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Implicit learning on a probabilistic classification task in adults and adolescents with Bulimia Nervosa

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ABSTRACT

Background: Dysfunction in frontostriatal circuits likely contributes to impaired regulatory control in Bulimia Nervosa (BN), resulting in binge-eating and purging behaviors that resemble maladaptive habits. Less is known about the implicit learning processes of these circuits, which may contribute to habit formation.
Methods: We compared 52 adolescent and adult females with BN to 55 healthy matched-controls during performance of a probabilistic classification learning task, one form of implicit learning. Groups were compared in accuracy and response times, using mixed-models with block, age, and diagnosis as predictors, corrected for multiple comparisons with confounds covaried.
Results: BN participants showed differences in performance on a probabilistic classification learning task that varied by age. Adolescents with BN initially performed as accurately as healthy adolescents, but showed poorer perseverance over time. Adults with BN initially performed less accurately than healthy adults, but improved to perform equivalently. Symptom severity was associated with poorer accuracy in both adults and adolescents with BN.
Conclusions: Frontostriatal dysfunction may underlie abnormalities in regulatory control and probabilistic classification learning in BN, likely contributing to the dysregulation of implicitly learned, maladaptive binge-eating and purging behaviors. Such dysfunction in BN may progress with increasing age, first manifesting in poor regulatory control over behaviors and then expanding to implicit learning processes that may underlie habitual behaviors.

1. Introduction

Bulimia Nervosa (BN) is characterized by the presence of recurrent episodes of binge eating that are associated with a sense of loss of control, followed by compensatory behaviors to counteract weight gain (American Psychiatric Association, 2013). These behaviors suggest the presence of self-regulatory control deficits likely due to a failure to engage frontostriatal systems appropriately (Marsh et al., 2009b, 2011). While frontostriatal dysfunction and concomitant regulatory deficits are established in BN (Berner and Marsh, 2014), unknown is how these disturbances affect other functions that these circuits subserve, such as implicit learning.

Implicit learning, alternatively referred to as *procedural* or *habit learning*, occurs outside conscious awareness, and encompasses the acquisition of stimulus-response associations without recognition that learning is taking place. Implicit learning functions differently from declarative memory or action-outcome learning in which explicit awareness of stimulus-response associations drives responding, resulting in increased behavior when rewarded and decreased behavior when punished. Rather, implicitly-learned behavior develops gradually outside of awareness over time and many repetitions; as a result, the behavior becomes automated, relatively insensitive to reward, and highly resistant to change (Walsh, 2013). As such, individuals with BN may initially engage in binge-eating or purging behaviors because they produce rewards (i.e., praise for weight loss, pleasure from eating, or alleviation of

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negative affect). However, over time, repetition may allow them to become overtrained and habitual, a sort of "default" response that no longer requires reward and persists despite negative consequences (Walsh, 2013).

Findings from lesion studies indicate that implicit learning of automatic behaviors is supported by the striatum, a system that is both anatomically and functionally separate from the declarative learning system of the medial temporal lobe (Packard and Knowlton, 2002). In humans, implicit learning likely depends on parallel processing between the striatal implicit memory system and the medial temporal lobe explicit/associative memory systems, requiring adequate functioning of both subcortical systems alongside prefrontal regulatory mechanisms (McNamee et al., 2015). Frontostriatal dysfunction is implicated in disorders characterized by both regulatory disturbances and compulsive, repetitive behaviors (Marsh et al., 2004, 2009a; Steinglass and Walsh, 2006; Veltman et al., 2011). The automatic behaviors that characterize these disorders can be considered dysfunctional habits that escaped from prefrontal regulatory control. Likewise, the recurrent nature of the binge–purge cycle may represent maladaptive habit learning, wherein feeding behaviors are released from regulation and become compulsive in nature.

Probabilistic classification learning is one form of implicit learning in which cues are probabilistically associated with outcomes and participants process associations without explicit awareness. In the Weather Prediction Task (WPT), participants try to predict either "rain" or "shine" based on the presentation of cards whose cue–outcome associations vary probabilistically. Despite believing that they are simply guessing, healthy participants demonstrate above-chance ability to guess the correct outcome. In contrast, patients with diseases affecting frontostriatal circuitry (i.e., Parkinsons, Tourettes) demonstrate impaired performance, despite being able to adequately answer explicit questions about the task (Marsh et al., 2004); those who perform most poorly have documented frontostriatal abnormalities, deficits in regulatory capacity, and repetitive behaviors resembling habits (Kataoka et al., 2010; Leckman et al., 2014). As such, the WPT can be used to assess the functioning of the striatal-based implicit learning system in persons with BN.

Previous findings from adults diagnosed with Eating Disorder Not Otherwise Specified (EDNOS) suggested abnormal frontostriatal functioning during performance of the WPT (Celone et al., 2011). Although task performance was similar to healthy participants, those with sub-threshold BN symptoms demonstrated increased caudate and dorsolateral prefrontal cortex activation compared to healthy participants. Frontostriatal hyperactivity during implicit learning may compensate for inefficient circuit functioning in patients with binging and purging behaviors, consistent with previous findings of deficient frontostriatal functioning in patients with BN during tasks requiring regulatory control (Marsh et al., 2009b, 2011). Together, these findings point to frontostriatal dysfunction in BN, but unknown is when differences in striatal-based implicit processes manifest or if they vary with severity.

To this end, we used the WPT to compare striatal-based implicit learning across a large sample of adolescents and adults with and without BN. Although performance differences were not detected in persons with subclinical-BN symptoms (Celone et al., 2011), we hypothesized that differences in performance would emerge when comparing a larger sample of adolescents and adults with full-syndrome BN to healthy matched-controls. In exploratory analyses, we also assessed whether severity of bulimic symptoms was associated with WPT performance. Finally, we compared BN and control groups in performance on tasks requiring the intact functioning of declarative memory and self-regulatory processes to assess whether any observed differences in WPT performance were specific to implicit processes or associated with both executive and implicit functions.

2. Methods

2.1. Participants

Data were acquired from 107 participants, who were either healthy controls (HC; $n = 55$) or individuals with BN ($n = 52$) recruited to participate in MRI studies of cognitive processes. All participants were females between the ages of 12–40; participants were classified as adolescents if aged 12–17 ($n = 39$) and adults if aged 18+ ($n = 68$). BN and HC groups did not differ in age, body mass index (BMI), or full-scale intelligence quotient (FSIQ). Participants with BN had an average illness duration of over four years and experienced significant symptomatology; 34% were currently taking SSRI medications (see Table 1).

All adults with BN met DSM-V criteria, whereas adolescents with BN were included if they experienced an average of one binge-eating episode (objective or subjective) and one purging episode per week for the past three months, with at least one binge-eating and purging episode occurring within the past month (Darcy et al., 2015). Exclusion criteria for all participants included history of neurological illness or head trauma, mental retardation or pervasive developmental disorder, or current substance disorder. HC participants and adults with BN were excluded for any current comorbid disorder; adolescents with BN were excluded only for comorbid disorders known to affect frontostriatal circuitry (i.e., ADHD, TS, OCD; Marsh, 2009). Five adults with BN (ages 18–21) were included despite having a current comorbid disorder because they were originally recruited as adolescents. Participants with BN with and without comorbidities did not differ in BMI, IQ, BN severity, or lifetime comorbid diagnoses.

BN and HC participants were recruited through advertisements, and group-matched by age, FSIQ, and BMI. Research was conducted in accordance with the Declaration of Helsinki and approved by the NYSPI Institutional Review Board. Written informed consent was obtained from adults and the parents of adolescent participants, and assent was obtained from adolescents. Participants were compensated for their time.

2.2. Procedure

2.2.1. Participant characterization

The *Structured Clinical Interview for DSM-IV Disorders* (18+; First et al., 2002) and *Kiddie Schedule for Affective Disorders and Schizophrenia* (<18; Kaufman et al., 1997) were administered. Severity of BN symptoms was assessed using the *Eating Disorder Examination* (Cooper and Fairburn, 1987). The *Beck Depression Inventory-II* (18+; Beck et al., 1996) and *Children's Depression Inventory* (<18; Kovacs, 1992) measured depressive symptoms. The *DuPaul-Barkley ADHD Rating Scale* (DuPaul, 1991) gauged inattention and hyperactivity symptoms, and the *Wechsler Abbreviated Scale of Intelligence* (Weschler, 1981) estimated FSIQ.

2.2.2. Weather Prediction Task (WPT)

An abbreviated version of the WPT, with five blocks of 18 trials (total 90 trials), was selected to reduce participant burden. Although a longer 200-item version exists, the 90-item version has been successfully used with both youth and adults (Marsh et al., 2004), and as few as 10–20 trials have been shown to demonstrate probabilistic classification learning (Knowlton et al., 1994). Accuracy and latency scores for each block were calculated by averaging within block. A 1-min break was provided after the first