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An empirical taxonomy of reward response patterns in a transdiagnostic eating disorder sample

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ABSTRACT

Reward response patterns may contribute to risk and maintenance of eating disorders (EDs), and there may be clinically meaningful heterogeneity in behavioral responses to different actual and anticipated rewards across ED diagnoses. We used an empirical approach to classify individuals with EDs based on self-reported tendencies for responding to reward-related stimuli. Latent profile analysis was conducted in a transdiagnostic ED sample ($N = 104$) using Temperament and Character Inventory (Cloninger et al., 1993) subscales to categorize participants on reward responses of behavioral activation towards immediate, hedonic rewards (Novelty Seeking subscale), persistence towards long-term rewards (Persistence subscale), and maintenance by social rewards (Reward Dependence subscale) rewards. Two profiles were identified: (1) Behavioral Activation group (elevated Novelty Seeking; $n = 62$); and (b) Behavioral Persistence group (elevated Persistence; $n = 42$). Generalized linear models comparing profiles showed that frequency of these reward response profiles did not differ in probable AN, BN, or OSFED groups; however, individuals with probable BED more often demonstrated the Behavioral Activation profile ($p = .041$). These profiles exhibited comparable ED severity, but different presentations. Across probable ED diagnoses, the Behavioral Activation group reported greater binge eating ($p = .006$, $d = 0.32$) and had higher BMIs ($p = .001$, $d = 0.57$); the Behavioral Persistence group endorsed greater driven exercise ($p = .042$, $d = 0.33$). Categorization by activation to novel, immediate rewards versus persistence towards long-term rewards was associated with different symptoms across diagnoses, potentially supporting the role of specific reward response profiles in ED phenomenology.

It has been suggested that specific eating disorder (ED) diagnoses are characterized by extremes in behavioral responses to rewards, with individuals with anorexia nervosa (AN), especially restricting subtype (AN-R), *under*-responding to rewards and individuals with bulimia nervosa (BN) and binge eating disorder (BED) *over*-responding to rewards (Wierenga et al., 2014). These proposed response tendencies could account for the extremes in avoidance or approach behavior towards palatable foods in EDs. Although considerable research investigating reward response patterns supports this hypothesis (Atiye et al., 2015; Miettunen & Raevuori, 2012), a number of studies report discrepant findings, such as heightened reward responding in AN (including AN-R) and dampened reward responding in BN (Atiye et al., 2015; Haynos et al., 2020).

These incongruities may be explained by two main factors. First, different assessments capturing disparate aspects of behavioral responding to rewards have been used between studies (Haynos et al., 2020). Among the studies using self-report measures to assess responsivity to rewards, some have used measures assessing behavioral approach tendencies that involve pursuit of immediate, hedonic rewards (e.g., Behavioral Activation System [BAS] Fun Seeking subscale; Temperament and Character Inventory Novelty-Seeking subscale [TCI-NS]). Others have used measures evaluating behavioral persistence

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tendencies involving long-term reward pursuit despite short-term reward denial (e.g., BAS Drive subscale, TCI Persistence subscale [TCI—P]). Still others have used measures assessing behavioral maintenance through social rewards (e.g., TCI Reward Dependence subscale [TCI-RD]) (Carver & White, 1994; Cloninger et al., 1993). When measures are examined individually, more consistent findings emerge. Individuals with BN typically display highest scores on measures related to behavioral approach to immediate hedonic rewards and individuals with AN, especially AN-R, typically display highest scores on measures of behavioral persistence and maintenance towards long-term and social rewards (Atiye et al., 2015; Miettunen & Raevuori, 2012; Sancho et al., 2008). Thus, we have proposed that ED presentation may relate more to the *types* of rewards individuals find compelling, rather than global reward responsivity (Haynos et al., 2020).

Second, studies often compare reward indices across narrowly defined diagnostic categories, particularly AN and BN. Most studies exclude BED or other specified feeding and EDs (OSFED), despite these diagnoses constituting over half of ED cases (Fairweather-Schmidt & Wade, 2014). Further, there is considerable phenotypic heterogeneity within and shared characteristics between ED diagnoses (Wildes & Marcus, 2013). Examining behavioral response tendencies towards reward only by diagnosis limits the ability to understand whether similar underlying mechanisms influence shared transdiagnostic symptoms (e.g., binge eating). Empirical classification methods such as Latent Profile Analysis (LPA) may assist in identifying subtypes of behavioral responding to reward that characterize individuals across ED diagnoses. Although LPA has produced other ED classification models with clinical utility, such as those categorized by symptom or emotional profile (Wildes & Marcus, 2013), no research has examined whether empirically-derived profiles of behavioral responses to reward characterize ED subgroups.

This study investigated whether a heterogeneous ED group could be meaningfully classified by behavioral response tendencies to reward. We employed LPA to identify latent profiles with TCI subscales as indicator variables assessing behavioral responses to novel, immediate rewards (i.e., TCI-NS), long-term rewards involving short-term frustration (i.e., TCI-P), and affiliative rewards (i.e., TCI-RD). We evaluated the external validity of these profiles by comparing them on ED symptoms, behaviors, and impairment. Although this research was primarily considered to be hypothesis-generating, based on prior research and theory (Cloninger et al., 1993; Wierenga et al., 2014; Wildes & Marcus, 2013) we expected: 1) to identify 2–4 profiles differing on TCI subscales that would be represented across all diagnoses; and 2) profiles with higher TCI-NS values to demonstrate more binge eating and higher BMIs, those with higher TCI-P values to demonstrate more restrictive eating, driven exercise, and lower BMIs, and those with higher TCI-RD values to demonstrate more shape and weight concerns.

1. Materials and methods

1.1. Participants

Participants ($N = 104$) were individuals ≥18 years old with an ED based on self-report and the Eating Disorder Examination-Questionnaire (EDE-Q) (Fairburn & Beglin, 1994). The sample was predominantly White (90.4%, $n = 94$), female (98.1%; $n = 102$), and college educated (94.2%, $n = 98$). Age was available on 76% of the sample ($n = 79$)[1]; among these participants, average age was 29.75 ($SD = 10.59$) years. Over two-thirds of the sample (67.3%, $n = 70$) reported currently receiving ED treatment. Probable DSM-5 ED diagnoses were derived by well-established EDE-Q diagnostic algorithms with good to excellent sensitivity and specificity (Berg et al., 2012). Probable diagnostic distribution in the sample was: 13.5% AN ($n = 14$; 5 AN-R, 9 AN-BP), 21.2% BN ($n = 22$), 25.0% BED ($n = 26$), 38.5% OSFED ($n = 40$), and 1.9% ($n = 2$) undetermined due to missing data.

[1] Due to a technical error, the survey did not record age for the first 25 study participants.

1.2. Procedures

The local Institutional Review Board approved study procedures. Advertisements recruiting for EDs (e.g., "Have you been diagnosed with an eating disorder?") were distributed at local treatment centers, universities, and community spaces. Interested individuals accessed the survey online, electronically consented, and completed questionnaires assessing response tendencies towards reward and ED symptoms.

1.3. Measures

1.3.1. Indicator variables

TCI NS, P, and RD subscales were LPA indicators. The TCI is a 240-item assessment measuring personality dimensions that capture "individual differences in associative learning in response to novelty, danger or punishment, and reward," p. 977 (Cloninger et al., 1993). Cloninger's theory posits that traits such as impulsivity and persistence fall under the umbrella of behavioral response patterns to external stimuli subserved by different biologically-based motivational systems (e.g., behavioral activation, persistence, and maintenance systems) (Cloninger, 1994; Cloninger et al., 1993). Whereas certain TCI subscales (e.g., harm avoidance) measure behavioral inhibition under signals of threat, others subscales, including NS, P, and RD, predominantly assess behavioral response tendencies to actual or anticipated reward. The NS subscale ($\alpha = 0.88$; all α values derived from current study sample) is said to reflect bias towards *behavioral activation* or initiation of behaviors to novel rewarding stimuli, potentially mediated through dopaminergic signaling. The P subscale ($\alpha = 0.73$) is said to measure *behavioral persistence* towards long-term rewarding stimuli. This trait is hypothesized to emerge from reward conditioning of the behavioral inhibition system to interpret signals typical of punishment as rewarding. The RD subscale ($\alpha = 0.73$) is said to measure *behavioral maintenance* by affiliative rewards, such as social approval and support, potentially facilitated by oxytocin release in reward circuitry.

1.3.2. External validators

The EDE-Q (Fairburn & Beglin, 1994) Global ($\alpha = 0.89$) and subscale scores (Restraint, Eating Concern, Shape Concern, Weight Concern; $\alpha = 0.70–0.87$) measured ED symptoms. Episode frequencies for objective binge eating, purging (laxatives, vomiting), and driven exercise within the prior month were also assessed by EDE-Q. The Dietary Restriction Screener (DRS) (Haynos & Fruzzetti, 2015) measured past-month restrictive eating frequency, as the DRS has been shown to predict reduced food intake more effectively than EDE-Q Restraint (Haynos & Fruzzetti, 2015). The Clinical Impairment Assessment (CIA; $\alpha = 0.90$) (Bohn et al., 2008) assessed ED-related clinical impairment. Body Mass Index (BMI) was calculated using self-reported height and weight. Previous research indicates that individuals with EDs can accurately self-report height and weight (McCabe et al., 2001).

1.3.3. Data analytic plan

LPA classifies individuals into latent categorical groups according to responses on indicator variables. Latent Gold version 4.5 (Statistical Innovations, Inc., Belmont, MA) fit 1- to 10- class LPA models with TCI subscales (TCI-NS, TCI—P, TCI-RD) as indicator variables. Bayesian Information Criterion (BIC) (Schwarz, 1978) and Consistent Akaike Information Criterion (cAIC) (Bozdogan, 1987) identified the best fitting model (lower scores = better fit). Posterior Bayesian probabilities determined class membership. Prior research (Goldschmidt et al., 2014; Lavender et al., 2013) suggests that our sample size was adequate for this statistical approach. Chi-square analyses (with effect size *w*) were used to examine how latent reward response profiles corresponded to

probable ED diagnoses.

Generalized linear modeling was conducted to compare derived latent classes on internal indicators (TCI subscales) and external validators (EDE-Q scores; binge-eating, purging, driven exercise, and restrictive eating frequency; CIA score; BMI). Outcome variables and TCI-P were skewed; therefore, gamma with log link models was used for scale data and negative binomial models for count data. Cohen's *d* is reported for effect size. Analyses were repeated controlling for probable ED diagnosis to determine if behavioral reward response clusters provided additional ability to account for ED symptoms over diagnostic category.

2. Results

2.1. Latent profile analysis

The best-fitting model LPA supported a 2-class solution (Table 1). Identified profiles included Behavioral Activation (Class 1: $n = 62$; 59.6%) and Behavioral Persistence (Class 2: $n = 42$; 40.4%) groups, named after Cloninger's model (Cloninger, 1994; Cloninger et al., 1993). The Behavioral Activation group scored significantly higher on the TCI-NS ($p < .001$; Table 2). The Behavioral Persistence group scored significantly higher on the TCI-P ($p < .001$). Behavioral Activation and Persistence groups did not differ on the TCI-RD ($p = .622$), although the full sample demonstrated elevated TCI-RD scores compared to community norms (Cloninger et al., 1993) ($p = .001$). BED was more often associated with the Behavioral Activation (76.9%) versus Behavioral Persistence (23.1%) profile, $\chi^2(1) = 4.31$, $p = .041$, $w = 0.41$. AN, BN, or OSFED diagnoses did not statistically differ between Behavioral Activation and Persistence profiles (AN: 50.0% vs. 50.0%, $\chi^2(1) = 0.62$; $p = .560$, $w = 0.21$; BN: 68.2% vs. 31.8%, $\chi^2(1) = 0.85$; $p = .465$, $w = 0.20$; OSFED: 47.5% vs. 52.5%, $\chi^2(1) = 3.96$; $p = .064$, $w = 0.32$).

2.2. External validation of LPA subgroups

The behavioral reward response groups differed on ED symptoms (Table 2). The Behavioral Activation group reported significantly more binge eating ($p = .006$) and higher average BMIs ($p = .001$). The Behavioral Persistence group reported greater driven exercise ($p = .042$). After accounting for probable ED diagnosis, behavioral reward response profiles continued to be significantly associated with binge eating ($p = .026$) and driven exercise ($p = .031$), but not BMI ($p = .059$). Groups did not significantly differ on other clinical variables, including global ED severity or impairment.

3. Discussion

We examined whether a heterogeneous ED sample could be empirically categorized into meaningful subgroups according to behavioral response patterns to available or anticipated rewards. Using LPA, two profiles were identified, respectively characterized by relation to the Behavioral Activation system (responsivity to immediate, novel rewards) and Behavioral Persistence system (pursuit of long-term delayed rewards necessitating temporary discomfort). Although these profiles did not differ in overall ED severity or impairment, they differed in clinical presentation. The Behavioral Activation group reported more binge eating and had higher average BMIs, whereas the Behavioral Persistence group reported more driven exercise. Thus, across diagnoses, behavioral response patterns to available short-term versus anticipated long-term rewards likely contribute to an individual's specific ED symptoms, but not global severity. Individuals may be prone to different types of ED behaviors (e.g., driven exercise) because they align with their temperamental tendency to respond to rewards in particular

Table 1
Fit indices for 1- to 10-class latent profile analysis models.

Number of classes	Number of parameters	BIC	cAIC
1	6	1846.52	1852.52
2	**13**	**1815.11**	**1828.11**
3	20	1831.90	1851.90
4	27	1853.52	1880.52
5	34	1871.56	1905.56
6	41	1895.46	1936.46
7	48	1917.65	1965.65
8	55	1945.48	2000.48
9	62	1967.07	2029.07
10	69	1976.46	2045.46

Note: Bold indicates best fitting model; BIC = Bayesian Information Criterion; cAIC = Consistent Akaike Information Criterion.

Table 2
TCI indicator variables and eating disorder external validator variables across behavioral reward response profiles.

	Behavioral activation subtype (n = 62)	Behavioral persistence subtype (n = 42)	Test statistic		Effect size
	M (SD)	M (SD)	Wald $\chi^2_{(3)}$	p	d
LPA indicator variables					
TCI Novelty-Seeking Subscale	21.19 (7.15)	10.86 (4.71)	69.09	**<.001**	1.70
TCI Persistence Subscale	6.08 (1.93)	10.07 (0.81)	87.36	**<.001**	2.55
TCI Reward Dependence Subscale	17.23 (4.33)	16.79 (4.64)	0.25	.618	0.10
External validator variables					
EDE-Q Global Score	4.26 (0.92)	4.12 (1.15)	0.41	.522	0.14
EDE-Q Restraint Score	4.67 (1.67)	4.64 (1.71)	0.01	.946	0.02
EDE-Q Eating Concern Score	4.68 (1.17)	4.58 (1.38)	0.14	.704	0.08
EDE-Q Shape Concern Score	5.03 (1.03)	4.71 (1.15)	1.72	.190	0.30
EDE-Q Weight Concern Score	4.67 (1.06)	4.55 (1.27)	0.21	.648	0.11
Clinical Impairment Assessment Score	32.68 (8.47)	32.02 (8.88)	0.12	.733	0.08
Binge eating frequency (episodes/month)	11.19 (18.12)	6.26 (10.07)	7.47	**.006**	0.32
Purging frequency (episodes/month)	11.45 (27.84)	8.46 (15.35)	1.63	.202	0.13
Driven exercise frequency (episodes/month)	5.50 (8.62)	8.50 (10.19)	4.15	**.042**	0.33
Restrictive eating frequency (days/month)	15.55 (9.67)	19.15 (9.33)	1.01	.315	0.38
Body mass index (kg/m^2)	28.05 (11.51)	22.71 (6.03)	10.26	**.001**	0.57

Note: EDE-Q = Eating Disorder Examination Questionnaire (Fairburn & Beglin, 1994); TCI = Temperament and Character Inventory (Cloninger et al., 1993). Significant *p*-values are bolded.

ways (e.g., orient to delayed over immediate rewards). This study did not provide clear information regarding the role of responding to affiliative rewards in ED symptoms.

Behavioral response tendencies to reward were not purely defined by probable diagnoses. Although BED was more commonly linked to the Behavioral Activation profile, nearly one quarter of participants in the BED group were categorized under the Behavioral Persistence profile. Other ED diagnoses did not significantly differ in behavioral reward response group classification. Further, reward response profiles were significantly associated with binge eating and driven exercise even after controlling for diagnosis. This adds to the literature indicating that shared mechanisms exist across ED diagnoses and that different mechanisms operate within the same diagnosis (Wildes & Marcus, 2013). Since reward-related mechanisms have been implicated in other psychiatric populations (e.g., mood disorders) (Baskin-Sommers & Foti, 2015), propensity towards novel immediate or anticipated long-term rewards may mechanistically extend beyond EDs. The reward response profiles identified in this manuscript may account for common ED comorbidities associated with activation in response to immediate novel rewards (e.g., substance use disorders) versus effort towards long-term rewards (e.g., obsessive-compulsive personality disorder) (Hudson et al., 2007; Lempert et al., 2019). Future research should examine reward response profiles as predictors and moderators of clinical outcomes and compare the validity to other classification systems (Wildes & Marcus, 2013).

Our results potentially suggest that understanding the ways in which an individual responds to different external reward stimuli may lend more nuance than determining if they have global reward over- or under-responsivity. Some individuals may be behaviorally activated under conditions of immediate, high-intensity rewards and may exhibit this tendency through a strong drive towards palatable food (Dalton & Finlayson, 2014; Wierenga et al., 2014). Clinical interventions for such EDs might benefit from decreasing the salience of hedonically-driven rewards or enhancing inhibitory control in response to compelling stimuli. Other individuals demonstrating behavioral persistence in pursuit of long-term rewards and may engage in driven exercise, which requires sustained effort to obtain a desired reward (e.g., weight loss) (Dalle Grave, 2009). These individuals could benefit from interventions that enhance the salience of adaptive momentary rewards or increase cognitive flexibility to disengage from problematic long-term goals. Long-standing theory supported by emerging neurobiological findings indicate that these behavioral reward response tendencies may be mediated by different brain-based mechanisms (Volkow & Baler, n.d.; Cloninger, 1994; Cloninger et al., 1993). Further research is needed to determine whether the identified reward response profiles vary as biological endophenotypes.

Study strengths include the use of advanced empirical categorization methods and a heterogeneous ED sample, including participants with probable BED and OSFED diagnoses, which are commonly excluded in reward research. There are also study limitations. Assessments were self-reported and could be affected by reporting biases. Although the sample was diagnostically heterogeneous, some groups were not well represented (e.g., AN-R), and sample diversity was limited across key demographics (e.g., gender, race/ethnicity). EDE-Q diagnostic algorithms demonstrate validity; however, different diagnoses may have been derived using interview assessments. The 28-day timeframe of the EDE-Q provides an additional limitation for deriving diagnoses. Sample size may have limited our ability to detect all but the strongest diagnostic differences. Due to multicollinearity constraints, we could not use multiple measures to assess reward response patterns in the LPA. It is possible, therefore, that our measures captured constructs besides behavioral response tendencies towards reward (e.g., control). For instance, the TCI-NS is said to capture impulsivity and frustration avoidance in addition to activation towards novel rewards (Cloninger, 1994; Cloninger et al., 1993). Given that Cloninger theorized these traits to reflect response patterns to external rewards, (Cloninger, 1994; Cloninger et al., 1993), our findings represent an initial step towards characterizing how different responding to reward signals may affect behavior across ED diagnoses. However, future research including larger, diverse samples and longitudinal, multi-method approaches is needed to further understand reward response tendencies in EDs.

4. Conclusions

Response tendencies to different reward stimuli, including those signaling immediate, reward and those signaling delayed rewards, are associated with certain ED symptoms across diagnoses, constituting promising putative mechanisms for future ED research.

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CRediT authorship contribution statement

Ann Haynos: Conceptualization, Methodology, Investigation, Formal analysis, Data Curation, Writing - Original Draft, Writing - Review & Editing.

Shirley Wang: Writing - Original Draft, Writing - Review & Editing.

Sarah Russell: Writing - Original Draft, Writing - Review & Editing.

Jason Lavender: Formal analysis, Writing - Review & Editing.

Carol Peterson: Writing - Review & Editing.

Karen Mathis: Writing - Review & Editing.

Scott Crow: Conceptualization, Methodology, Resources, Writing - Review & Editing.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

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