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Reinforcer Pathology: Narrative of hurricane-associated loss increases delay discounting, demand, and consumption of highly palatable snacks in the obese

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Abstract

Reinforcer pathology is derived from the integration of two measures, 1) self control (i.e., delay discounting) and 2) reward valuation (i.e., behavioral economic demand). Narrative theory asserts that vividly imagining oneself in a hypothetical, yet realistic, scenario can acutely alter decision-making, valuation of reinforcers such as food, and how much food is consumed. The present study measured changes in reinforcer pathology for highly palatable snacks following either a negative or neutral scenario in obese individuals. Participants ($n = 48$), BMI ≥ 30 , rated their liking of 7 calorie-dense snack items, and completed discounting and purchase demand tasks for their top-rated snack. Participants then read a randomly assigned hypothetical scenario (i.e., a devastating hurricane [negative] or minor storm [neutral]), completed the tasks again, and were given ad-libitum access to their top 3 ranked snack foods. Results indicated that delay discounting, demand

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Declaration of Interests

The authors Alexandra M. Mellis, Lindsey M. Poe, and Matthew A. Kocher all report no biomedical financial interests or potential conflicts of interests. Sarah E. Snider and Warren K. Bickel report being Principals in BEAM Diagnostics, Inc. Warren K. Bickel also reports being a Principal in HealthSim, LLC and NotifiUs LLC as well as a general partner in Red 5 Group LLC.

Prior Dissemination

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for participants' top-rated snack food, and negative affect all increased in the hurricane group, compared to the minor storm group. The hurricane group also consumed more calories, even when hunger was standardized with a preload meal bar. Consistent with reinforcer pathology, these results suggest that vivid consideration of a devastating scenario constricts the temporal window and increases demand for hedonic snack foods among obese individuals.

Keywords

Reinforcer Pathology; Narrative Theory; Delay Discounting; Behavioral Economic Demand; Scarcity

INTRODUCTION

Excessive delay discounting has been increasingly implicated in a wide variety of maladaptive health behaviors (Daugherty & Brase, 2010; Snider, S. E., DeHart, W. B., Epstein, L. H., Bickel, W. K., 2018), including functioning as a behavioral marker for substance use disorder (Bickel, Koffarnus, Moody, & Wilson, 2014). Importantly, this marker may also be extended to food addiction, a recently demonstrated phenotype of obesity (Davis et al. 2011). In fact, a recent meta-analysis supported a relationship between discounting the future and obesity (Amlung, Petker, Jackson, Balodis, & MacKillop, 2016). Delay discounting is a decision-making process in which the subjective value of a delayed reward decreases as a function of the length of time to the reward's receipt. Excessive delay discounting, therefore, indicates a faster rate of decline in value of the delayed reward. In other words, the individual does not value the delayed reward, cannot wait for it, and instead often chooses the immediately available option, even if that choice is less adaptive in the long run.

As an example, body fat percentage was significantly associated with delay discounting for food, suggesting that obese individuals are sensitive to a delay to food (Rasmussen, Lawyer, & Reilly, 2010). Moreover, individuals with greater discounting rates for monetary rewards chose to consume more energy dense foods when eating away-from-home or eating ready-to-eat foods (e.g., pre-packaged snacks) (Appelhans et al., 2012), suggesting that not only is obesity related to a focus on immediate options, but that also these individuals engender an enhanced sensitivity of rewarding properties of energy dense foods (Volkow, Wang, & Baler, 2011), and have an increased demand for them (Epstein, Salvy, Carr, Dearing, & Bickel, 2010). The co-occurrence of these two behavioral risk factors -- greater delay discounting and greater demand for unhealthy commodities -- creates a state of unique susceptibility to negative health outcomes (Epstein et al., 2014). For example, one study demonstrated that the contribution of demand for unhealthy foods to individual differences in overweight/obesity is moderated by delay discounting rate (Feda, Roemmich, Roberts, & Epstein, 2015). This susceptibility rooted in both greater delay discounting and demand for particular reinforcers is conceptualized by the theory of *reinforcer pathology*.

When presented with significant stressors, both components of reinforcer pathology, an individual's perception of the future and valuation of particular reinforcers, can be altered. For example, individuals in poverty become biased toward the immediate, constricting their

temporal horizon (Sheehy-Skeffington & Haushofer, 2014) wherein incoming acute stressors enhance an individual's biases toward risky (Morgado, Sousa, & Cerqueira, 2015) and maladaptive decision-making. With respect to food, stressors also commonly increase caloric intake, especially from energy dense foods (i.e., "comfort foods") (Dallman, 2010; Dallman, Pecoraro, & la Fleur, 2005; Rutters, Nieuwenhuizen, Lemmens, Born, & Westerterp-Plantenga, 2009). When female college students were asked to complete a psychologically stressful task, some of the participants reported increased wanting to binge eat, although these reports came only from those who reported pre-existing disordered eating habits (Cattanach, Malley, & Rodin, 1988). Together, these studies suggest that when an individual's temporal horizon is constricted, an added acute stressor can constrict the horizon further and produce increased impulsive decision-making and behavior. Therefore, we hypothesized that an acute stressor presented to obese individuals would increase their discounting of future rewards and also increase hedonic overeating.

Narrative theory asserts that simply vividly imagining oneself in a hypothetical, yet realistic, stressful scenario is sufficient to acutely alter behavior and decision-making (see Bickel, Stein, et al., 2017). We have demonstrated previously that coming into contact with a real stressor is not required to change decision-making. When participants were presented with and asked to imagine themselves in a realistic scenario about losing their job and being forced to move across the country, they decreased their valuation of future rewards as measured by a delay discounting task (Bickel, Wilson, Chen, Koffarnus, & Franck, 2016; Mellis, Snider, & Bickel, 2018). That is, when the negative scenario was presented, participants preferred an immediately available small amount of money over a larger amount of money after some delay, suggesting a constriction of their temporal horizon and reduction of self-control. Most recently, when an online sample of obese individuals were presented with the job loss scenario they demonstrated an increased discounting rate of delayed rewards and an increase in demand for fast-food compared to the neutral scenario group (i.e., lateral departmental position change)(Mellis, Athamneh, et al., 2018).

The present study was designed to expand upon these findings to understand how obese individuals make decisions in the presence of a narrative theory-based hypothetical stressful scenario. Specifically, we aimed to measure differences among the components of reinforcer pathology; their temporal horizon (i.e., delay discounting), valuation of energy-dense foods, and actual calorie consumption following presentation of a negatively valenced stressful scenario, compared to a neutrally-valenced scenario about a minor storm. We hypothesized that the presence of a scenario about hurricane-associated loss would produce an increase in 1) delay discounting for both monetary and food rewards, 2) demand for energy-dense snacks, and 3) consumption of those snacks when given ad-libitum access, compared to the neutral control scenario.

MATERIALS AND METHODS

Participants

Participants ($n = 48$) were recruited from Roanoke, Virginia and surrounding areas through flyers, online advertisements, referrals, and by contacting previous volunteers through the Addiction Recovery Research Center database. Eligible participants were a) between the

ages of 18 and 65; b) obese, as determined by >30 Body Mass Index; and c) not planning on altering their dietary behavior during the study. Exclusion criteria included self-reported pregnancy, immediate plans to move away from the area, and unmanaged medical or psychiatric conditions. Individuals with dietary restrictions interfering with study procedures (e.g., allergies, religious beliefs, diabetes) and those recently prescribed medication determined to affect appetite, taste, or smell were also excluded. Eligible participants were screened through an online questionnaire, over the phone, or in person, and informed consent was required. Demographic characteristics of participants randomly assigned to both groups are presented in Table 1. The Virginia Tech Institutional Review Board approved all procedures and protocols implemented.

Procedure

Participants were randomly allocated to either the hurricane ($n = 24$) or minor storm ($n = 24$) scenario group and invited to attend two sessions, both of which lasted approximately two hours. The first session included the informed consent process and a taste test of the study snacks (M&M's®, Doritos® Nacho Cheese, Reese's Peanut Butter Cups®, Sour Patch Kids®, Skittles® and Oreo Cookies®, 5 grams each). Participants rated liking of these snacks (1=strongly dislike; 7=strongly enjoy) and ranked snack preferences from favorite to least favorite. Ratings had to be a 3 (Neutral) or above for at least 3 of the 7 snacks to continue. Participants were also asked to sample a Clif Bar® meal bar (5 grams) to determine willingness to eat a full-sized bar prior to the second session to standardize all participants' hunger level. The first session also included the Three-Factor Eating Questionnaire (TFEQ), the Positive and Negative Affect Schedule (PANAS), baseline delay discounting tasks, and a hypothetical purchase. Prior to the second session, all participants were asked to abstain from eating or drinking anything except water for at least 3 hours. This was followed by consumption of a full sized Clif Bar® in order to standardize all participants' hunger levels. During the second session, participants were asked to consider themselves in either a hurricane-associated loss or minor storm scenario (described in detail below) and complete the same PANAS questionnaire, delay discounting tasks, and hypothetical purchase task followed by an Ad Libitum Eating task.

Assessments

Three-Factor Eating Questionnaire (TFEQ-R-18).—The revised 18-item TFEQ was administered to ask participants about their general eating habits and behavior. Answers to these questions are scored in three distinct factors: cognitive restraint, uncontrolled eating, and emotional eating (De Lauzon et al., 2004).

Positive and Negative Affect Schedule.—This 20-item questionnaire assesses the participant's current affect. The questionnaire can be separated into two factors, positive and negative affect (Watson, Clark, & Tellegen, 1988). Prior to answering this questionnaire at the second session, participants were reminded of their assigned scenario and asked to consider it for a moment before answering.

5-Trial Adjusting Delay Discounting Tasks.—Participants completed three 5-trial adjusting delay discounting tasks comparing commodities, each taking less than one minute

(Koffamus & Bickel, 2014). All were computerized choice programs (Python 2.7.8) in which participants were asked to choose between two hypothetical commodities now or at varying delays. The commodity combinations for each of the three tasks were, 1) money now-money later, 2) snack now-money later, and 3) snack now-weight loss later.

Money now-Money later: Participants' delay discounting rate for \$100 monetary reward was obtained by presenting 5 preference choices. The first choice presented the option of receiving \$50 now or \$100 in 3 weeks. The participant's response to this question adjusted the time delay in the next trial, while the dollar amount of both rewards remained the same. Depending on the choice made at each subsequent trial, the delay adjusted up or down to determine the participant's ED50 (i.e., $1/k$, or the delay at which the subjective value of reward receipt is half of its nominal value) (Odum, 2011).

Snack now-Money later: This task was near-identical to the above money task, however participants were asked to complete 5 preference choices between receiving a small number of snack servings now or a \$100 after some delay. The snack item offered during the task was the participant's top rated snack from the taste test. To assist participants while completing the tasks, they were provided with an image depicting the intended serving size of their snack food, approximately equal to 100 calories. Immediately prior to beginning the delay discounting tasks, participants were asked about how many servings of their chosen snack food they considered to be equivalent in value to \$100. If the participant's favorite snack food was Doritos®, the question read,

“Imagine that you had a choice between servings of your favorite snack item Doritos® or receiving money. How many servings of Doritos® is equal in value to \$100?”

As an example, entering 15 means you'd view 15 servings of Doritos® as equal to receiving \$100.”

One half the number of servings of snacks they selected was utilized as the participant's immediately available option for the task. For example, if a participant said that 20 servings of Doritos® were equivalent to \$100, the first question in this task presented the choice between receiving 10 servings of Doritos® now or \$100 in 3 weeks. The delay was titrated as in the other tasks to product the participant's ED50 and $\ln(k)$ value (see above).

Snack now-Weightloss later: This task was incorporated the modifications above and replaced the delayed monetary reward with an amount of weight loss subjectively equivalent to \$100. That is, participants were asked to complete 5 preference choices between receiving a small number of snack servings now or a pounds of weight loss after some delay. Again, the snack item offered during the task was the participant's top rated snack from the taste test and the image depicting the intended serving size of their snack food was present. In addition to the snack item equivalence question, immediately prior to beginning the delay discounting tasks, participants were also asked about how many pounds of weight loss they considered to be equivalent in value to \$100. The question read,

“Imagine that you had a choice between either losing pounds or receiving money. How much weight loss in pounds is equal in value to receiving \$100?”

As an example, entering 15 means you'd view losing 15 pounds as equal to receiving \$100."

The amount of the snack item presented was based on the above snack item equivalence question, and pounds of weight loss were presented as the delayed choice. For example, if a participant said that 20 pounds of weight loss was equivalent to \$100, the first question in this task presented the choice between receiving 10 servings of Doritos® now or 20 pounds of weight loss in 3 weeks. Again, the delay was titrated as in the other tasks to product the participant's ED50 and ln(k) value (see above).

Of note, because these discounting tasks were designed to be equivalent to one another (i.e. \$100 was equal to the number of servings and pounds of weight-loss), the discounting rates are comparable to each other. At session 2, the hurricane or minor storm scenario was read aloud prior to the task set, and each participant was encouraged to think about the scenario as if it were actually happening while answering.

Hypothetical Purchasing Task.—All participants hypothetically purchased 100 calorie servings of their top rated snack to eat over a 24-hour period across ascending prices (\$0.01, 0.05, 0.10, 0.25, 0.50, 1.00, 2.50, 5.00, 10.00, 20.00, 40.00, and 80.00 per serving). For example, "If individual servings of Skittles® cost \$0.50 each, how many servings would you purchase to eat in a 24-hour period?" Participants were provided with the same image of their preferred 100 calories worth of food, and were instructed to purchase as if no other sources of their particular snack were offered anywhere else, and as if they could not save or give away any food purchased. The purchase data are used to generate a demand curve to assess how the individual values their favorite snack item by measuring intensity (Q0), how much an individual would "purchase" at a \$0 price, and elasticity (alpha), how sensitive the individual is to increases in price (see Data Analysis section for more detail). A baseline hypothetical purchasing task was completed at the first session, followed by the same task during the second session. Prior to the start of the task during the second session, participants were read aloud the hurricane or minor storm scenario and asked to answer as if the scenario were happening to them.

Hurricane and Minor Storm Scenarios.—Preceding the start of assessments during the second session, participants were presented with either a hypothetical hurricane or minor storm scenario. Participants then completed the delay discounting and purchase task assessments and Ad Libitum Eating task with the hypothetical context in mind, after considering how they would feel. The two scenarios are matched on word count, sentences, and reading level.

Hurricane Scenario:

"There was a major hurricane in your area. Your car and house have been destroyed by the storm. Your family is depending on you to come up with a solution. The storm shelters are full of other hurricane victims and you will have to be separated from your family to get a bed. You have no idea when you will see them again or how you will get food."

Minor Storm Scenario:

“There was a minor storm in your area. Hail fell on both your house and car, and you have a small dent in the hood of your car. You contacted your insurance company, and the repair is fully covered. The earliest available appointment is next week, when the repair team will travel to you and fix your car while you are at work. Your house appears to be undamaged.”

Ad Libitum Eating Task.—All participants were asked to abstain from eating or drinking anything except water at least three hours prior to attending the second session. Preceding the start of assessments and the presentation of the hurricane or minor storm scenario, all participants were asked to eat a full-sized Clif Bar® for normalization of hunger levels. Water was available *ad libitum* during this phase. After completing all assessments, participants were asked to sit in a room supplied with magazines, TV, chairs, a table, and a print-out of either the hurricane or minor storm scenario for 20 minutes. The participant’s top three rated snacks from the taste test, in approximately 100 gram portions, were provided in large bowls and the participant was instructed to eat as much or as little of the foods as desired while considering their scenario. If all portions of the food were consumed, participants could request more, and water was available *ad libitum*. The weight of the snack foods was weighed before and after the task to calculate total consumption. From this, nutrition intake was evaluated based on the nutrition values provided by the manufacturer.

Data Analysis

Natural log normalized delay discounting rates ($\ln k$) between hurricane and minor storm scenario groups were compared using a 2-way ANOVA (between groups, within task type). Two 2-way within-subject ANOVAs were also used to compare $\ln k$ values between baseline and scenario discounting in both the hurricane and minor storm groups. Sidak multiple comparison post hoc tests were used as follow ups in all cases. Purchasing of (i.e., demand for) the participant’s highest rated snack was assessed by fitting the exponentiated behavioral economic demand model (Koffarnus, Franck, Stein, & Bickel, 2015). Individual curve fits for intensity of demand (i.e., Q_0) and sensitivity to price (α) were then subjected to both a between scenario group 2-way ANOVA and a within-subject baseline-post scenario 2-way ANOVA with Sidak multiple comparison post hoc tests. Ad Libitum Eating was measured by weighing the snack foods consumed (grams) which were then converted to calories based on the nutrition information of the snack item. The difference in calories consumed between groups was obtained using a simple unpaired t-test. Finally, the two factors of the PANAS, positive and negative affect, were assessed separately in between group 2-way ANOVAs with Sidak multiple comparison post hoc tests. All analyses were performed using GraphPad Prism (Version 7.0 for Mac OSX).

RESULTS

Demographics

Table 1 describes the participant demographics separated by group. Importantly, the two groups did not differ significantly on any demographic variable (i.e., sex, race, age, education, BMI), except for monthly income ($p=0.044$), nor did they differ on any of the

three factors of the TFEQ. Of note, when monthly income was included as a covariate, it did not explain a significant portion of the variance between groups in any of the delay discounting, purchase task, or PANAS results described below.

Delay Discounting

Hurricane vs. Minor Storm.—Figure 1 demonstrates a main effect of delay discounting rate ($\ln k$) between the hurricane and minor storm scenarios $F(1, 46) = 9.63, p=0.003$. Specifically, Sidak post hoc comparisons reported that discounting rates following presentation of the hurricane scenario were greater for the food-money ($p=0.01$, Cohen's $d = 0.89$), and in the food-weightloss ($p = 0.004$, Cohen's $d = 0.83$) delay discounting task, compared to the minor storm scenario. No differences in discounting rate $\ln k$ between scenarios were detected in the money-money task type ($p = 0.30$), however the Cohen's $d = 0.53$, demonstrated a large effect. A main effect of task type (money-money, food-money, and food-weight loss) was also present, $F(2,92) = 16.67, p<0.0001$. That is, discounting rates were lower in the food-money ($p < 0.0001$, Cohen's $d = 0.66$) and food-weightloss ($p < 0.0001$, Cohen's $d = 0.68$) task types, compared to money-money. Of note, discount rates of money-money and food-money ($r=0.45; p=0.001$), money-money and food-weightloss ($r=0.33; p=0.022$), and food-money and food-weightloss ($r=0.65; p<0.0001$) tasks were highly correlated with each other.

Within Subject Effects.—Participants presented with the hurricane scenario increased their discounting $\ln k$ compared to their own baseline discounting rates, $F(1, 23) = 9.002, p = 0.0064$ (Figure 2A). Specifically, Sidak post hocs revealed that after being presented with the hurricane scenario, participants discounted more in the money-money ($p = 0.036$, $d_{\text{repeated measures}} = 0.61$, food-money ($p = 0.023$, $d_{\text{repeated measures}} = 0.73$) and the food-weightloss ($p=0.011$, $d_{\text{repeated measures}} = 0.47$) task types, compared to their own baseline rates. Moreover, a main effect of task type emerged, $F(2,46) = 5.35, p = 0.0082$. Here, Sidak post hocs for multiple comparisons demonstrated that food-money ($p = 0.032$) and food-weight loss ($p = 0.014$) tasks produced less discounting compared to the money-money task.

No differences between baseline and scenario discounting rates were observed within subjects on any of the task types in the minor storm scenario group (Figure 2B). Differences remained, however, between task types $F(2, 46) = 23.82, p<0.0001$. Sidak post hocs for multiple comparisons revealed less discounting in the food-money ($p<0.0001$) and food-weight loss ($p<0.0001$) task types, compared to money-money.

Behavioral Economic Demand

Figure 3A illustrates that no difference was observed in group curve demand for participant's chosen snack food between groups at the baseline time point (i.e., before scenario presentation). However, the group curves did demonstrate differences in demand intensity (Q_0) between the two groups following scenario presentation ($p=0.0014$; Figure 3B). Moreover, when individual Q_0 's were generated and compared using a 2-way ANOVA, a main effect of scenario group $F(1,46) = 4.077, p=0.049$ (Figure 4C). Sidak post hoc tests for multiple comparisons revealed a difference in Q_0 between the hurricane and minor storm scenario groups after presentation ($p=0.012$, Cohen's $d = 0.59$), but not during baseline

($p=0.97$, Cohen's $d = 0.21$). Moreover, Q0 increased for participant's favorite snack item in the hurricane group compared to their own baseline ($p=0.02$, $d_{\text{repeated measures}} = 2.15$), but no difference was observed between baseline and minor storm scenario presentation Q0 ($p=0.99$, $d_{\text{repeated measures}} = 0.077$). No differences between scenario groups nor between baseline and post presentation were observed for the elasticity (alpha) values when analyzed using a 2-way ANOVA (Figure 3D). These analyses were repeated excluding all responses indicating purchasing of more than 100 servings, as potentially unrealistic quantities for 24 hour consumption, but the pattern of results were unchanged. Only analyses on the full dataset are reported here for ease of interpretation.

Ad Libitum Eating

Figure 4 illustrates that, given free access to their top three rated snack foods, participants who were presented the hurricane scenario consumed more calories of food compared to participants presented with the minor storm scenario, $t(46) = 2.009$, $p = 0.05$, Cohen's $d = 0.58$.

Positive and Negative Affect Schedule (PANAS)

Figure 5 illustrates the differences and changes in negative and positive affect. A 2-way ANOVA (between scenario group and within baseline-post presentation) indicated a main effect of scenario group $F(1, 46) = 64.97$, $p<0.0001$, timepoint $F(1,46)= 121.2$, $p<0.0001$, and interaction $F(1,46) = 63.43$, $p<0.0001$ on negative affect (Figure 5A). Specifically, Sidak multiple comparisons post hoc tests found an increase in negative affect between the hurricane and minor storm scenario groups post scenario presentation, $p<0.0001$, Cohen's $d = 2.40$. Moreover, this increase in the hurricane group was also an increase over that group's baseline negative affect score, $p<0.0001$, $d_{\text{repeated measures}} = 9.18$. Figure 5B shows the positive affect scores between scenario groups and within-group baseline and post presentation scores. A main effect of timepoint was present $F(1,46) = 15.54$, $p=0.0003$). Post hocs revealed that positive affect scores dropped compared to baseline in the minor storm group, $p=0.0012$, $d_{\text{repeated measures}} = 0.70$, but did not change in the hurricane group. No differences in positive affect between scenario groups was present at either timepoint.

DISCUSSION

The present study illustrates that vividly imagining oneself in a realistic and stressful scenario can increase snack food reinforcer pathology in obese participants. Specifically, we found that imagining a hypothetical scenario about hurricane-associated loss increased delay discounting for an immediately available favorite snack, behavioral economic demand for that snack, ad-libitum hedonic eating, and negative affect. These increases were evident when compared to the changes in decision-making, eating behavior, and affect following presentation of a relatively neutral scenario in which a minor storm dented the car without any injury or significant financial loss, and when compared to the participants' baseline responding in the absence of a scenario. Together, these results suggest the strength of narratives, in that simply thinking about a hypothetical stressor has the potential to be just as harmful to reinforcer pathology as coming into contact with real life stressors.

Reinforcer pathology is derived from the interaction between two distinct decision-making processes, 1) excessive preference for immediately available small rewards (i.e., excessive delay discounting) and 2) over-valuation of those rewards (e.g., high behavioral economic demand) (Bickel, Jarmolowicz, Mueller, & Gatchalian, 2011; Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014; Bickel, Snider, Quisenberry, & Stein, 2017). We note here that while we refer to behavioral economic demand as valuation, as described in Bickel et al. (2011), reward demand is not the only measure of valuation. The construct of reward value may include self-administration, craving, and salience, among others. Nonetheless, the interaction between delay discounting and demand can be visualized as a 2-by-2 matrix in which individuals exhibiting greatest preference for immediate rewards (e.g., alcohol or drugs) paired with their high demand, would be at the greatest risk for addiction (Bickel et al., 2011; Carr, Daniel, Lin, & Epstein, 2011). Importantly, the concept of food addiction as a phenotype of obesity (Davis et al. 2011) allows us to extend the reinforcer pathology theory to another disorder suffering from a common underlying mechanism. The rationale for this prediction of synergy is derived from decades of research demonstrating the value of each decision-making process separately in accurately predicting severity of use disorders and risk for the individual. Together, however, the reinforcer pathology framework describes how these two processes interact by illustrating how individuals might integrate valuation of energy-dense comfort foods as a function of their temporal horizon. Specifically, delay discounting functionally measures the temporal window (how far the individual can imagine into the future) over which the reinforcer value can be integrated. Consider the often opposing features of excessive overeating and longterm health. Comfort foods deliver a brief, intense reinforcer with immediate and reliable effects, whereas long term health (e.g., healthy eating, consistent exercise) functions at lower intensity, is more variable, and accrues its value over a longer temporal window. If the temporal window is constricted (i.e., excessive delay discounting), the relative value is much greater for comfort foods than for long term health, resulting in the overvaluation of food. Thus, a constricted temporal window increases food's relative reinforcing value as competing healthy habit reinforcers are valued less, producing reinforcer pathology. The following sections discuss possible modes by which the hurricane narrative may have impacted each of the two components of obese individuals' reinforcer pathology and hedonic eating.

Narratives and Delay Discounting

The concept of using narratives to modify decision-making and delay discounting rates is not a new one (see Bickel, Stein, et al., 2017). When presented with a scenario about losing their job and being forced to move across the country, participants increased their delay discounting for monetary (Bickel et al., 2016) and cross-commodity (Mellis, Athamneh, et al., 2018) rewards. Also, in hypothetical negative contexts, participants demonstrate increased risky decision making (Mishra & Gregson, 2012). Delay discounting may also be decreased (i.e., an increase in self controlled decision-making) following presentation of differently valenced narratives. For example, narratives expressing regret from a close friend promoted choices of delayed sexual gratification (i.e., decreased delay discounting) in a risky sex decision-making task (Quisenberry, Eddy, Patterson, Franck, & Bickel, 2015). Moreover, episodic future thinking, the process of vividly imagining a positive future event, has demonstrated great strength in reducing delay discounting rates in obese and overweight

individuals (Tinke Oluyomi Daniel, Stanton, & Epstein, 2013; T. O. Daniel, Stanton, & Epstein, 2013; O'Neill, Daniel, & Epstein, 2016; Stein et al., 2017), as well as individuals with alcohol use disorder (Snider, LaConte, & Bickel, 2016) and smokers (Stein et al., 2016).

The current study found that under conditions of hurricane-associated loss, participants were more likely to choose smaller, immediately available options over larger but delayed options. These results suggest a constriction of the temporal horizon and focus on the value of only the immediately available snack over delayed money or weight loss. These results are supported by previous literature which describes that scenarios of poverty and/or scarcity constrict an individual's cognitive function (Mani, Mullainathan, Shafir, & Zhao, 2013) and self-controlled decision-making (Bickel et al., 2016). We originally hypothesized that discounting rate for immediately available money would also increase, however this was not the case. Past research has identified that individuals who are obese demonstrate greater rates of discounting for food, and not for money (Rasmussen et al., 2010), although other research has identified systematic relationships between discounting of money and obesity (see Amlung et al., 2016 for meta-analysis). The possibility remains that the present study was underpowered to detect a difference between the scenario groups for money discounting; indeed, the effect size was smaller than the others. Alternatively, perhaps the acute stressor of the scenario was not sufficient to modify the participant's temporal horizon for money. To better understand the relationship between money and the snack item value under these conditions the participants also completed a behavioral economic demand task.

Narratives and Behavioral Economics

Behavioral economics allows researchers to explore how an individual's environment affects how they make decisions about the value of food (Epstein & Saelens, 2000). Using a modified version of the hypothetical purchase task, we assessed how individuals would hypothetically purchase snack food items at increasing prices while vividly imagining themselves in their scenario. As mentioned in the introduction, obese individuals demonstrate a greater valuation of energy dense food (Stojek & MacKillop, 2017), compared to non-obese individuals. Moreover, when obese participants were presented with a negative income shock scenario they exhibited greater demand for fast-food compared to control scenario (Mellis, Athamneh, et al., 2018). Interestingly, others have demonstrated that obese and overweight participants were willing to work harder to obtain snack foods compared to normal weight participants, suggesting increased demand. This difference was specific to snack foods, and not food in general, suggesting a greater sensitivity to the rewards of snack foods (Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010). Therefore, we were curious to see whether narratives would alter this already increased valuation in an obese population.

Narrative theory derived studies have previously demonstrated some small effect size reductions in demand have been demonstrated for both alcohol (Snider et al., 2016) and cigarettes (Stein et al., 2016) following an episodic future thinking intervention in which participants were asked to vividly imagine a positive future. Most notably, Mellis et al. (2018) demonstrated that a negative income shock (i.e., job loss) increased intensity of

demand for fast-food servings among obese individuals. Here, we support those findings by demonstrating that in the presence of the hurricane-associated loss scenario, participants increased intensity of demand for their favorite snack food. That is, when the snack was free, they would purchase/take more servings, suggesting increased valuation of the snack. This increase in demand intensity may be driven by increased sensitivity to the rewarding properties of preferred snack foods.

An alternative explanation for the increased preference for immediately available snacks could be the manner in which the participants engaged with the scenario. Participants were instructed to vividly imagine their assigned scenario and answer the task questions as if the scenario were actually happening to them. The hurricane associated-loss scenario explicitly stated that the individual will be unsure of how he or she will get food. This uncertainty for obtaining a primary reinforcer, food, could have driven the preference for immediate food over delayed money and weight loss. Moreover, because the scenario did not mention money, nor would one likely need or value immediate money in a situation in an emergent crisis involving your family's safety, this may explain the lack of change in the monetary discounting task. As for the demand for their favorite snack, the effect could have been driven by the thought that because food will not be immediately available (per the scenario), taking as much free food as possible would be an adaptive response. A limitation of the present study is that distinguishing this mechanism is challenging without explicitly asking the participants. Future studies may be interested in specifically manipulating the scenario and/or the task restraints to tease apart *how* the participants are engaging with the scenario. However, simply projecting themselves into the scenario and responding adaptively does not explain the narrative's impact on hedonic eating behavior.

Comfort Foods, Stress, and Hedonic Eating

The term "comfort foods" has come to describe the ability of calorie-dense, usually carbohydrate and sugar loaded, foods to interoceptively reduce the negative effects of stress. However, the idea of eating to relieve stress is not novel, the literature has shown that acute stressors will induce eating (Adam & Epel, 2007; Dallman, 2010). Stressors, whether physical or emotional, induce the production of cortisol by activation of the hypothalamic pituitary adrenal (HPA) axis. Under ideal circumstances, the released cortisol exerts a negative feedback to inhibit a continued stress response and the individual returns to normal levels. However, in individuals with repeated and chronic stress, the HPA becomes dysregulated, leading to decreased sensitivity to the inhibition signal. Obesity is associated with HPA axis dysregulation leading to decreased sensitivity to shutting a stress response down. Food, especially "comfort foods", release many rewarding neurotransmitters including dopamine (Dallman et al., 2005), and endogenous opioids, which reduce the HPA activation and the negative valence of the stressor (Dallman, 2010). Over time and repeated bouts of stress, an individual learns that food that releases dopamine and opioids will reduce that stress response (Dallman, 2010).

Chronic stress and a dysregulated HPA axis can lead to an over activation of the HPA axis and response mechanism when stress is actually present, leading to palatable food "dependence" (Adam & Epel, 2007). In fact, individuals categorized as high stress, as

measured by their cortisol release, eat more in naturalistic settings (Adam & Epel, 2007). Given that individuals suffering from obesity tend to have enhanced sensitivity to the rewarding properties of energy dense foods (Volkow et al., 2011), the observed increase in consumed calories in the presence of an emotionally-charged stressful scenario is in line with our hypothesis. Most importantly, these calories were consumed over and above the calories of the pre-load meal bar, suggesting that this eating was hedonic only and not in response to hunger. Moreover, the stressor presented here was not a true situation but instead a hypothetical scenario, further supporting the utility of narratives to examine behavior in a narrative theory framework.

We note a few possible limitations for this study. First, although the three delay discounting tasks were counterbalanced among themselves, the order of the task types were administered in the same order (the order described in the methods section) to all participants. While we do not expect order effects from this design given the independence of the tasks from one another, order effects may be present. Second, the current study did not explicitly examine stress in the participants following the scenario presentation precluding direct demonstration of stress on behavior and decision-making. However, the negative and positive affect subscales of the PANAS are positively and negatively correlated with the validated Perceived Stress Scale providing some support for our discussion above (Ezzati et al., 2014). Finally, as noted above, factors other than changes in valuation of snack foods may have driven the increase in demand for and self-administration of the snack foods in this study. While these other factors may not be ruled out by the current study, we interpret the changes in demand and self-administration as robust components of the construct of reward valuation. In particular, the reward value does describe the intensity and elasticity of a demand curve as well as consumption (i.e., self-administration) (Hursh, 1984).

In sum, the present results suggest that narratives can impact behavior just as real-life stressors do. The driving mechanism behind narrative theory is that humans are highly social animals with a sensitivity to storytelling (see Bickel, Stein, et al., 2017). In fact, others have suggested that storytelling is the way in which humans “experience the world” (Connelly & Clandinin, 1990; Gottschall, 2012). Providing a narrative and expecting another individual to place himself in that scenario is something individuals do regularly through modern media and entertainment (e.g., movies, books, radio, etc). Therefore, the results of this and other narrative theory-related assessments demonstrate the strength of our ability to place ourselves into a story and allow us to better understand how to harness that strength. Ultimately, our improved understanding has the potential to lead us to narrative theory based interventions for obesity, substance use disorders, and maladaptive behaviors in general.

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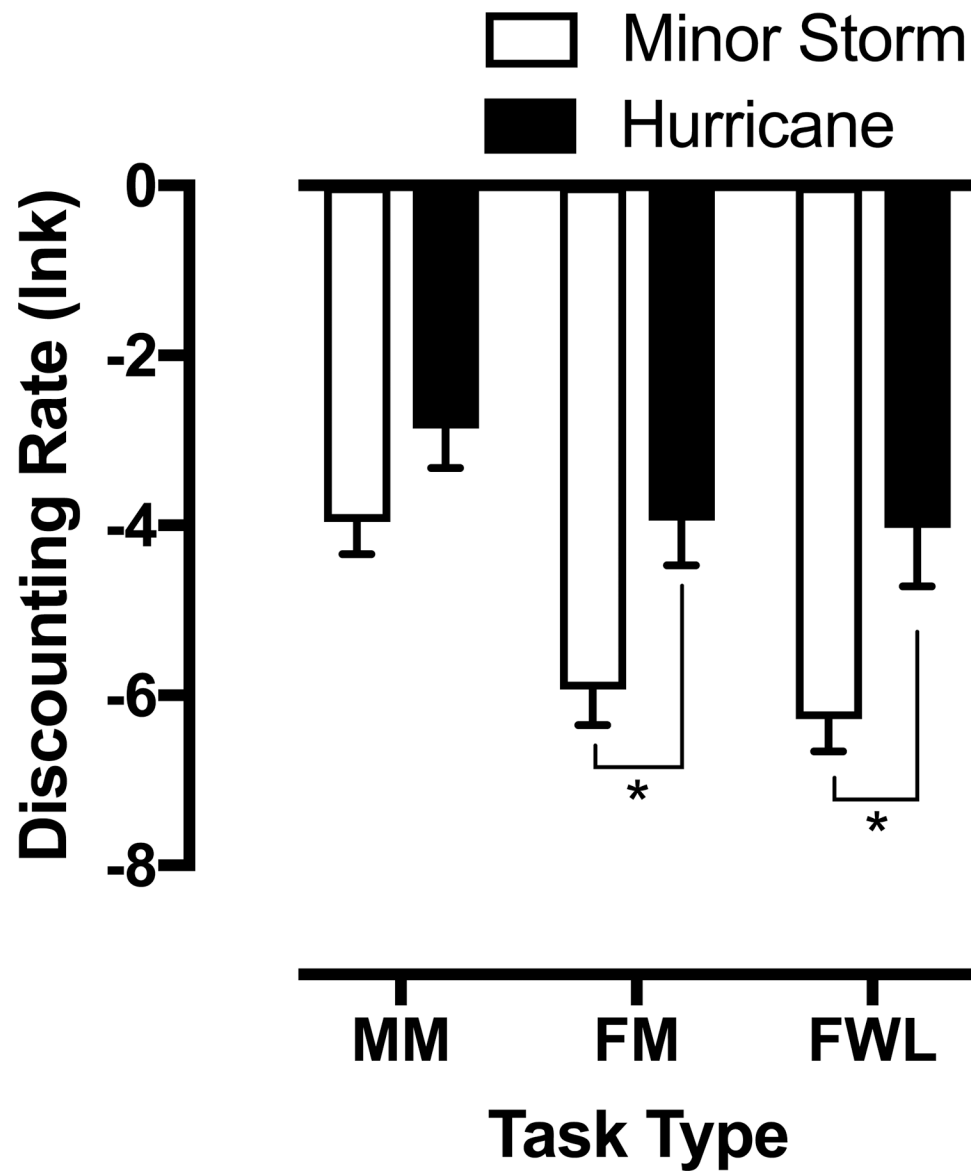


Figure 1. Between group delay discounting rates following presentation of a hurricane-associated loss or minor storm scenario. Discounting task type abbreviations represent money now-money later (MM), food now-money later (FM), and food now-weight loss later (FWL), respectively. * indicates a difference between scenario groups ($p < 0.05$).

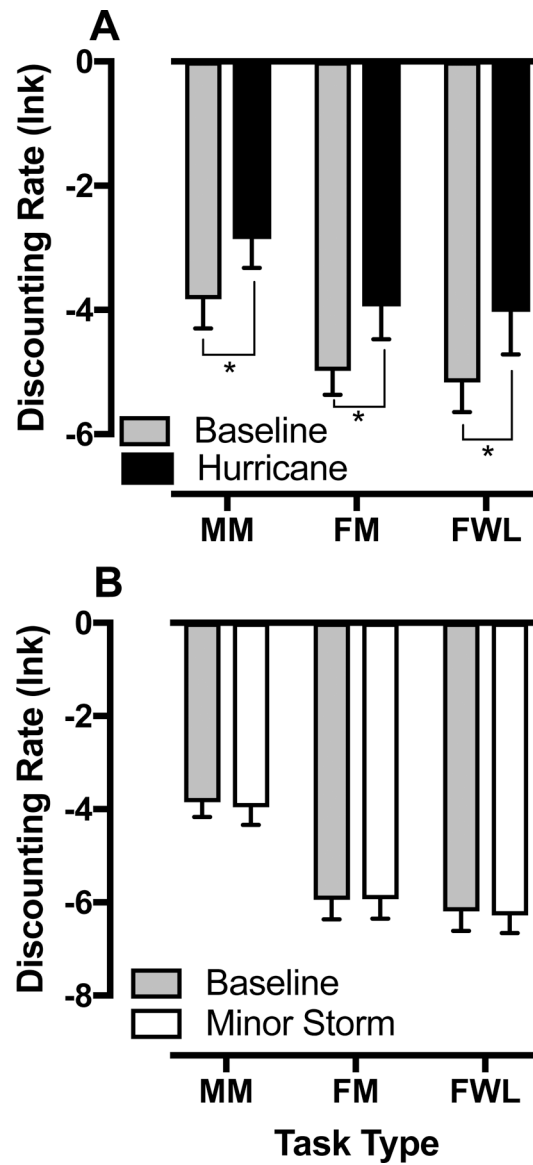


Figure 2.

Within group delay discounting rates following presentation of a hurricane-associated loss or minor storm scenario. Discounting task type abbreviations represent money now-money later (MM), food now-money later (FM), and food now-weight loss later (FWL), respectively. Panel A represents the discounting rates of the hurricane scenario group at baseline and following presentation of the scenario. Panel B represents the discounting rates at baseline and following presentation in the minor storm scenario group. * indicates a difference between baseline and post scenario ($p < 0.05$).

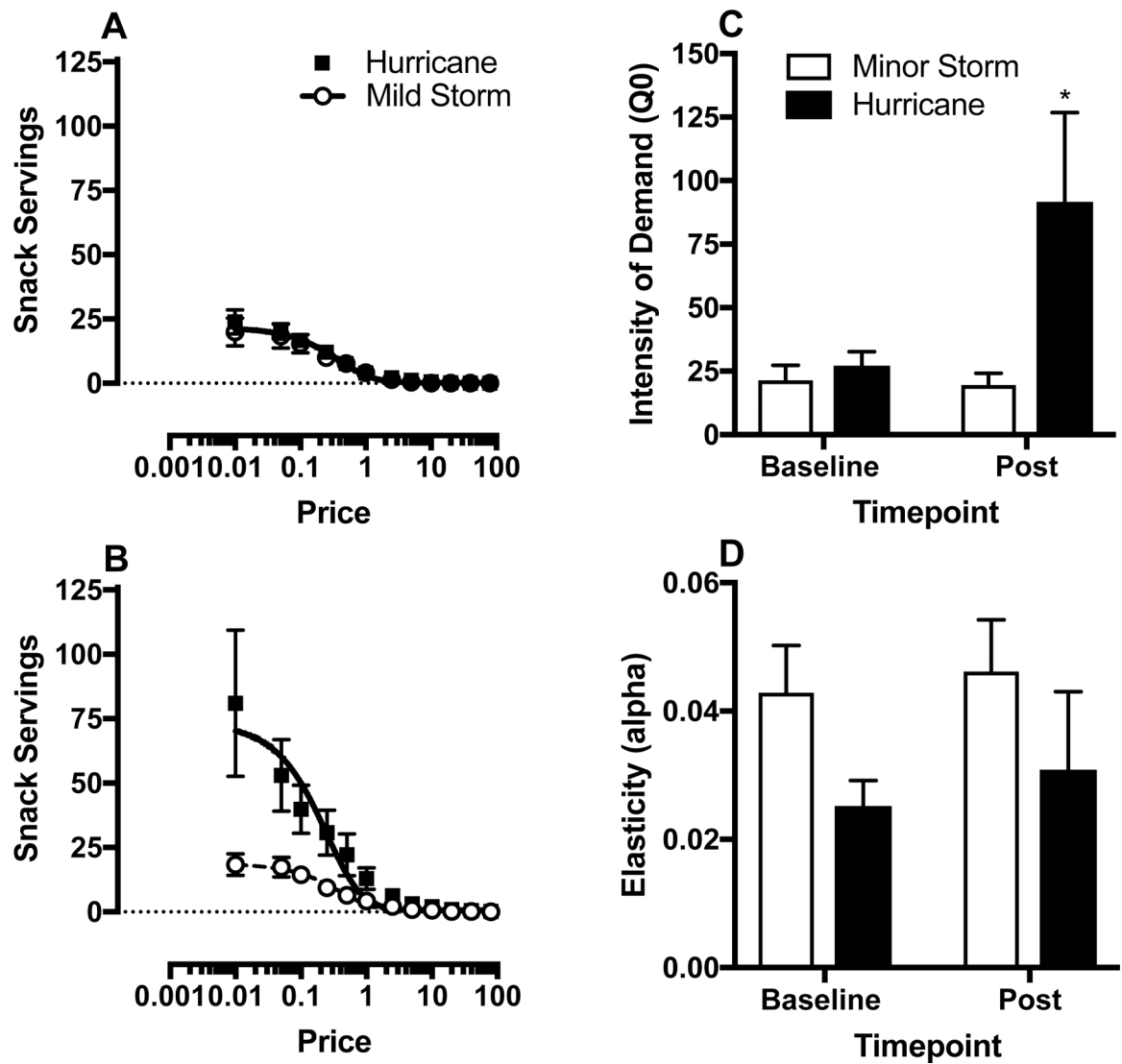


Figure 3. Behavioral economic demand for highest rated snack item. Panels A represents the group demand curves for the hurricane and minor storm groups at baseline. Panel B represents the same group curves, but following presentation of the scenario. Panels C represents the generated intensity (Q_0) between scenario groups at each timepoint. Panel D represents the sensitivity to price (α). Error bars indicate SEM. * $p < 0.05$.

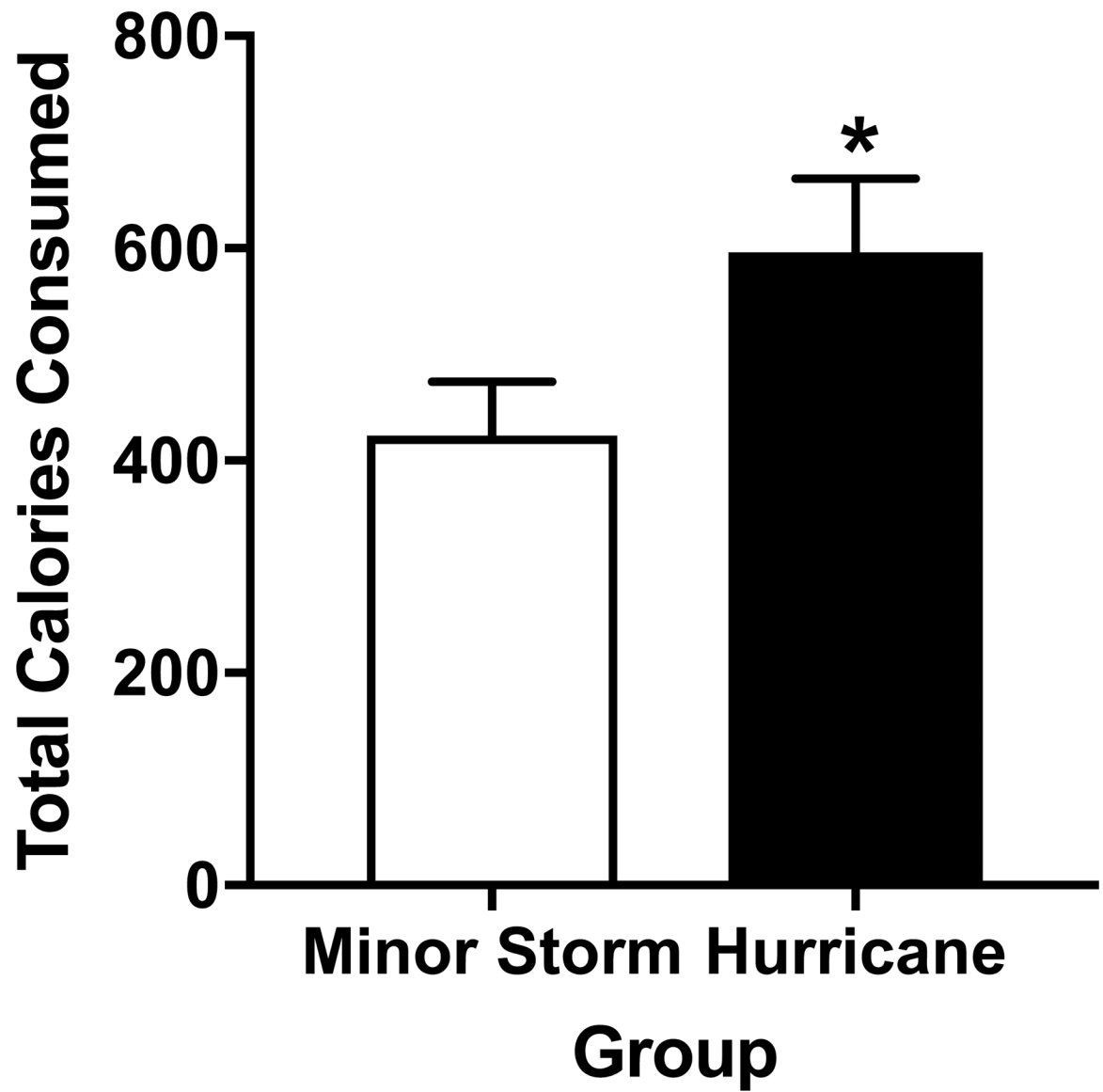


Figure 4. Total calories consumed following presentation of either the hurricane-associated loss or minor storm scenario. * $p=0.05$.

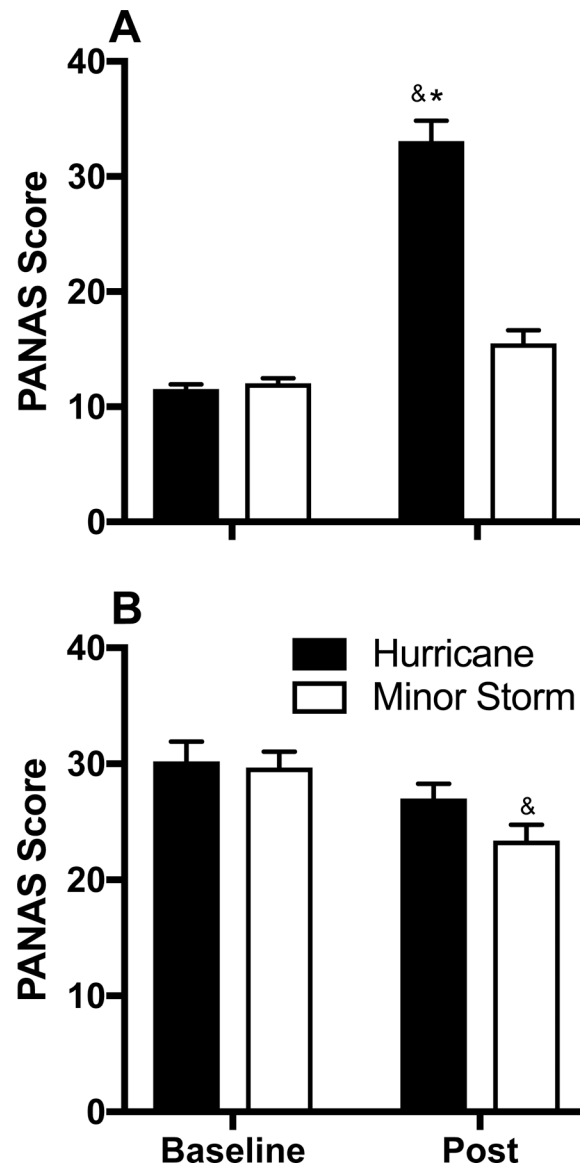


Figure 5. PANAS affect between scenario groups at baseline and post scenario presentation. Panel A represents negative affect. Panel B represents positive affect. * indicates a difference between scenario groups ($p < 0.05$). & indicates a difference between a scenario and its baseline ($p < 0.05$).

Table 1.

Demographic characteristics of participants randomly assigned to either the Hurricane or Minor Storm scenario. Percentage of male and Caucasian participants in each group. Age, Education, Monthly Income, and BMI all presented as group averages (\pm SD).

Group Condition	Sex (%male)	Race (%Caucasian)	Age (years)	Education (years)	Monthly Income (\$)	BMI Scores
Hurricane (n=24)	33.3	75	43 (10.8)	15.2 (2.3)	2146 (1708)	42.0 (9.2)
Minor Storm (n=24)	37.5	75	37.4 (11.7)	14.5 (2.2)	1268 (1187)	38.8 (7.8)