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A multimodal, naturalistic investigation of relationships between behavioral impulsivity, affect, and binge eating

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Abstract

While binge eating is associated with both emotion regulation deficits and cognitive control impairments related to impulsivity, thus far research has not examined how dimensions of behavioral impulsivity may influence momentary relationships between affect and binge-eating episodes. The present study utilized multimodal methods to examine the extent to which individual differences in impulsive choice (i.e., delay and probabilistic discounting) and impulsive action (i.e., response inhibition) moderated momentary relationships between negative and positive affect (NA and PA) and binge eating measured in the natural environment. Participants were 30 adult women with binge-eating symptoms who completed measures of behavioral impulsivity (i.e., Monetary Choice Questionnaire, Cued Go/No-Go task, Game of Dice Task), followed by a 14-day ecological momentary assessment protocol during which they reported affect levels and binge-eating episodes. Results of generalized estimating equations indicated that greater delay discounting (i.e., preference for immediate, yet smaller rewards) strengthened momentary relationships between both PA and NA and binge eating. However, and unexpectedly, the relationship between momentary PA and binge eating was negative among individuals with greater Cued Go/No-go commission errors, suggesting that higher PA actually attenuated risk of binge episode occurring in these individuals. Together these findings highlight important distinctions between facets of behavioral impulsivity as well as their relationships with affect valence and intensity in predicting binge episodes. Specifically, temporal rather than probabilistic discounting may be most relevant to momentary processes that contribute to binge eating, and promotion of momentary positive affect may be helpful for individuals with poorer response inhibition.

Keywords

binge eating; impulsivity; ecological momentary assessment; affect; emotion

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Impulsivity is a multidimensional construct that has been consistently implicated in the onset, maintenance, and classification of eating disorder (ED) psychopathology, and has been most closely linked to binge-eating symptoms (e.g., Culbert, Racine, & Klump, 2015; Pearson, Wonderlich, & Smith, 2015; Wildes & Marcus, 2013). Recent literature has identified distinct but interrelated dimensions of impulsivity, including impulsive choice (i.e., decision-making), impulsive action (i.e., response inhibition), and impulsive personality traits (Bari & Robbins, 2013; MacKillop et al., 2016), each of which may be examined from different levels of analysis and may contribute to failures in self-regulation (Nigg, 2017). However, despite prior work demonstrating the interrelated nature of cognitive control and emotion (e.g., Okon-Singer, Hendler, Pessoa, & Shackman, 2015), little is known about how facets of impulsivity interact with momentary affective processes to predict binge eating in naturalistic settings. Such investigation could help identify the specific types of impulsivity that are most salient in the maintenance of binge eating, and the moments at which particular individuals are most vulnerable to engage in such behavior.

Impulsivity and Binge Eating

While much of the research in EDs historically has utilized self-report measures of impulsive personality traits, a burgeoning literature using neurocognitive tasks has indicated that EDs characterized by binge eating are associated with aberrant executive functioning related to impulsivity (Smith, Mason, Johnson, Lavender, & Wonderlich, 2018a). Task-based and behavioral measures of impulsivity offer important advantages over self-report questionnaires of impulsive traits or tendencies. That is, behavioral measures yield objective data that are not subject to biases related to participants' interpretation of items, and provide observable indices of behavioral inhibition known to correspond to specific neural circuits, which may serve to enhance understanding of bio-behavioral mechanisms underlying binge eating (Bari & Robbins, 2013).

Two facets of executive functioning that are particularly relevant in understanding the neurocognitive underpinnings of impulsivity are that of response inhibition and decision-making processes (MacKillop et al., 2016). Response inhibition is a facet of behavioral inhibition that refers to the ability to withhold or stop a motor response, and is often assessed using the go/no-go task, during which participants respond to stimuli when a "go" signal appears, and inhibit responses when a "no go" signal appears (Bari & Robbins, 2013). Response inhibition has been shown to be impaired in a range of psychiatric illnesses (Wright et al., 2014), and in a recent meta-analysis of bulimic-spectrum EDs (i.e., anorexia nervosa binge-purge subtype [AN-BP], bulimia nervosa [BN], binge-eating disorder [BED]), Wu and colleagues (2013a) reported significant deficits in response inhibition across ED groups compared to healthy controls measured via the go/no-go task.

In addition to response inhibition (i.e., impulsive *action*), another subtype of behavioral inhibition identified in the literature is that of impulsive *choice*, which refers to aspects of decision-making that are influenced by motivational and affective processes, and can be operationalized by measures of delay and probability discounting (Bari & Robins, 2013; MacKillop et al., 2016; Nigg, 2017). Specifically, *delay discounting* (or temporal

discounting) refers to the degree to which individuals prefer smaller, more immediate rewards compared to larger, future rewards (Odum, 2011), with high discounting being associated with a broad range of addictive behaviors (Amlung, Vedelago, Acker, Balodis, & MacKillop, 2017). Such measures require individuals to choose between smaller rewards that are available soon (e.g., “\$25 today”) or larger amounts that are available at variable delays (e.g., “\$60 in 14 days”), with a steeper discounting parameter (k) indicating a greater preference for immediate rewards (Odum, 2011).

In contrast, measures of *probabilistic discounting* require participants to choose between smaller rewards delivered with higher probability and larger rewards delivered with smaller or variable probabilities. The Game of Dice Task (GDT; Brand et al., 2005) is one commonly used measure of probabilistic discounting; in this task, participants select one of four choices, two of which are high risk (high reward with low probability to win) and two of which are low risk (smaller reward with higher probability to win), with decision-making indexed by the number of safe choices minus the number of risky choices. Thus, while delayed discounting depends on the timing of outcome (with later rewards typically discounted), risk-taking depends on probability (with the probability of negative outcomes discounted, regardless of timing). In binge-type EDs, recent meta-analyses have identified impairments across these domains compared to healthy controls, though there have been some inconsistencies in the magnitude of effects (Guillaume et al., 2015; Wu et al., 2013b).

However, across each of these domains (i.e., response inhibition, delay and probabilistic discounting), it is important to note that the weight status of ED and comparison groups has been implicated as a potential confound contributing to heterogeneity in effects. That is, extant research suggests that overweight and obesity are associated with executive functioning impairments irrespective of ED status (Fitzpatrick, Gilbert, & Serpell, 2013; Smith, Hay, Campbell, & Trollor, 2011). Given that studies of executive functioning in EDs have not consistently accounted for weight status, findings have been inconclusive as to whether ED status, particularly EDs characterized by binge eating, exacerbates inhibitory control and decision making deficits in the context of obesity/overweight (Bartholdy et al., 2016; Guillaume et al., 2015; Lavagnino et al., 2016; Wu et al., 2013b).

Affect, Impulsivity, and Binge Eating

Negative affect and emotion dysregulation have been established as important risk and maintenance factors for binge eating (Lavender et al., 2015; Leehr et al., 2015). Theoretical conceptualizations and findings from ecological momentary assessment (EMA) studies suggest that individuals engage in binge eating as a way to reduce or escape from negative affect, which in turn perpetuates the symptomatology via negative reinforcement processes (e.g., Heatherton & Baumeister, 1991; Smyth et al., 2007; Wonderlich et al., 2008). Outside of EDs, there has been substantial research demonstrating that cognitive control and emotion-related processes are intertwined (Okon-Singer et al., 2015), and cognitive control and decision-making deficits have been broadly implicated as transdiagnostic mechanisms contributing to psychopathology (e.g., Goschke, 2014; McTeague, Goodkind, & Etkin, 2016; Snyder, Miyake, & Hankin, 2015). Despite the fact that binge eating had been shown to be related to both aberrant emotional and neurocognitive functioning, prominent

theoretical models of EDs have not explicitly articulated interrelationships between affect and relevant neurocognitive processes such as behavioral inhibition. These relationships are nevertheless consistent with affect regulation, personality, and resource depletion accounts of EDs, and particularly binge-eating behavior.

For example, strategy-based and temporal process models of emotion regulation posit that inhibition of impulsive behavioral tendencies and choices is an inherent component of adaptive emotion regulation, including the ability to engage in goal-directed behavior and control impulses when experiencing negative affect (Gratz & Roemer, 2004; Gross, 1998; Mitchell et al., 2011; Okon-Singer et al., 2015). Relatedly, the construct of negative urgency (i.e., the tendency to behave impulsively when distressed), has been implicated as a dispositional risk factor for binge eating symptoms (e.g., Culbert et al., 2015; Fischer, Smith, & Cyders, 2008).

While negative urgency and emotion regulation difficulties are often conceptualized as relatively stable, trait-like characteristics, resource depletion accounts also highlight momentary processes by which the experience of distress and depleted self-control together lead to impulsive, maladaptive responding to negative affect (Baumeister & Heatherton, 1996). Applied to EDs, this suggests that when under emotional distress, individuals devote resources to regulate or escape from negative affect (Loth et al., 2016; Pearson, Wonderlich, & Smith, 2015). As a result, individuals who have fewer trait-level “top-down” cognitive control resources may have more difficulties modulating momentary affect and previously learned response tendencies to eat in response to negative affect. Thus, underlying trait-level behavioral inhibition deficits combined with states of high negative affect may contribute to an inability to down-regulate emotionally salient information, thereby potentiating episodes of binge eating.

Although applications of affect regulation, urgency, and resource depletion theories to EDs generally focus on the role of negative affect, it is important to consider the role of positive affect in relationship to impulsivity and binge eating. Notably, urgency theory also suggests that the tendency to act impulsively when experiencing states of high *positive* affect (i.e., positive urgency) is related to a range of addictive behaviors; however, studies in EDs have indicated negative urgency is more strongly linked to bulimic behaviors than positive urgency (Smith & Cyders, 2016). In light of research demonstrating that positive affect is broadly related to better health outcomes (e.g., Pressman & Cohen, 2005), it is also possible that positive affect has a buffering effect in reducing the likelihood of binge eating. In particular, the broaden and build theory of positive emotions (Fredrickson, 1998; Garland et al., 2010) and attentional scope models (e.g., Whitmer & Gotlib, 2013) hold that, unlike negative emotions, positive emotions broaden individuals’ attentional scope and thought-action repertoires, thereby allowing individuals to engage in more flexible responding to situations.

With respect to EDs, EMA research has been somewhat inconclusive regarding momentary relationships between positive affect and binge eating (Smyth et al., 2007; Smith et al., 2018b). Therefore, it may be useful to consider the role of moderating factors such as trait levels of behavioral impulsivity. That is, unlike negative affect, relative elevations in positive

affect may mitigate risk of binge eating among individuals with underlying impulse control problems, possibly via facilitation of self-efficacy and goal-oriented behavior. However, thus far there is a dearth of literature examining how momentary positive affect interacts with neurocognitive processes to potentiate ED behaviors.

The Present Study

In sum, evidence suggests that binge eating is associated with a range of cognitive control deficits related to impulsivity, particularly lower response inhibition, preference for immediate gratification (i.e., increased delay discounting), and riskier decision-making (Smith et al., 2018a). These processes have also been linked to various affective processes and are relevant to several ED theories. Despite evidence that the interrelationship between affect and impulsivity has meaningful implications for psychopathology, thus far there has been little research examining the extent to which the impairments in behavioral impulsivity (i.e., impulsive choice and action) that have been observed in binge-type EDs may interact with affective states to potentiate symptoms in naturalistic settings.

Notably, one recent EMA study of adults with obesity/overweight in behavioral weight loss treatment found that poorer response inhibition (i.e., measured via the stop signal task), but not delay discounting, strengthened the momentary relationship between stress and dietary lapses (i.e., eating or drinking likely to cause weight gain or put weight loss/maintenance at risk; Manasse et al., 2018). However, to our knowledge there have been no studies examining moderating effects of *individual differences* in behavioral impulsivity on *momentary relationships* between affect and binge eating. Such research has meaningful clinical implications, as examining these effects may identify which individuals are most prone to binge eating in the context of particular affective states (i.e., high or low negative and positive affect).

Therefore, the aim of the present study was to utilize a multi-modal approach to assess the moderating effect of individual differences in behavioral impulsivity on the momentary relationships between affect and binge eating assessed via EMA. While several theoretical models of EDs implicitly implicate relationships between affect and impulsivity, such an investigation will help to better understand specific neurocognitive processes contributing to binge eating in naturalistic settings. Specifically, it was expected that when individuals with greater deficits in facets of behavioral impulsivity experienced relative increases in momentary negative affect, they would be particularly likely to engage in subsequent binge eating, whereas increases in positive affect would mitigate the relationship between impulsivity and binge eating. Given that weight status has been linked to behavioral impulsivity, we also sought to examine the relative influence of impairments in these domains irrespective of weight status by co-varying for body mass index (BMI) in analyses. Finally, no specific a-priori hypotheses were made regarding differences in moderating effects across impulsivity measures.

Methods

Participants and Procedure

Participants were 30 adult women who reported regular binge eating (93% Caucasian; Age: $M=36.07\pm13.92$ years; BMI: $M=34.73\pm9.23$ kg/m²). Participants were recruited through clinical and community sites and initially screened for eligibility via phone or in-person at a clinic visit at a local ED treatment center. Those who met criteria then completed an in-person study visit during which they completed the informed consent process, assessment of vital signs, and clinical interviews to assess all eligibility criteria. Clinical interviews were administered by trained master's level assessors. The study was reviewed and approved by an institutional review board.

Regular binge eating was defined as reporting at least one objective binge-eating episode in the past month via a selected module from the Eating Disorder Examination clinical interview (i.e., "bulimic episodes and episodes of overeating;" Fairburn, Cooper, & O'Connor, 2014). Exclusion criteria were as follows: 1) inability to read or speak English; 2) current psychosis determined by the Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders – IV (SCID-I), Research Version (First, Spitzer, Gibbon, & Williams, 2002); 3) current mania determined by the SCID-I; 4) acutely suicidal as determined by the Suicide Behavior Questionnaire-Revised (Osman et al., 2001); 5) current medical instability as determined by vital signs and blood pressure; 6) severe substance use disorder in the past year as determined by the SCID-I; 7) severe cognitive impairment or mental retardation determined by a phone screen; 8) currently pregnant or breastfeeding; 9) inpatient or partial hospitalization currently or in the past four weeks; and 10) changes to eating disorder treatment protocol in the past four weeks.

If participants met all inclusion and exclusion criteria, they completed self-report questionnaires, computerized neurocognitive tasks administered via Inquisit 5 Lab (see Measures), and received training on the EMA protocol, which included completing a practice EMA survey with study staff and receiving definitions of ED behaviors. The Real Time Assessment In the Natural Environment (RETAIN) system was used to administer EMA surveys via text message and web for the next 14 days. Participants received five semi-random text messages per day, which were delivered to their mobile phones administered within five pre-determined windows starting in the morning through the evening. At each signal, they were provided a link to complete the EMA survey. During the recordings, participants were asked about ED behaviors, mood, and other contextual factors. A research assistant called participants halfway through the EMA protocol to remind participants about compliance and answer questions/concerns. Participants received \$110 for completion of in-person interviews and assessments, and \$2 per signal that they completed during the EMA protocol.

Measures

Cued Go/No-Go Task (CGNG; Fillmore, Rush, & Hays, 2006).—At the study visit, participants completed the CGNG as a measure of response inhibition. As described by Fillmore et al. (2006), in the CGNG, cues provide preliminary information about the target

stimulus that is likely to be presented and therefore establish response prepotency to speed reaction times (RTs) to “go” stimuli. Each trial of this task, consisted of the following: (1) presentation of a fixation cross for 800 ms; (2) a blank screen for 500 ms; (3) a cue displayed for one of five stimulus onset asynchronies (SOA=100-500 ms); (4) the go or no-go target displayed for 1000 ms or until a response occurred; followed by (5) an intertrial interval (700 ms). The cue was a rectangle in the center of the screen that was presented in either a vertical or horizontal orientation, and the go and no-go targets were the green and blue colors (respectively) that filled the inside of the rectangle. Participants were instructed to press the (/) key as quickly as possible when go (green) targets appeared and refrain from responding when a no-go (blue) target appeared. The orientation of the cue signaled the probability of a go or no-go target appearing: vertical rectangles preceded the go target on 80% of the trials and preceded the no-go target on 20% of the trials; conversely, horizontal rectangles preceded the no-go target on 80% of the trials and preceded the go target on 20% of the trials.

The CGNG consisted of 250 trials presenting an equal number of vertical (125) and horizontal (125) cues that were presented before an equal number of go (125) and no-go (125) targets. Each cue-target combination was presented at each of the five SOAs, with random presentation of cue-target combinations and SOAs. Response inhibition was measured as the no-go commission error rate (i.e., failure to inhibit responding) in the context of prepotent cues (i.e., vertical rectangles).

Game of Dice Task (GDT; Brand et al., 2005).—The GDT was used as a measure of probabilistic discounting (i.e., decision-making). The GDT is a computerized dice game in which participants are instructed to increase their starting amount of money by placing bets on 18 throws of dice. Before each roll, participants select one to four numbers, each of which is related to specific winning probability (i.e., congruence of selected number to thrown number) ranging from 1:6 to 4:6. Bets of one and two numbers are classified as risky (i.e., less than 50% probability of winning but with higher gains and penalties), whereas bets of three and four numbers are safe (i.e., 50% probability of winning but with lower gains and penalties). The net score is calculated as the number of safe minus risky bets, with lower net scores reflecting riskier decision-making.

Monetary Choice Questionnaire (MCQ; Kirby, Petry, & Bickel, 1999).—The MCQ is a widely-used and validated self-report measure of delay discounting (Myerson, Baumann, & Green, 2014). Participants respond to 27 items in which they have to select between a hypothetical smaller, more immediate reward or a larger, delayed reward (e.g., “Would you prefer \$54 today or \$55 in 117 days?”). Each participant’s discount rate parameter (k) was calculated via the automated scorer previously described by Kaplan and colleagues (2014, 2016), with higher k values indicating preference for more immediate, yet smaller rewards.

EMA questions.—At each EMA signal, participants rated their current positive and negative affect using the 10-item Positive and Negative Affect Schedule Short Form (PANAS-SF; Thompson, 2007; Watson & Clark, 1988); the five positive affect (PA) and five negative affect (NA) items were summed to calculate composite PA and NA scores at each

signal, with higher scores indicating greater PA or NA intensity. In addition, participants were asked to indicate whether they engaged in a binge-eating episode (yes/no) since their last recording.

Statistical Analyses

Descriptive statistics and multilevel reliability estimates (ω ; Geldhof, Preacher, & Zyphur, 2014) were calculated. Generalized estimating equations (GEEs) were used to examine the extent to which measures of behavioral impulsivity (i.e., CGNG error rate, GDT net score, MCQ k), momentary affect (PA and NA), and their interaction predicted binge-eating episodes. Separate GEEs were estimated using a binary logistic function given the dichotomous dependent variable (occurrence of binge episode) and an AR1 serial autocorrelation to account for the dependence within the nested data. Scores from impulsivity indices and EMA affect were used as the independent variables. EMA PA and NA were lagged from the previous signal (within the same day) to assess relationships with binge eating at the subsequent signal.

Separate GEE models were conducted for each EMA predictor (i.e., PA and NA) of binge eating and each moderator (i.e., impulsivity indices), resulting in a total of six GEEs. EMA predictors were separated into within- and between-person components; *within-person effects* were person-mean centered and therefore reflected momentary changes relative to an individual's average level, whereas *between-person effects* were grand-mean centered and therefore reflected how an individual's average level compares to the overall sample average. Each GEE model included the main effects of the within-person and between-person components of the EMA predictor, the main effect of the impulsivity measure, which was grand-mean centered, and the two-way interaction term between the within-person effect of the EMA predictor and the between-person effect (i.e., grand-mean centered) impulsivity measure, as the present study was focused on individual differences in momentary relationships. Given possible relationships between weight status and executive functioning (Fitzpatrick et al., 2013; Smith et al., 2011), BMI was included as a covariate in all models. Analyses were conducted using SPSS version 25.

Results

Baseline and EMA Data

At baseline, the mean number of binge episodes reported in the past 28 days on the EDE interview was 12.27 ± 13.78 episodes (Range: 1-76). During the EMA protocol, 213 binge episodes were reported, which represents 13.7% of the total EMA recordings (1,558). The mean number of binge episodes reported during the EMA protocol per participant was 7.10 ± 4.40 episodes (Range: 1-16). The mean number of signals completed per participant was 51.93 ± 13.49 (Range: 16-70); with respect to compliance, participants responded to 78.3% of signals. The number of EMA recordings completed was unrelated to demographic variables. Within-subjects internal consistency reliabilities (ω s) were .81 for NA and .90 for PA, and between-subjects ω s were .98 for NA and .93 for PA. Across the sample, mean ratings of NA and PA were 1.97 ± 1.17 and 2.42 ± 1.13 , respectively (Range: 1-5). The inter-

correlations between the CGNG, GDT, and MCQ indices of behavioral inhibition were low ($r = -.01$ to $.12$), which supports the discriminant validity of these measures.

Generalized Estimating Equations

As shown in Table 1, GEE results indicated that there was a significant interaction between momentary NA and MCQ k scores predicting binge-eating episodes, such that when individuals with greater delay discounting (i.e., higher k) experienced a relative increase in NA compared to their average level, they were more likely to report a binge episode at the following signal (Figure 1). Specifically, when individuals with higher k values (i.e., one standard deviation above the sample mean) reported an increase in NA (i.e., one standard deviation above an individual's mean), they experienced a .06 increase in the probability of binge eating, whereas individuals with lower k values (i.e., one standard deviation below the sample mean) experienced $<.01$ increase in binge probability at moments of increased NA. Similarly, there was a main effect of MCQ k as well as a significant interaction of within-person PA and MCQ k predicting binge episodes, such that when individuals experienced a one standard deviation increase in momentary PA (i.e., one standard deviation above an individual's mean), individuals with higher k values (i.e., one standard deviation above the sample mean) had a .04 increase in likelihood of subsequent binge eating, whereas those with lower k values (i.e., one standard deviation below the sample mean) had a .05 *decrease* in the probability of binge eating (Figure 2). In addition, there was an interaction between CGNG no-go commission error rate and within-person PA. As depicted in Figure 3, momentary PA had little influence on the likelihood of a subsequent binge episode among individuals with better response inhibition (i.e., commission error rates one standard deviation below the sample mean), in that there was $<.01$ change in the probability of binge eating at high versus low momentary PA values (i.e., one standard deviation above and below individuals' means). However, for individuals with poorer response inhibition (i.e., one standard deviation above the sample mean commission error rate), there was a negative association between within-person PA and binge likelihood, such that moments of higher PA (i.e., one standard deviation above an individual's mean) were .03 less likely to be followed by binge episodes. There were no relationships between within-person NA, CGNG, and binge eating, nor were there main effects or moderating effects observed for the GDT models.

Discussion

The present study was the first to our knowledge to examine the moderating effects of behavioral measures of impulsivity on momentary relationships between affect and binge-eating episodes. Findings demonstrated partial support for hypotheses, and highlight important distinctions between facets of behavioral impulsivity as well as affect valence versus intensity in the momentary mechanisms that potentiate binge eating. Specifically, steeper delay discounting strengthened the momentary associations between both NA and PA and binge eating, whereas a negative association was observed between momentary PA and binge eating among individuals with poorer response inhibition and those with lower delay discounting. However, no effects were found with respect to probabilistic discounting (i.e., measured via the GDT).

A particularly interesting finding was that when individuals with greater preference for immediate rewards (i.e., higher MCQ k) experienced states of higher affect intensity, regardless of valence, they were more vulnerable to subsequent binge eating. Such results are notable in light of literature demonstrating interrelationships between emotion and judgement and decision-making processes, in that individuals' trait- and state-level emotional dispositions may influence conscious and nonconscious evaluation of and selection of response options (Lerner, Li, Valdesolo, & Kassam, 2016). For example, possible outcomes are judged based on anticipated emotional responses, and one's emotional state during decision-making can influence depth of processing and activate particular implicit goals, thereby influencing which aspects of the choice and outcome the individual focuses on (Lerner et al., 2016). It is possible that individuals who prefer immediate rewards are particularly susceptible to the impact of emotional intensity, as both NA and PA may enhance focus on immediate, short-term rewards (Hirsh, Guindon, Morisano, & Peterson, 2010; Tice, Bratlvsky, & Baumeister, 2001; Wilson & Daly, 2004). This is also consistent with research findings that both positive and negative emotions have been shown to predict eating behavior (e.g., Bongers et al., 2013; Macht, 2008), and impulsive behaviors such as binge eating may occur in the context of heightened negative or positive affect, which may be reflective of negative and positive urgency, respectively (Cyders et al., 2007). Taken together, it may be that when those with dispositional tendencies to prefer immediate rewards experience states of increased emotional arousal, regardless of valence, they are particularly likely to increase focus on potential benefits (i.e., relief of NA or increased PA) they may experience via binge eating, and engage in this behavior as an immediate means of coping or reinforcement.

Furthermore, momentary increases in PA appeared to differentially *mitigate* the risk of binge eating depending on the facet of behavioral impulsivity. That is, elevations in PA had a protective effect against binge eating among individuals with *poorer* response inhibition (reflecting higher impulsive action tendencies), as well as those with *lower* delay discounting (reflecting lower impulsive choice tendencies). Consistent with the broaden and build theory (Garland et al., 2010), one possibility is that positive affect facilitates goal-directed behavior via consideration of a broader range of responses, and therefore individuals who tend to have difficulties inhibiting *impulsive actions* such as binge eating may be less likely to respond impulsively in the context of PA. However, it is intriguing that the reverse relationship was observed for delayed discounting. It may be that for individuals with a greater capacity for delayed gratification (i.e., a greater preference for later, larger rewards vs. immediate, smaller rewards), PA reinforces self-control and future-oriented thinking. However, additional work with larger clinical samples is warranted to replicate these findings.

Despite the moderating effect of response inhibition on the relationship between PA and binge eating, there was no interaction between response inhibition and momentary NA, which is somewhat contrary to previous EMA research (Manasse et al., 2018) and the literature supporting the confluence of NA and impulsivity predicting binge eating (e.g., Clyders & Smith, 2008; Fischer, Peterson, & McCarthy, 2013). Some of the inconsistency may be due to differences in the constructs assessed, as Manasse et al. (2018) utilized a measure of reactive response inhibition (i.e., stop signal task) rather than proactive response

inhibition (CGNG in the present study) and assessed dietary lapses rather than binge eating. Thus, it would be useful for future EMA research to assess whether measures of reactive response inhibition have stronger relationships with affect and binge eating. In addition, the negative urgency literature is largely based on self-report measures of trait-level personality characteristics, which reflect participants' perceptions of themselves across a range of situations. Thus, response (i.e., motor) inhibition alone may not capture the nature of emotion-based impulsivity that has been found to predict binge eating. Therefore, additional trait- and state-level factors, such as negative affect eating expectancies (i.e., belief that eating will reduce negative emotions), would be useful to examine in conjunction with affect and response inhibition. Furthermore, there is evidence that impairments in response inhibition may be magnified or only present in the context of ED-relevant stimuli (e.g., food or shape/weight-related) in ED samples (Smith et al., 2018a), and thus future research is warranted to examine the influence of commission errors for ED-specific stimuli on momentary relationships.

The lack of main or moderating effects of probabilistic discounting (i.e., GDT) was somewhat unexpected given evidence from recent meta-analyses suggesting that individuals with EDs, including those with binge eating, evidence riskier decision-making compared to healthy controls as measured by the GDT and similar tasks (Guillame et al., 2015; Wu et al., 2016). It may be the case that probabilistic discounting is impaired in EDs, but is related to other features of these disorders (e.g., reward and punishment sensitivity). However, it may not predict specific instances of binge eating. This may be due to the fact that delayed and probabilistic discounting (i.e., risk-taking) paradigms differ fundamentally with respect to the type and magnitude of effects (Nigg, 2017). That is, one possible explanation is that individual differences in the temporal aspects of impulsivity (i.e., delay discounting) are most relevant to momentary processes in which individuals seek immediate relief/reward via maladaptive behaviors (e.g., binge eating). Conversely, based on previous findings (e.g., Almy, Kuskowski, Malone, Myers, & Luciana, 2018; Franken & Muris, 2005), individual differences in probability computations (i.e., risk-taking) may be more strongly related to sensitivities to reward and punishment or approach and avoidance motivations. While these processes are nevertheless relevant to binge eating, they may have less impact on momentary processes linking affect and binge episodes.

Limitations

There are several limitations in the present study to note. The sample was limited to women and was mostly Caucasian, so findings may not generalize to other demographic groups. EMA measurement of binge episodes was assessed by a single dichotomous item, and was thus subject to participants' interpretations, although they received in-lab training on the definition of such episodes. Future EMA studies using dimensional measures of loss of control and overeating may yield more accurate assessments of this construct. Also, given that the sample was diagnostically heterogeneous and included multiple binge-type EDs, further study is needed to examine the extent to which the observed relationships may vary across ED subtypes. The sample size of the present study was also modest, which may have precluded our ability to detect moderated effects. Lastly, the assessments of behavioral impulsivity were limited to one assessment and treated as trait-like constructs; however,

recent evidence suggests that neurocognitive functioning varies within persons and importantly, may be influenced by contextual factors such as affect (Sliwinski et al., 2018). Thus, future research incorporating repeated neurocognitive assessments into EMA paradigms would be useful to examine the extent to which intra-individual variability in behavioral impulsivity is related to affect and binge eating.

Conclusions

In sum, the present study, via the use of multimodal methods, offers a nuanced perspective of the practical significance of neurocognitive functioning related to impulsivity in the context of binge eating. Specifically, differential findings emerged with respect to influences of individual differences in impulsive choice and action on momentary processes that potentiate binge eating, and highlight the importance of considering how these individual differences relate to both affect intensity and valence. However, additional study with larger samples across ED diagnoses would be helpful for replication and to assess generalizability to other ED symptoms.

Nevertheless, if replicated, findings could have relevant implications for theoretical models and potential interventions. That is, most ED theories lack explicit discussion of neurocognitive functioning in relationship to emotion regulation and temperament, each of which have been consistently implicated in models of EDs (e.g., Wildes & Marcus, 2013). Identifying the specific neurocognitive processes underlying these dimensions, and the nature of relationships between neurocognitive functioning and other relevant trait- and state-level factors, will provide a more nuanced understanding of the pathophysiology contributing to ED phenotypes. Doing so may in turn inform the development of empirical classification approaches and more targeted interventions, should such processes prove to be modifiable.

Furthermore, continued examination of trait- and state-level processes will serve to identify inter- and intra-individual targets of interventions. For example, the temporal attention hypothesis posits that delay discounting could be improved by helping individuals focus on distal events or goals, which has received some support by interventions targeting episodic future thinking (Daniel, Stanton, & Epstein, 2013; Kaplan, Reed & Jarmolowicz, 2016). Thus, for individuals with greater delay discounting, such interventions may reduce vulnerability to binge eat in the context of high affective arousal. In addition, promotion of momentary positive affect may be particularly helpful in reducing binge eating among individuals with poor response inhibition, which may be facilitated using a range of strategies (e.g., behavioral activation, physical activity). Finally, the within- and between-person relationships identified in the present study and similar EMA research may hold promise for novel implementations of interventions via the use of ecological momentary interventions (EMIs) and just-in-time adaptive interventions (JITAI), which are gaining support for a range of health-related behaviors, including ED symptoms (Juarascio, Parker, Lagacey, & Godfrey, 2018).

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Figure 1. Momentary negative affect (NA) and Monetary Choice Questionnaire (MCQ) discounting parameter (k) predicting the likelihood of binge episodes. NA was lagged from the previous signal and reflected the within-person (i.e., person-mean centered) effect. High and low values reflect ± 1 SD above the sample mean (MCQ) or individual mean (NA).

Figure 2.

Momentary positive affect (PA) and Monetary Choice Questionnaire (MCQ) discounting parameter (k) predicting the likelihood of binge episodes. PA was lagged from the previous signal and reflected the within-person (i.e., person-mean centered) effect. High and low values reflect ± 1 SD above the sample mean (MCQ) or individual mean (PA).

Figure 3.

Momentary positive affect (PA) and cued go/no-go (CGNG) error rate predicting the likelihood of binge episodes. Note: CGNG error rate reflects commission errors (i.e., failure to inhibit responding) in the context of pre-potent cues. PA was lagged from the previous signal and reflected the within-person (i.e., person-mean centered) effect. High and low values reflect ± 1 SD above the sample mean (CGNG) or individual mean (PA).

Table 1.

Generalized estimating equations predicting likelihood of binge occurrence

Negative affect models										Positive affect models					
95% confidence interval										95% confidence interval					
MCQ	B	SE	Lower	Upper	Wald χ^2	p	MCQ	B	SE	Lower	Upper	Wald χ^2	p		
Intercept	-1.86	0.25	-2.36	-1.36	53.27	<0.001	Intercept	-2.24	0.38	-2.98	-1.49	34.29	<0.001		
BMI	0.01	0.01	-0.01	0.03	0.50	0.479	BMI	0.00	0.01	-0.01	0.02	0.22	0.642		
NA between	0.06	0.12	-0.18	0.29	0.23	0.631	PA between	0.19	0.13	-0.05	0.44	2.35	0.125		
NA within	0.24	0.17	-0.09	0.56	2.02	0.155	PA within	-0.07	0.11	-0.28	0.14	0.41	0.522		
MCQ	4.05	3.17	-2.16	10.26	1.63	0.202	MCQ	5.33	2.58	0.28	10.38	4.28	0.039		
NA within x MCQ	9.83	4.64	0.74	18.92	4.50	0.034	PA within x MCQ	14.94	4.15	6.80	23.07	12.95	<0.001		
GDT							GDT								
Intercept	-2.05	0.30	-2.63	-1.47	47.64	<0.001	Intercept	-2.14	0.40	-2.92	-1.37	29.30	<0.001		
BMI	0.00	0.01	-0.03	0.02	0.11	0.740	BMI	0.00	0.01	-0.03	0.02	0.20	0.655		
NA between	0.10	0.15	-0.19	0.39	0.47	0.495	PA between	0.12	0.14	-0.16	0.40	0.72	0.396		
NA within	0.17	0.16	-0.16	0.49	1.02	0.314	PA within	-0.05	0.14	-0.32	0.22	0.14	0.709		
GOD	-0.01	0.01	-0.04	0.01	1.33	0.249	GDT	-0.01	0.01	-0.03	0.01	0.96	0.326		
NA within x GDT	0.00	0.01	-0.03	0.03	0.01	0.935	PA within x GDT	-0.01	0.01	-0.02	0.01	0.48	0.487		
CGNG							CGNG								
Intercept	-2.05	0.30	-2.63	-1.47	47.64	<0.001	Intercept	-2.22	0.38	-2.97	-1.47	33.75	<0.001		
BMI	0.00	0.01	-0.03	0.02	0.11	0.740	BMI	0.00	0.01	-0.02	0.03	0.07	0.784		
NA between	0.10	0.15	-0.19	0.39	0.47	0.495	PA between	0.15	0.14	-0.13	0.43	1.15	0.284		
NA within	0.17	0.16	-0.16	0.49	1.02	0.314	PA within	-0.07	0.12	-0.31	0.17	0.35	0.555		
CGNG	-0.01	0.01	-0.04	0.01	1.33	0.249	CGNG	-2.77	2.95	-8.56	3.01	0.88	0.348		
NA within x CGNG	0.00	0.01	-0.03	0.03	0.01	0.935	PA within x CGNG	-4.90	1.96	-8.75	-1.06	6.24	0.013		

Note. BMI=body mass index; NA=negative affect; PA=positive affect; MCQ=Monetary Choice Questionnaire (k); GDT=Game of Dice Task (net score); CGNG=Cued Go/No-go task (vertical no-go commission error rate).

“Between” refers to between-person effects (i.e., grand-mean centered); “within” refers to within-person effects (i.e., person-mean centered).

NA and PA within-person effects were lagged from the previous signal.

BMI, MCQ, GOD, and CGNG measures were grand-mean centered.