse, which represents a significant problem following discharge from inpatient treatment for AN. Given the limitations of the current study, additional longitudinal studies are needed to draw more substantial conclusions and to test the hypotheses generated from current results, including additional correlates of performance (e.g., neural activation, rate of weight gain) and whether decision-making deficits increase risk for relapse in AN. Overall, this study contributes to the growing literature on cognitive functioning in AN and highlights decision-making impairment as a potential target for the treatment and prevention of AN.

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Figure 1.

IGT performance (Net Score per Block) in the AN and Comparison groups.

Notes. AN=anorexia nervosa; IGT=Iowa Gambling Task. A, C. n=22 AN, 20 controls. B, D. n=13 AN good, 9 AN poor, 20 controls. AN good and poor groups represent participants' status at baseline.

Table 1

Clinical Characteristics of Patients with Anorexia Nervosa before and after Weight Restoration.

	Low Weight N=22		Weight Restored N=22		t	p value
	Mean	St. Dev	Mean	St. Dev		
Age (years)	25.58	5.83	--	--	--	--
BMI (kg/m ²)	15.78	2.25	20.60	0.86	-10.26	<.001
Duration of Illness (years)	5.9	5.5	--	--	--	--
EAT	40.77	13.24	11.58	5.75	10.98	<.001
Education (years)	14.68	2.19	--	--	--	--
EDI BD	24.73	8.64	19.01	6.70	2.54	.02
EDI BUL	5.27	5.21	1.74	1.79	3.76	.001
EDI DT	18.59	7.37	12.26	5.00	3.81	.001
FSIQ	110.5	12.11	--	--	--	--
HAMD	14.45	7.37	5.29	2.61	6.78	<.001
HAMA	15.95	10.02	6.03	3.92	5.69	<.001
YBC Preoccupations	11.41	3.26	5.41	1.87	7.89	<.001
YBC Rituals*	10.55	3.50	4.03	2.76	5.01	<.001
YBC total	21.95	6.32	8.87	3.76	7.71	<.001

Notes. Values represent imputed missing data unless otherwise specified. AN= anorexia nervosa; EAT=Eating Attitudes Test; EDI BD= Eating Disorder Inventory body dissatisfaction subscale; EDI BUL= Eating Disorder Inventory Bulimia Subscale; EDI DT= Eating Disorder Inventory Drive for Thinness Subscale; FSIQ= Full Scale Intelligence Quotient; HAMD= Hamilton Depression Rating Scale; HAMA= Hamilton Anxiety Rating Scale; IBW=ideal body weight; YBC= Yale-Brown-Cornell Eating Disorder Scale.

* Little's chi-square test indicated that scores on the YBC Rituals subscale were missing completely at random, so missing values were not imputed (n=15).

Table 2

Brain Volumes of Patients with Anorexia Nervosa before and after Weight Restoration.

	Low Weight N=22		Weight Restored N=22		t	p value
	Mean (mm ³)	St. Dev	Mean (mm ³)	St. Dev		
Intracranial Volume	1471612.61	103359.41	1479668.14	94806.9608	-1.55	.14
Right Lateral OFC	7515.64	885.13	7793.54	981.49	-3.21	.004
Right Medial OFC	5275.09	771.19	5343.82	625.26	-0.84	.41
Left Lateral OFC	7655.86	770.18	8083.19	839.10	-7.00	<.001
Left Medial OFC	5217.05	808.83	5528.42	870.59	5.90	<.001

Notes. Values represent imputed missing data. AN= anorexia nervosa; OFC= orbitofrontal cortex

Table 3
Correlations among Brain Areas, BMI, and IGT Performance in low weight AN patients (Baseline)

	1	2	3	4	5	6	7
1 Intracranial Volume	1						
2 Right Lateral OFC	.66**	1					
3 Right Medial OFC	.66**	.68**	1				
4 Left Lateral OFC	.69**	.85**	.72**	1			
5 Left Medial OFC	.75**	.61**	.72**	.71**	1		
6 BMI	.29	.43*	.42*	.53*	.36	1	
7 IGT Performance	.41	.29	.31	.45*	.61**	.53*	1

Note.
* p<.05;
** p<.01. N=22. BMI= body mass index; IGT=Iowa Gambling Task; OFC= orbitofrontal cortex.