Examining Effects of Early Life Stress and Moderating Influences of Current Life Stress on Reward Processing in Young Adults

By

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University of Toronto

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EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

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Abstract

This study investigated whether high levels of perceived life stress (Perceived Stress Scale; PSS) moderate the relationship between higher levels of childhood adversity (Childhood Trauma Questionnaire; CTQ) and reduced reward processing functions in a university sample. It was hypothesized that early life adversity and perceived stress would lead to reduced reward sensitivity, measured through performance on the Monetary Incentive Delay Task (MIDT). Further, early life adversity was predicted to reduce motivational behaviours, measured through performance on the Effort Expenditure for Rewards Task (EEfRT).

While results did not reveal a significant interaction between childhood adversity and current life stress on reward processes, higher CTQ scores were associated with reduced accuracy in the MIDT. Participants in the high stress group also demonstrated increased reaction times across MIDT trials. There were no significant effects on the EEfRT. These results demonstrate independent associations between early life adversity, current perceived stress, and reduced reward sensitivity.
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Examining effects of early life stress and possible moderating influences of current life stress on reward processing in young adults

Introduction

Reward processing is a cognitive function implicated in decision making, and is modulated by environmental influences including childhood adversity, anxiety, stress, and substance use. Current literature focuses on the direct relationships between such influences and reward processes; however, the effects of these variable interactions on reward processing remains a relatively unexplored field. This study seeks to examine the effects of early life stress on reward processing, and to determine how this relationship may be moderated by experiences of perceived current life stress in early adulthood, a time during which individuals tend to be especially sensitive to the effects of stress.

Early life stress and reward processing

Human research on early life stress encompasses experiences of emotional and physical neglect, and emotional, physical and sexual abuse. The relationship between early life stress and reward processing has been studied using behavioural paradigms and neurobiological assessments, both in human participants and laboratory animals. In this work, is has been well established that reward processes are influenced by environmental experiences, and modulated by specific brain regions, namely, the nucleus accumbens (NAc) and ventral tegmental area (VTA), as well as the striatum and prefrontal cortex (PFC). The amygdala and anterior cingulate cortex (ACC) have also been shown to have a role in reward processes, such as reward learning (Murray, 2007; Rudebeck, Ripple, Mitz, Averbeck, & Murray, 2017; Der-avakian et al., 2017).
Studies aimed at examining reward processing focus on different aspects of the construct, including reward/reinforcement learning, reward sensitivity, motivational or approach behaviours, and/or biological and environmental factors encompassing individual differences in performance. Hanson et al. (2017), for example, used a probabilistic reward learning task to study in adolescents, aged 12-17 years, the effects of childhood abuse on responding to stimuli with differential probabilities of being associated with a positive outcome. Briefly, two visual stimuli were simultaneously presented over the course of several trials, and participants were required to select one with the goal of gaining more points. The experiment was designed in a way where responding for a stimulus on one side of a visual display would lead to a greater amount of points being earned when compared to responding for a stimulus on the other side of the display (Hanson et al., 2017). Overall, they found that adolescents with a history of child abuse displayed relatively lower levels of associative learning, such that they were less likely to select highly rewarding stimuli compared to controls (Hanson et al., 2017).

The effects of reward processing have also been studied using various other behavioural tasks that focus on different aspects of the construct, including reward sensitivity and motivation. One such task is the monetary incentive delay task (MIDT). In the MIDT, visual cues indicate whether the upcoming trial will allow for a monetary gain, loss, or neither outcome. The MIDT requires a behavioural response, typically a button press, in response to the target presentation, and provides feedback following each trial. This task is often employed in visual imaging studies to differentiate between processes of reward and punishment anticipation, and reward and punishment outcome. Additionally, the MIDT provides measures of response reaction times and the proportion of trials completed successfully. In one such study, Dillon et al. (2009) investigated the effects of childhood adversity, in the form of emotional, physical, and/or sexual
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abuse, on performance on the MIDT, while participants underwent functional magnetic resonance imaging (fMRI). Behavioural differences were found between participant groups, where participants with adverse childhood experiences had slower response reaction times and rated reward cues less positively when compared to controls (there was no difference between groups for ratings of loss cues or neutral cues) (Dillon et al., 2009). Relative to controls, the group with adverse childhood experiences displayed reduced activity in response to reward cues in the left globus pallidus, a brain region primarily linked to motor control, but that has also been linked to the reward-related pathway (Münte et al., 2017). These results suggest a reduced reward sensitivity, such that brain and behavioural responses to rewarding stimuli are reduced in those with adverse childhood experiences compared to individuals without adverse childhood experiences. Further, the results show that childhood adversity is associated with neural abnormalities in brain regions that may lead to dysfunctions regarding inhibition and, potentially, reward-related information processing following experiences of childhood abuse.

Hardin et al. (2006) also employed the MIDT with a focus on reward sensitivity, investigating differences in reaction times between shy and non-shy individuals. They discussed reward and punishment sensitivity variances that had been demonstrated in previous work between such personality characteristics, stating that outgoing individuals tend to demonstrate a high reward sensitivity while shy individuals tend to demonstrate high punishment sensitivity. They believed these differences would result in shorter reward latencies and shorter punishment latencies, respectively (Hardin et al., 2006). In their study, they found a group by condition interaction, such that reaction times were modulated between groups as a function of the condition. Specifically, however, shy individuals showed shorter reaction times to reward than to punishment, which Hardin et al. (2006) attributed to an “enhanced sensitivity to potential
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reward”. It was further discussed that behavioural differences (reaction times or successful task completion) were a result of differences in reward versus punishment sensitivity, influencing the “approach” or “avoidance” motivational system (Hardin et al., 2006).

Similar speculations were presented by Costumero et al. (2013), who discussed this link between reward sensitivity and motivation. They employed the MIDT in a healthy sample of participants in order to study activity throughout the reward circuit in the brain. They found a tendency for participants to respond fastest to reward trials with higher levels of incentive, compared to lower incentive levels, or neutral or punishment trials (Costumero et al., 2013). Their analysis revealed that hit success also depended on the valence and incentive magnitude of trials, such that participants were more successful when rewards were higher compared to lower, and when trials were reward-based compared to punishment-based; however, these findings did not reach significance (Costumero et al., 2013).

Comparable results have been obtained from studies focusing on other populations as well. For example, Helfinstein et al. (2013) employed the piñata task, which is an analogous, child-friendly version of the MIDT. Specifically, the piñata task includes a more entertaining story line as well as more interesting, child-friendly graphics, in place of simpler cues. They examined behavioural and neuroimaging aspects of the reward-focused task in a healthy sample of children aged 8-14 years. Similar to Costumero et al. (2006), participants here demonstrated faster response times and performed most accurately in trials associated with greater potential reward (Helfinstein et al., 2013). Further, Kappel et al. (2013) conducted a child-focused reward study and compared performance of the MIDT to performance on the MID task for Children (CID). They focused on a young adult population as well as a child population, and also found that participants responded fastest during gain and loss trials in comparison to neutral
trials (Kappel et al., 2013). Interestingly, they reported no differences in performance accuracy depending on the task.

In another study, Kamkar et al. (2017) evaluated behavioural differences between children with and without adverse early life experiences on both a probabilistic selection task, which provided a measure of reward learning, and a delay discounting task, which provided a measure of reward-related decision-making. Although the sample was considered normative in regard to what defined experiences of early life adversity (e.g., moving homes or the loss of a grandparent), performance on the tasks varied reliably as a function of this factor. In this case, participants who had experienced early life adversity, relative to those who had not, demonstrated a selective benefit in learning from positive rewards (Kamkar et al., 2017). The researchers also reported that participants with these experiences discounted delayed rewards more readily in comparison to participants without adverse experiences. Overall, these results contrast with those of Hanson et al. (2017) in which adolescents with a history of childhood abuse were actually less likely than those without such a history to choose highly rewarding stimuli on a probabilistic reward learning task, thereby demonstrating lower levels of associative learning. An important question for future research is what factors (e.g. age of participants, nature of adversity experienced) contribute to these differences in outcome between studies.

Childhood adversity and reward processing have also been studied in the context of their relationship to morphological brain changes. Teicher and Samson (2016) reported that adverse early life experiences in the form of physical, emotional, and sexual abuse, led to reduced volume in several brain regions, including the dorsolateral prefrontal cortex and orbitofrontal cortex (OFC). Further, they found that childhood abuse was associated with reduced striatal activity in response to anticipated rewards (Teicher & Samson, 2016). Pearson et al. (2014)
found similar results, reporting an interaction between specific serotonergic polymorphisms, childhood abuse and/or neglect, and reward processing dysfunction. Specifically, they found that polymorphisms, or “risk alleles” on serotonin receptor genes (e.g. 5-HTR1A/2A) interacted with experiences of childhood abuse and/or neglect to predict scores on the behavioural approach system (BAS) scale, a self-report survey measuring fun seeking (e.g. impulsivity), reward responsiveness, and drive towards desired stimuli or outcomes (Pearson et al., 2014). This relationship was only significant when multiple risk alleles were present in combination with childhood adversity, leading to significantly lower BAS scores and, thus, reduced reward motivation and sensitivity. These studies together suggest that early life stress, in the form of childhood abuse and neglect, leads to reductions in reward sensitivity and motivation, and are associated with physical changes in the brain.

Overall, the abovementioned studies suggest that experiences of early life stress, neglect, and abuse typically lead to reductions in effective reward learning, although alternate outcomes have been reported that may reflect differences between studies in the extent of adversity experienced, and/or the valence of contextual information (Dillon et al., 2009; Kamkar et al., 2017). For example, associative learning outcomes have shown to depend on the severity of adverse experiences (e.g. normative experiences or abusive experiences), and also on the type of information being processed – whether positive and reward-related, or negative and punishment-related (Hanson et al., 2017; Kamkar et al., 2017). Behavioural and neurological studies have also demonstrated that adverse childhood experiences typically lead to a decrease in reward motivation and sensitivity. This was demonstrated by subjective ratings and reduced brain activity in reward-related brain regions (Dillon et al., 2009; Teicher & Samson, 2016). Further, though there seems to be a natural tendency for individuals to respond faster in reward
conditions compared to punishment or control conditions, some authors have reported mixed findings.

**Stress and reward processing**

Acute forms of stress have also been shown to alter reward learning, reward sensitivity and motivation for rewards. In their study, Lighthall, Gorlick, Schoeke, Frank, and Mather (2013) investigated reward-learning differences between stressed and non-stressed healthy participants. The stress condition included the cold presser task, which requires individuals to immerse their hand in ice water while they are observed by an experimenter (other studies will often include recording the participant, or falsely informing the participant that they will be recorded). The control condition was similar to the cold presser task, except that warm water was used. Following completion of the cold presser task, participants completed a probabilistic learning task, in which they were required to learn which symbols (out of three presented pairs) were more likely to predict positive feedback, and which would more often predict negative feedback (Lighthall et al., 2013). Participants in the stress condition displayed a reduced sensitivity to recent feedback (positive and negative), relative to controls, during the training trials and prior to the learning of stimulus associations (Lighthall et al., 2013). However, in test trials, when stimulus-reward associations were familiar, participants in the stress condition more accurately selected cues more often associated with positive rewards. These results demonstrate that acute stress can improve learning of positively-associated cues, and also suggest a potential negative relationship between current stress and reward sensitivity.

Park, Lee and Chey (2017) also investigated how stress influences reward learning by evaluating reward-seeking behaviours on a two-stage Markov decision-making task, in which reward probabilities associated with stimuli were intermittently reversed. Reward-seeking
behaviours were characterized as “model-free”, which are habit-driven behaviours and typically influenced by immediate outcomes, and “model-based”, which are goal-driven, and typically more adaptive to a task structure or design (Park et al., 2017). Undergraduate student participants were randomly assigned to either the stress condition, which included the socially evaluated cold presser test (SECPT), or the control condition, which included a non-stressful modification of the SECPT (Park et al., 2017). The SECPT was similar to the cold presser task used in Lighthall et al.’s (2013) study, except that participants also believed they were being recorded. Using the visual analogue scale (VAS), a single-item survey which assessed subject stress levels, participants in the stress condition rated the SECPT experience as significantly more stressful than controls (Park et al., 2017). Decision-making reaction times did not differ between groups; however, stress led to reduced performance, such that participants earned significantly fewer points across trials, relative to controls (Park et al., 2017). Further, participants in the stress condition were less likely to choose more rewarding stimuli, and more often demonstrated model-free reinforcement learning, modifying choices based on immediate negative outcomes (Park et al., 2017). Finally, Park et al. (2017) found that stress decreased the learning rate in which participants, compared to controls, did not as effectively incorporate new information into further decision-making over trials. These results demonstrate an association between stress and reduced reward-learning, which are in contrast to the findings of Lighthall et al. (2013). These differences in outcome may be due to the nature of the experimental task, as well as the behavioural outcomes being investigated. For example, Lighthall et al. (2013) only found improvements in learning for positive rewards, and the task design was more straightforward, such that rewards associated with stimuli were held constant, compared to the reversed reward stimuli paradigm used in Park et al.’s (2017) work.
In another study, Morris and Rottenberg (2015) investigated the effects of induced stress on reward-learning in individuals with anxiety. Reward learning was evaluated using a signal detection paradigm. The researchers employed an arithmetic stress task in which participants were instructed to, quickly and accurately, serially subtract from a starting number while being monitored via camera. In the non-stress, control condition, participants were instructed to complete similar arithmetic questions on paper, and that their answers would not be scored. Under stressful conditions, individuals diagnosed with anxiety demonstrated improved reward learning, relative to controls, who actually demonstrated blunted reward learning, as indicated by scores of response bias (Morris & Rottenberg, 2015). These results provide valuable insight into the interaction of variables such as stress and anxiety, demonstrating that certain traits may aid individuals to adapt to stress in more efficient ways.

Reward learning has also been studied by Bogdan, Santesso, Fagerness, Perlis, and Pizzagalli (2011), who investigated the influence of acute stress, induced by threat of shock, and genetic interactions. They employed an electroencephalography- (EEG) monitored probabilistic reward learning task with young adult female participants, specifically focusing on feedback-related positivity (FRP) activity. As discussed by Bogdan et al. (2011), FRP activity is believed to originate in the ACC and striatal brain regions, and is stimulated by rewards and prediction errors. In this study, reward learning was disrupted in the stress group, relative to the non-stress group, as demonstrated by a reduced response bias and smaller and delayed FRP. The stress group also displayed reduced activation in the ACC and the orbitofrontal cortex (OFC) in response to reward (Bogdan et al., 2011). Saliva samples were used to genotype a subset of these participants to further examine gene-environment influences on the demonstrated reduction in neural activity in response to positive feedback. The researchers focused on polymorphisms
of the corticotropin-releasing hormone type 1 receptor (CRHRI), which is known to contribute to
the regulation of the hypothalamic-pituitary-adrenal (HPA) stress response, and is associated
with ventral striatal activity in response to reward feedback (Bogdan et al., 2011). Specific allele
polymorphisms were associated with increased susceptibility to stress-induced reductions in
reward learning (Bogdan et al., 2011). These results demonstrate that stress typically leads to
disruptions in reward learning and reduced reward sensitivity, and that these differences are
partially complemented by specific genetic traits.

Pool, Brosch, Delplanque, and Sander (2015) took an interesting approach to study the
effects of stress on reward processing, dissociating reward wanting from reward liking by
adapting the Pavlovian- Instrumental Transfer (PIT) test for human participants. During the
procedure, participants learned to associate a neutral visual stimulus and an instrumental action
(squeezing a handgrip) with a positive reward (chocolate odour) (Pool et al., 2015). Participants
were then randomly placed in a stress or no-stress group, which included completion of a
socially evaluated cold presser test as well as a modified, non-stressful water-immersion test,
respectively. Following stress-induction, participants repeated the PIT test, and were then asked
to evaluate different features of the positive odour, such as the pleasantness and familiarity of the
scent (Pool et al., 2015). Participants in the stress condition displayed an increase in physical
exertion in response to the positively conditioned stimulus relative to those in the non-stress
condition, while odour ratings between the groups did not differ (Pool et al., 2015). These
results demonstrate that stress can increase cue-triggered wanting without influencing the
affective response towards, or liking of, rewards.

Researchers have also induced stress using pharmacological methods. For example,
Montoya, Bos, Terburg, Rosenberger, and van Honk (2014) conducted a pharmaco-fMRI study
in young adult males to investigate the effects of cortisol on reward processing. Cortisol is produced in the adrenal cortex and is one of the primary glucocorticoids involved in the stress response. High doses of cortisol were administered in healthy participants prior to completing the MIDT. Compared to the placebo control, cortisol led to a reduced activity in reward-related regions, including the striatum, amygdala, and NAc, as well as in areas associated with motor response, such as the cerebellum and supplementary motor cortex (Montoya et al., 2014). Relative to those who received placebos, participants who received cortisol also had reduced initial reaction times (with some improvement over the course of testing), and also reduced objective ratings of reward-related stimuli (Montoya et al., 2014). In addition, the researchers administered self-report questionnaires to identify levels of early life stress in the form of abuse and neglect. As anticipated from previous findings, individuals with experiences of early life stress also displayed blunted responses in reward-related brain regions (Montoya et al., 2014). These findings support previous work in adversity- and stress-related studies, demonstrating that early life stress and acute stress lead to a reduction in reward sensitivity.

In summary, behavioural and biological findings tend to support a negative relationship between stress and reward learning and sensitivity. Though findings have shown stress to be an adaptive mechanism in some situations, (e.g. Lighthall et al., 2013; Morris & Rottenberg, 2015), literature tends to show a reduction in reward response bias, response times, motivation for reward, and reward-related brain activity. Lighthall et al.’s (2013) results, as mentioned, were based on a simplistic task design, potentially allowing for individual stress responses to be adaptive. These findings inform our hypothesis that higher levels of stress may contribute to a reduction in reward sensitivity, but may potentially increase motivational behaviours.
Affective Reactivity

Positive and negative affective ratings are being used in the current study as a validation measure of potential engagement and interest in the cognitive tasks being administered. The ratings used illustrate individual levels of positive and negative affect at different timepoints throughout the experiment, as well as stress levels, and may demonstrate whether participants with adverse childhood experiences and/or those experiencing higher, relative to lower, levels of stress are more emotionally reactive.

Early life stress has been linked to dysfunctions in stress-reactivity later in life. This has been demonstrated in work by Hengsech et al. (2018), for example, who investigated the physiological and subjective effects of early life stress (in the form of orphanage institutionalization and adoption), on lab-induced stress in adults. They employed the Cold Pressor Test (CPT) to induce stress, which is similar to the previously discussed Cold Presser Task, except that participants place their feet in the cold water, instead of their hands. They also employed the Paced Auditory Serial Addition Task (PASAT), where participants were required to listen to a list of single-digit numbers, adding each presented number to the previous/total amount quickly and accurately (Hengsech et al., 2018). Both subjective ratings and cortisol samples were collected. Compared to controls, participants with the adverse childhood experiences displayed blunted HPA stress axis responsiveness and increased subjective ratings of arousal and anxiety (Hengsech et al., 2018). A similar study was conducted by Weltz, Armeli, Ford, and Tennen (2016), who examined the relationship between reported experiences of emotional abuse and neglect with subjective stress and negative affect ratings in college students. Emotional abuse was associated with higher levels of stress-reactivity, or negative affect, while emotional neglect appeared to reduce reported levels of negative affect in response to daily stress
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(Weltz et al., 2016). These results demonstrate that early life stress leads to dysfunctions in stress responses in adulthood, subjectively and physiologically.

Kuras et al. (2017) also investigated the effects of early life stress on stress regulation, focusing their study on a population with experiences of low-to-moderate experiences of childhood adversity. They employed the Childhood Trauma Questionnaire (CTQ) to healthy adults and obtained several cortisol samples over a two-day period. They found that low-to-moderate levels of reported childhood adversity was associated with reduced cortisol levels upon participants’ awakening, and throughout the day (Kuras et al., 2017). These results also suggest that early life stress, even in “moderate” levels compared to severe, may lead to altered HPA activity and stress regulation in adulthood.

Negative affect has also been studied in relation to perceived life stress as well as induced, acute forms of stress. For instance, Abbasi (2016) investigated the role of neuroticism on stress levels and negative affect, utilizing the PSS and PANAS, respectively. Participants were presented with visual stimuli that fell under a positive, negative, or neutral rating, and were then asked to complete the listed questionnaires. To induce acute stress, participants completed the Trier social stress test (TSST), in which they were required to prepare and present a speech in front of an audience (the experimenters) and was recorded and judged (Abbasi, 2016). Following the speech presentation, participants were required to verbally perform a mental arithmetic task in front of the judges, and then once again were administered the PSS and PANAS. Abbasi (2016) did find an association between higher, relative to lower, neuroticism scores and higher baseline perceived stress and negative affect scores; however, there were no significant group differences between high and low levels of neuroticism following the TSST. Further, stress and negative affect ratings differed between and within high and low neuroticism
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groups following positive and negative visual stimuli (Abbasi, 2016). While the focus of the study was linking stress and negative affect with neuroticism, the results do demonstrate that perceived stress and negative affect may share a positive relationship at baseline states, though these scores can vary depending induced stress and personality characteristics.

Çivitci (2015) investigated how negative affect moderated the role of social support on perceived current life stress. In this study, the PSS and PANAS were employed alongside the Multidimensional Scale of Perceived Social Support (MPSS), which gathers information regarding respondents’ support from friends, family and significant other. Results showed an association between higher, relative to lower, negative affect scores and higher perceived stress scores, and the expected beneficial effect of social support on stress was reduced (Çivitci, 2015). This study highlighted the correlation between negative affect and perceived stress and demonstrated that the relationship between these variables can reduce any positive moderating effects of social support.

Similarly, Asgari (2016) investigated the relationship between induced stress and support on negative affect and individual perceptions of support. A sample of undergraduate students were administered a series of questionnaires measuring levels of self-esteem, optimism, stress, and perceived support. Stress and support were also induced as laboratory manipulations, where participants in the “high stress” group completed the TSST (described previously). Participants in the “low stress” condition were instructed to write ideas for a “hypothetical” speech, and to perform a simpler arithmetic task as a control (Asgari, 2016). Support was also a manipulated independent variable, where participants in the “high-support” group received supportive or encouraging comments from the experimenter throughout the experiment, while those in the “low-support” group did not receive any comments. The analyses revealed that negative affect
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was associated with induced stress, regardless of the amount of support received. Though Asgari (2016) speculated that the level of social support may not have been sufficient enough compared the stress experienced, this study still demonstrated a clear association between acute stress and negative emotions.

In another study, Stawski, Sliwinski, Almeida, and Smyth (2008) investigated how “global” stress perceptions and age influenced stress reactivity over a two-week study on young and older adults. Participants were instructed to document daily stressors using the Daily Inventory of Stressful Events (DISE), and also completed the PANAS and PSS during the experiment. While younger and older adults were found to report similar severity ratings for stressful events, Stawski et al. (2008) also reported a significant relationship between PSS scores and stress reactivity, demonstrated by stress-related increases in the NA portion of the PANAS. This study illustrates the relationship between high perceived stress and higher stress, or negative affect reactivity in response to stressors.

Though dysfunctions in stress-reactivity have shown to differ depending on specific experiences of early life stress, it has been clearly established that such experiences do interfere with general HPA and stress functioning. Subjective ratings of stress appear to increase following early life stress, while physiological changes seem more dependent on the type of childhood stress experienced. A consistent relationship between perceived current stress and negative affect has also been established in the literature, as discussed. As such, affective ratings throughout the current study will provide a measure of stress-reactivity for participants, and will also function to corroborate reported experiences of early life stress and current, perceived life stress.
The present experiment

The abovementioned studies highlight the independent and interactive influences of multiple environmental factors on reward processing functions. The current study was designed to extend this examination of the effects of early life stress on reward processing in early adulthood, by exploring how this relationship by be modulated by factors of current perceived life stress. Participants were administered a variety of questionnaires aimed at assessing early life adversity (Childhood Trauma Questionnaire [CTQ] and perceived current life stress (Perceived Stress Scale [PSS]; see “Methods” for details). Additional questionnaires assessing symptoms of anxiety and depression, as well as substance use, were also administered, although the results from these measures were not included in the analyses reported in this thesis (see Appendix A-D). These data will be the focus of potential future studies, to further contribute to the literature regarding the complexity of early life adversity and reward processing. Reward processing was evaluated using two computerized behavioural tasks: 1) the Monetary Incentive Delay task (MIDT) and 2) the Effort Expenditure for Rewards Task (EEfRT). The MIDT provides measures of both reaction times to cues predicting monetary rewards (or punishments), as well as the proportion of trials completed successfully – in the context of “win trials” or “loss trials”, where money can potentially be won or lost. The EEfRT provides an effort- or approach-based output, where participants choose how much effort to exert for various monetary reward amounts. This task provides a measure of the proportion of “difficult” trials the participants select based on the various reward amounts and differing win probabilities (see “Methods” for more details).
Hypotheses

I expected to replicate previous findings on the relationships between childhood adversity and current perceived life stress. Initially, to validate the behavioural tasks, I analyzed the effects of the MIDT trial condition (reward, punishment, or neutral) and incentive condition (incentive or non-incentive) on the reaction times and proportions of correctly completed trials. I predicted that participants would respond fastest and most accurately to both incentive reward and incentive punishment trials, relative to control/neutral trials or non-incentive trials. Further, as informed by previous work by Treadway, Buckholtz, Schwartzman, Lambert, and Zald (2009), I expected that participations would choose more difficult trials in the EEfRT when the probability of receiving the reward following trial completion was higher rather than lower. I also predicted that higher reward amounts would be associated with an increase in difficult task choices, as was seen in Barch, Treadway, and Schoen’s (2014) work using the EEfRT.

Then, I categorized participants according to standardized criteria as experiencing severe, moderate, mild, or no levels of early life adversity (Kuras et al., 2017), and high or low levels of current perceived life stress, and analyzed how these factors affected outcome measures of reward sensitivity and motivation. Based on past literature, it was predicted that experiences of early life adversity, specifically participants scoring in the “severe” relative to “none” range on the CTQ would be associated with reduced response times and proportions of correctly completed trials on the MIDT. It was likewise predicted that individuals scoring in the “severe” relative to the “none” range on the CTQ would select fewer difficult trials on the EEfRT.

Based on the literature discussed here, I further predicted that high, relative to low, levels of perceived current life stress, as indicated by scores on the PSS would be associated with reduced reaction times and proportion of correctly completed trials on the MIDT. However,
given that stress has, in some studies, been shown to improve performance on motivational
behavioural tasks, I predicted that high, relative to low, PSS scores may in fact lead to increase
numbers of difficult trials selected on the EEfRT.

Although past literature does not greatly inform how early life adversity may interact
with measures of perceived current life stress on outcome measures of reward processing, I
included analyses that tested for such interactions. I also made several predictions, based on
conjecture in regard to how these relationships may be reflect in task performance. First, I
predicted that early life stress would interfere with typical reward-related functioning as well as
with motivational efforts to obtain rewards, and that perceived current life stress may selectively
counteract or reduce these effects on motivational efforts. While it is predicted that early life
stress will result in reduced reward sensitivity and motivation as described above, higher levels
of perceived current life stress is predicted to further reduce performance on MIDT reward
reaction times and proportion correct, but may improve motivational performance on the EEfRT,
where the number of selected hard tasks will be increased, or will be more comparable to
“normal” levels.

Finally, informed by previous work, I predicted that higher, relative to lower levels of
early life adversity would be associated with higher scores of negative affect and current stress
levels. Higher, relative to lower scores on the PSS were also predicted to lead to higher scores of
negative affect.
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Methods

Participants

We recruited university students (N=172) between the ages of 17 and 30 years for the study. The sample included 141 females and 31 males. Participants were recruited through various online platforms, including Kijiji, Craigslist, and Facebook. The posted advertisement included a brief description of the study, age requirements, as well as our lab email address and location. Individuals were asked to contact us via email to inquire about participation, at which time they received more detailed information about the study. They were informed of the behavioural tasks and surveys regarding mood, stress, and early life adversity they would be required to complete. Finally, they were informed that compensation included a base pay of $20, plus $3-$7 based on task performance. Those who were still interested in participating scheduled a time with the experimenter at one of four available locations in Mississauga, downtown Toronto (St. George area), or Scarborough.

Assessments

Surveys and questionnaires.

Stress. The VAS entails a single rated item, asking participants to use a value scale of 0 – 100 to describe how stressed they were currently feeling. In addition to the VAS, we measured levels of current life stress using the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). The PSS has shown to be both reliable and valid by a number of researchers, including Cohen, Kamarck and Mermelstein (1983). They tested for validity and reliability among two groups of undergraduate students, as well as a sample of individuals also participating in a smoking cessation program, and found the PSS to have adequate reliability (Cohen et al., 1983).
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They also determined that the PSS was a better predictor of specific outcomes, such as depressive symptomology and social anxiety, than “life event scores” (Cohen et al., 1983). More recent data also supports the PSS as a reliable measure, including Mitchell, Crane and Kim (2008) who evaluated three versions of the survey, all of which proved reliable. Roberti, Harrington and Storch (2006) also found the PSS-10 to be highly correlated to the trait portion of the STAI.

Early life stress. We administered the Childhood Trauma Questionnaire – Short Form (CTQ-SF; Bernstein et al., 2003) to measure levels of childhood adversity. The CTQ-SF is a 28-item measure that specifically identifies experiences of physical, emotional, and sexual abuse, as well as physical and emotional neglect (Bernstein et al., 2003). The CTQ-SF has been validated by a number of researchers, including Spinhoven et al. (2014) who found a moderate association with the Childhood Trauma Interview (CTI). They moreover reported that the CTQ-SF was better able to detect emotional abuse and neglect than the CTI, and that it was equally effective for individuals that were affected chronically or sporadically by emotional disorders (Spinhoven et al., 2014).

Affect and interest. Finally, we included a subset of four questions extracted from the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988), and an additional question which measures participant levels of tiredness. These specific questions were used to measure participants’ interest (or boredom) at four time-points (before and after each behavioural task) throughout the study, by asking participants to rate current feelings on a VAS, 0-100 value. An example of the five items chosen is “To what extent do you CURRENTLY feel INTERESTED?”. 
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Behavioural Tasks.

*Monetary Incentive Delay Task.* The Monetary Incentive Delay task (MIDT; Knutson, Westdorp, & Hommer, 2000) is a reward-processing/reinforcement learning task that separates the anticipation and delivery of monetary rewards or punishment. In the task, participants are briefly presented with a cue (one of several coloured squares), indicating whether the upcoming trial will be a “win” trial or a “lose” trial. In “win” trials, participants receive a monetary reward upon successful completion of the task (i.e. responding to the target with a button press within a short time window), and do not win anything if they do not complete the task successfully. In “lose” trials, participants experience a monetary loss if they do not complete the trial successfully, and do not experience a monetary gain or loss if they do complete the trial successfully. Win and lose trials are further broken into “incentive” trials, where participants’ performance does affect their reward gains or losses, or “non-incentive” trials, where successful or unsuccessful performance does not actually result in monetary change. The MIDT tracks individual reaction times for each trial and the proportion of correctly and incorrectly completed hits (e.g. where the response is fast enough following the cue) for each trial as well. Following each trial, participants are provided with feedback as to whether they completed the trial successfully, and how much money they won or lost.

The MIDT has been previously employed in both behavioural and imaging studies. As previously discussed, Dillon et al. (2009) used this task to investigate differences in reward-related brain regions between individuals with and without adverse childhood experiences. They found a general increase in reaction times across trial types (win versus loss versus neutral or non-incentive) in the maltreated group compared to the non-maltreated group, although these
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results were not significant at the p < 0.05 level. Both groups also responded fastest to “win”
trials, and took the longest to respond to “non-incentive” trials (Dillon et al., 2009).

The MIDT has also been used in previous studies examining the role of stress on reward
processing. Treadway, Buckholtz, and Zald (2013) conducted an fMRI-based study on healthy
individuals to examine how self-reported levels of perceived stress associated with neural
activation of reward-related brain regions. Using the PSS and MIDT, they found that individuals
who reported greater levels of overall stress also had reduced activation in reward-related areas
during the feedback phases of reward gain and loss (Treadway, Buckholtz, & Zald, 2013).
Specifically, higher results on the PSS were associated with lower neural responses, primarily in
the mPFC during the feedback phase for both win and loss trials. Treadway et al. (2013)
speculate that “stress-induced shifts in the mPFC function may impair appropriate encoding of
value information”, which compliments the previously mentioned findings of Bogdan et al.
(2011) of stress leading to a disruption in reward learning.

Effort Expenditure for Rewards Task. The Effort Expenditure for Rewards task (EEfRT;
Treadway et al., 2009) measures motivational levels of reward processing. Here, participants are
required to decide between completing an “easy” task for a small monetary reward ($1.00) or a
“difficult” task for a larger monetary reward (which are randomly generated, and range between
$1.24 – $4.30). The easy task required the individual to complete 30 button presses, within 7
seconds, with their dominant index finger. The hard task required 100 button presses, within 21
seconds, with the pinky finger on the non-dominant hand. Prior to choosing between the easy or
hard task, the probability level of receiving the reward upon task completion was also presented.
For example, there would be an 88% chance of receiving the reward if the task is completed
successfully (if the task was not completed successfully, there was no chance of receiving the
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reward). The probability levels were classified as “Low” (12%), “Medium” (50%), and “High” (88%).

The EEfRT has been studied in the context of various psychopathologies, including major depressive disorder, schizophrenia, and anhedonia (Treadway, Bossaller, Shelton, & Zald, 2012; Barch et al., 2014; Treadway et al., 2009). The EEfRT has yet to be studied thoroughly in the context of perceived stress, or with symptoms of anxiety and experiences of childhood adversity. This study design will offer preliminary data for these variables/relationships, and will serve to contribute to the existing literature for the EEfRT in general.

Procedure

A time-line of the procedure is provided in Figure 1. Briefly, prior to arriving for their scheduled session, participants were given a subject number and randomly assigned to one of six groups that differ in regard to the order in which the behavioural tasks are administered. The order of administration of the cognitive tasks, relative to their corresponding group, was as follows: Group 1) MIDT, EEfRT, SST; Group 2) MIDT, SST, EEfRT; Group 3) EEfRT, SST, MIDT; Group 4) EEfRT, MIDT, SST; Group 5) SST, EEfRT, MIDT; and Group 6) SST, MIDT, EEfRT.

Participants were asked to arrive at the test location 10-15 minutes prior to their scheduled time. Once they had arrived, they were greeted and presented with two consent forms – one copy for the experimenter and one for themselves. The consent form was briefly explained verbally, so participants were aware they would be completing several hardcopy and computerized surveys, as well as three computerized tasks. They were informed that compensation, in addition to the $20 that is guaranteed, would be based on task performance.
Once the participant provided informed consent, they were asked to keep their phones either turned off or on silent to prevent distractions from the tasks. They were then be asked to complete the demographic form. Next, participants were instructed to begin the initial set of surveys on the laptop, which included the anxiety, depression, and stress measures, followed by our subset of interest-related questions. The participant was told to notify the experimenter once questionnaires were complete, and following this, began the first behavioural task according to their assigned group (Figure 1). Following completion of the initial task, participants completed the subset of interest-related questions again, and were then invited to take a brief break before completing the second behavioural task. This process was repeated after completion of the second task, where the subset of questions was completed before starting the third and final cognitive task. Following completion of the final task, participants once again completed the subset of interest-related questions for a final time, and were then provided with the second set of surveys, which included the substance use surveys and the childhood trauma questionnaire.

Following completion of the surveys and behavioural tasks, participants were provided with a debriefing form for review, which they read themselves and was then briefly reviewed by the experimenter before being signed. While the participant reviewed the debriefing form, the experimenter accessed the laptop to review two specific components of the summary data in the behavioural tasks to determine the additional compensation. The EEfRT was programmed to randomly select the amount won over two separate “win trials”. This amount provided was rounded to the nearest dollar for convenience purposes and, as previously mentioned, was set at a minimum of $3 and a maximum of $7. The randomly selected amounts from the EEfRT typically varied between $2 and up to $9; however, the set range allowed for consistency, and a general average of $25. Participants were asked to print and sign their name on a receipt and
were provided with a copy. Following payment, the debriefing form was verbally explained and the participant was asked if they had any remaining questions before being dismissed.

**Statistical Analysis**

Survey and behavioural data were gathered using the Inquisit software and exported into Microsoft Excel, and statistical analyses were carried out using SPSS.

For the three scales of affect (positivity affect [PA]; negative affect [NA]; visual analogue scale [VAS]) that were administered before and after each behavioural task, initial three-way ANOVAs for the factors of Gender (Male and Female), PSS group (High and Low), and CTQ group (None, Low, Moderate) were carried out.

For the MIDT task, repeated measures analysis of variance (ANOVA) were carried out for the reaction time and proportion correct as dependent measures. In both cases, condition (Reward, Punishment, Control) and Incentive type (Incentive, No Incentive) were entered as repeated measures variables and Gender (Male, Female), CTQ (None, Low, Moderate), and PSS (Low, High) were entered as between-subjects variables. It was noted in the initial analysis that only 6 participants met the criteria for a “severe” rating on the CTQ, and that all were female. Thus, this group of participants were removed from subsequent analyses.

For the EEfRT, we adopted the statistical procedures described by Treadway et al. (2009). More specifically, we used data from the first 63 trials in our analysis in order to maintain consistency. The average number of test trials completed was 76, with a standard deviation of 13.03, and a range of 48-116 trials. Since there was a range of reward magnitudes offered for the “difficult” trial conditions, we followed suit with some previous studies and divided the range in order to simplify and narrow data analyses (Barch et al., 2014; Damiano,
Aloi, Treadyway, Bodfish, & Dichter, 2012). This resulted in two separate groups for Reward Magnitude (both offered for difficult trials, since easy trial rewards were fixated at $1.00), “Low Reward Magnitude”, ranging between $1.24-2.77, and “High Reward Magnitude”, ranging between $2.78-4.30. We then entered these values into mixed-factor ANOVAs with Reward Probability (High, Medium, Low), and Reward Magnitude (High, Low) on each trial as repeated measures factors and Gender (Male, Female), CTQ (None, Low, Moderate), and PSS (Low, High) were entered as between-subjects variables.

**Results**

**Participants**

As discussed in the “Methods”, data was collected from 172 participants. Due to both experimental error as well as incorrect completion of cognitive tasks and/or questionnaires, data from a total of 158 participants was used for the analysis. The final sample consisted of 130 (82.3%) females, and the mean age of participants was 20.6 years (SD=2.43).

**Affect Scales**

*Negative Affect (NA).* Figure 3A-B shows scores on NA in males (2A) and females (2B) for each NA Test (1-4) in participants classified as low PSS (solid line) and high PSS (dashed line). Participants classified as high relative to low PSS had, overall, higher NA scores (main effect of PSS: F[1,154]=12.284, p<.01); however, the difference between PSS groups varied across Test Number (Test Number by PSS interaction: F[3,462]=4.36, p<.01). Separate one-way ANOVAS for Test Number carried out in each PSS group, revealed a significant effect only in participants classified as low PSS (main effect of Test Number: F[3,201]=11.95, p<.001, Fig. 3C); the effect was non-significant in participants classified as high PSS (F[3,267]=1.93, p>.1). Whereas
participants classified as low PSS showed an increase in NA over repeated tests, those classified as high PSS did not show a change across tests. Finally, the factor of Test Number also varied by Gender (Test Number by Gender interaction: F[3,462]=7.30, p<.001). Whereas in males there was no change in NA over repeated tests (F[3,81]=1.28, p>.2), females showed a significant increase across tests (main effect Test Number: F[3,387]=14.16, p<.001, Fig3D).

For the CTQ, as for the PSS, the overall ANOVA also revealed a significant two-way interaction of NA Test by CTQ (F[6,465]=5.29, p<.001). Figure 3E shows scores on NA in both males and females for each NA Test (1-4) in participants classified as none, low, and moderate. Subsequent one-way ANOVAs carried out for each CTQ group (none, low, moderate) were significant only for those classified as “none” (F[3,219]=17.25, p<.001, Fig. 3E). In the “low” and “moderate” groups the results were non-significant (F[3,174]=1.61, p>.1 and F[3,72]=.16, p>.9 for “low” and “moderate” respectively). Whereas participants classified as “none” on the CTQ showed a time-dependent increase in negative affect, participants classified as “low” and “moderate” showed sustained elevated levels of negative affect at all time points.

Positive Affect (PA). Figure 4A-B show scores on PA in males (4A) and females (4B) for each PA Test (1-4) in participants classified as low PSS (solid line) and high PSS (dashed line). Overall, PA scores decreased over repeated tests (main effect Test Number: F[3,462]=6.37, p<.01), and those classified as high relative to low PSS scored lower overall on PA (main effect PSS: F[1,154]=10.35, p<.01). In the case of PA, there were no significant interactions of Test Number with either Gender or PSS. For this measure, there was no main effect of CTQ or interactions with the CTQ.

Visual Analogue Scale (VAS): Figure 5A-B shows scores on the VAS in males (5A) and females (5B) for each VAS Test (1-4) in participants classified as low PSS (solid line) and high
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PSS (dashed line). Overall, VAS scores decreased over repeated tests (main effect of Test Number: $F[3, 462]=7.40, p<.001$); however, the difference between PSS groups varied across Test Number (Test Number by PSS interaction: $F[3, 462]=7.40, p<.001$). Separate repeated measures ANOVAs for the factor of Test Number in each PSS group revealed a significant effect only in the high PSS group (main effect of Test Number: $F[3, 267]=12.32, p<.001$, Fig. 5C); the effect was non-significant in the low PSS group ($F[3,201]=.65, p>.5$). For this measure, as for PA, there was no main effect of CTQ or interactions with CTQ.

MIDT

*Reaction Time*

Figure 6A shows the mean (+/− SEM) reaction time (RT) on incentive and non-incentive trials in the different Trial Conditions (Reward, Punishment, Control). Because gender (male, female) did not reveal any main or interaction effects as a between-subject factor, this variable was collapsed for further analyses with the MIDT.

As predicted, and in keeping with past literature, participants generally responded fastest on reward and punishment trials compared to control trials (main effect of Condition: $F[2, 302] = 12.85, p<.001$), and also demonstrated shorter response latencies on incentive, relative to non-incentive, trials (main effect of Incentive Type: $F[1, 151] = 103.36, p<.001$). In addition, the effect of Condition varied differentially in incentive versus non-incentive trials (Condition by Incentive Type interaction: $F[2, 302] = 46.68, p<.001$). More specifically, follow-up comparisons between conditions revealed that participants responded fastest overall to Incentive Reward and Incentive Punishment trials, in comparison to non-incentive and control trials (Figure 6A).
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In contrast with our predictions, there was no significant main effect on RTs with the CTQ, nor was there a main CTQ x PSS interaction on RTs. There was, however, a main effect of PSS, such that participants scoring in the “high stress” range, relative to the “low stress” range had overall longer reaction times across conditions and incentive-types (F[1, 151] = 3.98, p<.05) (Figure 6B).

Proportion Correct

Figure 7A shows the mean (+/- SEM) proportion correct (PC) responses on incentive and non-incentive trials in the different Trial Conditions (Reward, Punishment, Control). Similar to the RT outputs, there were no main or interaction effects of gender (male, female) as a between-subject variable, so this was collapsed for the remainder of the PC analysis, as well. In line with our predictions and with previous literature, participants generally performed most accurately on reward and punishment trials compared to control trials (main effect of Condition: F[2, 302] = 14.57, p<.001). Participants also performed more accurately on incentive trials relative to non-incentive trials (main effect of Incentive Type: F[1, 151] = 221.27, p<.001). As was demonstrated in reaction times, the effect of Condition on PC also varied by Incentive Type (Condition by Incentive Type interaction: F[2, 302] = 89.84, p<.001), such that participants responded most accurately to Incentive Reward and Incentive Punishment conditions compared to Control and Non-incentive conditions.

While there was no main interaction effect between the PSS and CTQ, the repeated-measures ANOVA did reveal a significant main effect of CTQ on the PC outcome (F[2, 151] = 3.34, p<.05). Post-hoc analysis revealed that participants scoring in the “None” range on the CTQ responded with greatest accuracy compared to those scoring in the “Low” and “Moderate”
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ranges; however, this relationship was only significant for the “None” and “Low” range comparison (Figure 7B).

Effort Expenditure for Rewards Task

Figure 8A shows the mean (+/- SEM) trials selected on trials associated with high versus low magnitude of reward and different probabilities of reward (high, medium, low) collapsed across the between-subjects factors of Gender (male, female), PSS (high, low) and CTQ (high, moderate, low). Consistent with previous research, participants chose difficult tasks more frequently as the probability of receiving monetary reward following successful task completion increased (main effect of Reward Probability interaction: F[2, 302] = 186.87, p<.001). There was also a main effect of reward magnitude, such that participants more frequently selected difficult trials for the largest reward amounts, relative to smaller rewards for difficult trials and the easy trials (main effect of reward magnitude: F[1, 151] = 227.73, p<.001). Finally, overall, participants chose the greatest number of difficult tasks when both the Probability and Magnitude of the reward was highest, relative to lower values (interaction of Reward Probability by reward Magnitude, F[2, 302] = 85.76, p<.001).

The CTQ did have an effect on the proportion of difficult tasks selected, such that participants scoring in the “Moderate” range, relative to those in the “None” and “Low” ranges, selected the least amount of difficult trials when the reward magnitude was lower, compared to higher. These effects, however, did not quite reach significance (F[2, 151] = 2.58, p=.08), and also diminished when the reward magnitude was higher (Figure 8B). There was a significant within-subject interaction between the CTQ and Reward Probability (F[4, 302] = 2.73, p<.03). Finally, there was a near-significant within-subjects interaction between reward probability, reward magnitude, and PSS scores (F[2, 302] = 2.51, p=.08). Participants scoring in the “high
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stress” range on the PSS, compared to those in the “low stress” group, tended to choose more
difficult trials across probabilities when the reward magnitude was lower. When the reward
magnitude was higher, however, difficult trial selection was comparable to that of the “low
stress” group.

**Discussion**

Reward processing is a cognitive function that contributes to cost-benefit evaluation and
decision-making. Dysfunctions in reward processes have been linked to several
psychopathologies, including depression, schizophrenia, and addictive behaviours (Auerbach,
Admon, & Pizzagalli, 2014; Luijten, Schellekens, Kühn, Machielse, Sescousse, 2017; Ryan &
Skandali, 2016). Investigating the etiology of such cognitive dysfunctions or abnormalities can
provide a comprehensive understanding of the trajectory of such pathologies, and may also
inform future research and potential treatment and/or preventative methods and education.
Previous literature has shown reward processing to be influenced by factors such as early life
stress and current life stress. It has been established, for example, that experiences of early life
stress lead to a decrease in reward processing functions, such as reward sensitivity, motivational
behaviours, and depending on the severity of stress and on the task demands, associative learning
(Hanson et al., 2017; Dillon et al., 2009). While the topic of reward processing itself has been
studied extensively, the interaction of early and current life stress as it influences reward
processing remains a relatively unexplored topic. Thus, the primary aim of this study was to
contribute to the literature and investigate the interaction between early life adversity and
perceived current life stress on reward processes, including reward sensitivity and motivational
behaviours.
In the present study, I hypothesized that higher levels of early life adversity would lead to a disruption in reward sensitivity and motivation, as demonstrated by increased reaction times and reduced proportions of correctly completed reward and punishment trials on the MIDT, and by fewer difficult trials selected, despite high reward amounts or high reward probabilities on the EEfRT. Further, I expected current perceived life stress to moderate this relationship with reward sensitivity, while potentially reducing the effects on the motivational behaviours.

The EEfRT was included since reward processing literature highlights the link between reward sensitivity and the motivational or approach system. For example, Costumero et al. (2013) suggest that, while reaction times under reward conditioning provide measures of reward sensitivity, variance in such measures may also be partially influenced by motivational aspects of reward anticipation. Hardin et al. (2006) also highlighted this relationship, explaining that reward and punishment sensitivity is reflected through reaction time differences on reward (gain) or punishment (loss) tasks, as response times are “energized” by higher or lower levels of motivation. As such, this current study is focusing on the abovementioned measures of reaction times and proportion of successfully completed trials in the MIDT, as well as the proportion of hard trails selected in the EEfRT, to measure reward sensitivity and motivation, respectfully.

An initial analysis was run for the MIDT with the intention of replicating the effects of condition (reward, punishment, control) and incentive type (incentive, non-incentive) on response times and the proportion of correctly completed trials. In previous studies, fastest response times were found for reward and punishment trials compared to control trials (Kappel et al., 2013), although some have demonstrated a selective reduction in reaction times for reward trials specifically, followed by punishment trials, and then followed by control trials (Dillon et al., 2009; Costumero et al., 2011). It was predicted that the largest behavioural differences
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would be found between both reward and punishment trials compared to control trials. The statistical analysis supported this prediction, where the participants of the current study responded fastest to both reward and punishment trials relative to control trials, including non-incentive trials. As predicted, participants also responded most accurately to reward and punishment trials relative to controls. Slight differences were found between reward and punishment trials, also replicating previous research, where participants performed faster and more accurately on reward compared to punishment trials, though these differences were not significant.

Following up with analyses regarding early and current life stress, I analyzed whether scores on the CTQ and PSS predicted outcomes on the MIDT reaction times. I predicted that higher relative to lower CTQ scores would be associated with slower responses on reward and punishment trials, and that higher CTQ scores would also be associated with a smaller proportion of correctly completed trials. This prediction was informed from the studies discussed earlier such as Dillon et al. (2009), for example, who found that early life adversity was associated with reduced reward sensitivity, demonstrated by reduced reaction times and subjective ratings of reward cues, as well as reduced activity in reward-related brain regions.

Further, relative to low CTQ scores, higher scores were expected to be associated with a reduced proportion of difficult trials selected on the EEfRT. The EEfRT is a relatively newer laboratory measure and has been employed to study populations experiencing depression or anhedonia, schizophrenia, and ASD. For example, Treadway et al. (2009) found that reduced motivation for rewards, demonstrated by a reduced proportion of difficult trials selected, was associated with higher, relative to lower, levels of reported depressive symptoms and negative affect. It was predicted that early life adversity would lead to reduced motivation for rewards,
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since it has been demonstrated to lead to reduced reward sensitivity, and, as discussed, sensitivity and motivation or approach behaviours are intertwined. Effects of childhood adversity on reward processes may be mediated by such factors of current stress, or perhaps symptoms of depression or anxiety, as such experiences or variables tend to co-occur. Perhaps dissecting such influences on the EEfRT, specifically, could be an area for future research. The current study focused on investigating the sole relationship between the interaction of early life stress and current perceived life stress on reward-based motivation. Stress was predicted to demonstrate similar patterns to the CTQ, such that high, relative to lower stress scores were expected to be linked to reduced RTs and PCs on the MIDT. Higher stress scores, however, we not expected to reduce the proportion of difficult trials selected on the EEfRT, but to potentially increase this value.

Negative and positive affect scores, as well as stress scores, were taken at four time points throughout the experiment in order to validate reports of current life stress. As previously discussed, these affective ratings were also expected to be associated with reports of early life adversity, such that higher CTQ scores, relative to lower scores, were expected to be linked to higher NA and VAS scores. This prediction was supported, such that those classified in the “high stress” group had higher overall NA scores compared to those in the “low stress” group. Interestingly, NA scores increased across test numbers, but only for participants scoring in the “low stress” group, and this effect was also significant in females, but not males. Complimentary to the NA scores, PA scores did also decrease over the course of the experiment, and those scoring in the “high stress” relative to “low stress” range also received lower total PA scores. These findings suggest that participants in the low stress group were perhaps more
reactive to stress caused by the monetary-based tasks, or may have become less engaged throughout the duration of the study.

The overall higher NA scores for participants reporting higher levels of stress is consistent with studies as previously discussed (Abasi, 2016; Asgari, 2016). What was unexpected, however, was the increase in NA scores across timepoints for participants in the low stress group, since higher levels of perceived stress have been linked to emotional reactivity and negative affect. For example, Stawski et al.’s (2008) found a significant relationship between higher, relative to lower, levels of global perceived stress (utilizing the PSS), and greater stress reactivity (measured by NA scores) in response to stressful stimuli. Our findings may not have replicated these specific results since we did not include an acute stressor in our task design, as participants were completing relatively simple cognitive tasks. Further, the affect-based questions used in our design were a subset of questions taken from the PANAS, and were initially employed to focus more on engagement levels, using the adjectives “tired” and “irritated”. The original PANAS, on the other hand, such as the one employed by Stawski et al. (2008) was more emotion-focus and used “sad, annoyed, irritate, depressed, [and] worried” as adjectives. Therefore, while we did achieve initial effects of PSS scores on overall NA scores, affect and engagement may need to be specifically defined and separated for our future analyses.

Interestingly, VAS scores declined over the course of the experiment. Scores for individuals scoring in the “high stress” ranged tended to decline more significantly compared to those in the “low stress” range. This shift in ratings may be due to the initially high baseline VAS rating for participants in the high stress, compared to low stress, group, which would be expected, since the questionnaires are measuring the same thing. These individuals may have experienced a reduction in stress levels once they became more comfortable in the laboratory.
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setting. Since the current study did not include any stress manipulations, but rather questionnaires and cognitive tasks in quiet rooms, VAS scores were not necessarily expected to increase throughout the course of the experiment.

While the trial types of the MIDT (Incentive and Non-incentive Reward, Punishment, and Control conditions) did have significant effects on the RT and PC dependent variables, we did not find a significant interaction between trial types, CTQ scores, and PSS scores. Our results did reveal a main effect of PSS, however, such that participants scoring as “high stress” relative to “low stress” had increased reaction times across trial types. This finding is in line with previous work. For example, Montoya et al. (2014), demonstrated an association between high stress levels (using cortisol administration) and increased response times on the MIDT, as well as decreased subjective ratings of reward cues. Complimentary to the behavioural findings are those of Bodgan et al. (2011) who found that acute stress led to a decrease in brain activity in reward-related regions. Our findings do further support this relationship between current stress and reduced reward sensitivity.

While we did not find a significant interaction between high, relative to low, CTQ scores, and high, relative to low, PSS scores, this may have been attributable to the removal of the “severe” group from the CTQ analyses. The resulting sample size of this group was too small to include; however, focusing on a population with more “severe” experiences may result in a stronger CTQ effect throughout our reward-related tasks. Further, as our participants were all current student, higher education may have acted as a potential protective factor against potential effects of early life stress. Some previously discussed studies regarding the effects of early life stress on reward processing focused on various samples including children, adolescents, and “community members” (Kamkar et al., 2017; Pearson et al., 2014). Overall, both the lack of
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severe experiences in our sample, and the education levels and experiences of our participants may have prevented significant interference in reward-based performance.

Though CTQ scores were not significantly associated with RTs, our results did reveal a main effect of CTQ on the PC dependent variable. As expected, participants scoring in the “None” range of adverse childhood experiences performed most accurately across trials, though this was only significant in comparison to those in the “Low” group, and not participants in the “Moderate” group. As mentioned above, we did not have a large enough sample size to analyze “severe” levels of early life adversity. This may have influenced the lack of significance in performance between participants scoring in the “none” compared to “moderate” CTQ groups. Despite this, our predictions were still moderately supported, such that individuals reporting no levels of childhood adversity performed more successfully than those reporting even low levels. Though previous work does illustrate a decrease in reward sensitivity behaviours in relation to greater childhood adversity, some studies utilizing the MIDT have found dissociated outcomes for reaction times compared to accuracy, such as Hardin et al. (2006). Their study focused on performance differences between shy and non-shy individuals, but, importantly, they found significant differences on measures of reaction times between groups, but not on overall performance accuracy (Hardin et al., 2006). Reaction times are a more specific or accurate response measure compared to overall performance accuracy, so this may explain why outcomes on either measure did not exactly match. This may also explain why higher levels of perceived stress selectively increased reaction times without significantly reducing performance accuracy, while early life stress scores were associated with decreased accuracy without interfering with response times.
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While there were no significant main effects of PSS or CTQ for the proportion of difficult trials selected on the EEfRT, some near-significant patterns were found that did reflect our predictions. Firstly, participants with higher relative to lower scores on the CTQ tended to choose fewer difficult trials across reward magnitudes and probabilities. Further, participants reporting higher, relative to lower, levels of perceived current life stress tended to choose more difficult trials, but mainly when the reward magnitude was lower. While the EEfRT has not yet been extensively utilized in scientific literature, our predictions were informed from studies regarding reward sensitivity and other motivational behaviours. Costumero et al. (2013) and Hardin et al. (2006) both described a link between reward sensitivity and a dysfunction in the approach- and avoidance- behavioural systems, suggesting that deficits in sensitivity may underlie behavioural differences in specific tasks. As such, we predicted early life stress to interfere with reward-based motivational behaviours, reducing the amount of effort participants would be willing to exert on the EEfRT. Although our results did not reach significance, they did begin to demonstrate patterns we had anticipated. As with our other results, we presume that the inclusion of a representative “severe” group on the CTQ may have provided stronger results.

While we did expect high stress levels to decrease reward sensitivity behaviours, previous research has shown that stress may carry dissociative effects. For example, Pool et al. (2015) demonstrated that higher compared to lower reported stress levels led to an increase in physical exertion for a positive stimulus without influencing participants’ ratings for the same stimulus. In other words, participants experiencing higher, relative to lower, levels of stress appeared more motivated to obtain a reward without rating it as more desirable. Our primary hypothesis was not necessarily that high levels of perceived stress would be advantageous on the EEfRT, but that it may counteract the disadvantageous effects of the CTQ. This may have
ultimately influenced the lack of significance within our CTQ in addition to the lack of severe cases in the analyses.

Overall, our results did demonstrate a decrease in reward sensitivity measures with higher, relative to lower, reported perceived life stress and adverse childhood experiences. The effects of each independent variable, however, were isolated as no significant interactions were found for these between-subject effects. Further, and in line with previous literature, our results did begin to demonstrate a decrease in reward motivation in association with greater experiences of early life stress, though the effects did not reach statistical significance. The same findings were illustrated with high, relative to low, levels of current perceived stress, such that the outcomes in the current study were in line with previous work, but not at a significant level. Participants reporting greater levels of perceived current life stress demonstrated slightly increased motivational behaviours under specific task circumstances. Speculations as to why the results were not quite as strong as predicted are largely focused on the limitations discussed next.

The main limitation of this study was the rather homogeneous sample population. Focusing on a mainly student population, where the majority of participants were female, resulted in a lack of expected variance within the CTQ ranges, may have diluted potential gender effects, and may have reduced effects of stress with higher education as a protective factor. As early life stress was one of the primary variables being analyzed in this study, the CTQ was an essential measure being used in the current analysis. Perhaps due to the demographics and/or student status of the population, there were not many participants scoring in the “severe range” compared to those in the other ranges on the scale. For that reason, that category was removed from the analysis. Attaining more participants with such adverse childhood experiences would have allowed for a comparison of the opposite ends of the spectrum – no experiences of
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childhood adversity versus severe experiences of such adversity. This may have shed more light on the effects of early life stress on reward processing, potentially revealing expected patterns of reduced sensitivity and motivational behaviours.

Further, since the sample was composed of over four times more females than males, this may have reduced some gender effects that otherwise may have been more prominent with a more representative sample. For example, in the original study utilizing and validating the EEfRT (but not in all studies reviewed), Treadway et al. (2009) found significant main effects of gender on the proportion of difficult trials selected. Specifically, they found that males tended to select more difficult trials across trials relative to females (Treadway et al., 2009). While my analyses revealed some within-subjects interaction effects of gender, these patterns did not reach statistical significance, and thus, were removed from further analyses. A more heterogeneous sample, in terms of gender composition, may have revealed significant effects of gender on some of the outcome measures or interactions.

Finally, since the current study sampled from a strictly student population, perhaps the higher education setting was a common protective factor among participants. Studies have shown associations between lower (relative to higher) levels of education and psychological distress. For example, Sheikh (2018) conducted a longitudinal study regarding the overall relationship between childhood disadvantage, education levels, and psychological distress in adulthood. Childhood disadvantage was evaluated using measures of parental education and income, psychological and physical abuse, as well as “substance abuse distress” (Sheikh, 2018). Overall, their results showed a significant relationship between childhood disadvantage, lower education, and higher psychological distress. Though this relationship mostly demonstrated low education as a mediating role between higher disadvantage levels and distress, it may be implied
that higher levels of education may have the opposite effect – reducing adult distress caused by early life stress.

Another study by Ye et al. (2013) demonstrated that higher levels of education act as a protective factor against cognitive decline. Specifically, they investigated whether education levels affected the rate of cognitive decline in participants classified as “amnestic mild cognitively impaired”, defined as a state prior to the onset of dementia and/or Alzheimer’s disease, in either early stage or late stage. Following several neuropsychological tests over the course of a couple of years, they found that higher levels of education, relative to lower levels, were associated with slower cognitive decline in the early-stage participants (effects did disappear for those in the late stage) (Ye et al., 2013). This may inform future studies, where experimenters may benefit from focusing on a sample with more severe experiences, perhaps making such reports part of their inclusion criteria.

Further, Weltz et al. (2016) did find that emotional abuse and emotional neglect were associated with differential experiences of stress reactivity. Though literature leads to a general decline in reward sensitivity with experiences of childhood adversity, perhaps future directions should isolate different forms of adverse experiences when studying this variable in interaction with other individual factors. More overt forms of trauma, such as physical or emotional abuse may be associated with specific dysfunctions in reward processes or emotional regulation compared to cases of neglect, for example.

Finally, while we also found a main effect of high PSS scores on RTs in the MIDT, perhaps the CTQ-PSS interaction would have been more significant depending on the contextual stress factors. For instance, as discussed earlier, previous studies have demonstrated an overall decline in reward sensitivity, leading us to predict reduced performance on the MIDT in those
with both high CTQ scores and PSS scores. Perhaps these results were not achieved due to the sample population, as suggested, or due to the fact that there were no experimental stressors induced. While mean baseline VAS scores were 44.76 (SD=30) out of a potential 100, showing that individuals tended to experience “medium” levels of stress, overall scores reduced throughout the experiment, potentially contributing to a lack of interactive effects. In other words, induced acute stress may act as a stronger interactive variable in such a relationship compared to perceived current life stress.

In conclusion, our study demonstrated a decrease in reward sensitivity behaviours in association with higher, relative to lower levels of early life adversity and current, perceived life stress. Specifically, higher reported levels of childhood abuse or neglect were associated with reduced accuracy on reward-based tasks, suggesting a decrease in reward sensitivity. Higher reported levels of current life stress were associated with a reduction in reaction times in response to reward cues, also suggesting a decrease in reward sensitivity. While our results did not reach significance for effects on motivational behaviours, this may be attributable to a number of factors, including the potential for current life stress to counteract some effects of early life stress. Though a more representative sample, including participants with “severe” experiences of adversity may have strengthened some of the analyses, our results still highlighted how early and current life stress can lead to dysfunctions in reward processes.
References


EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

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doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.12738/estp.2015.3.2553

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EFFECTS OF EARLY AND CURRENT STRESS ON REWARD


EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1001/jamapsychiatry.2016.3084


*Psychoneuroendocrinology, 47*, 31-42.
doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1016/j.psyneuen.2014.04.022


doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1016/j.brs.2017.01.004


doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1371/journal.pone.0180588

doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1016/j.paid.2014.06.041


doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1037/xan0000052


doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1523/JNEUROSCI.0933-16.2017


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doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.3389/fnhum.2013.00180


doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1037/t03592-000


doi:http://dx.doi.org.myaccess.library.utoronto.ca/10.1017/S1041610212002001
**Figures**

**Figure 1.** Experimental design: participants first completed the consent form, followed by the demographic form and mood- and current stress-related questionnaires. The administration order of the MIDT, EEfRT, and SST varied depending on the one of six groups participants were randomly assigned to, in order to counterbalance all tasks. The VAS and PANAS questions were administered before and after each cognitive task. The last set of questionnaires included those regarding childhood adversity and substance use. The current study analysed results only from the PSS, CTQ, PANAS and VAS questions, MIDT and EEfRT.

**Figure 2.** Participants grouped by scores on the PSS and CTQ. Values represent the number of participants falling into each range.

**Figure 3A-B.** Negative affect ratings (raw scores presented) were obtained at four timepoints throughout the study between males (2A) and females (2B), with reported levels of high stress compared to low stress.

**Figure 3C-D.** Differences in NA scores between low and high stress groups (2C) were significant (Test Number by PSS interaction: F[3,462]=4.36, p<.01). Finally, the factor of Test Number also varied by gender (Test Number by Gender interaction: F[3,462]=7.30, p<.001, Fig. 2D)

**Low PSS group increased NA scores over time relative to high PSS group, p<.01 (2C)**

**Females showed significant increase in NA scores over time relative to males, p<.001 (2D)**

**Figure 3E.** Scores on NA in males and females for each NA Test (1-4) in participants classified as none, low and moderate on the CTQ. Subsequent one-way ANOVAs carried out for each CTQ group (none, low, moderate) were significant only for those classified as “none” (F[3,219]=17.25, p<.001).

**“None” CTQ group showed significant increase in NA scores over time relative to “low” and “moderate” groups, p<.001**

**Figure 4A-B.** Figure 3A-B show scores on PA in males (3A) and females (3B) for each PA Test (1-4) in participants classified as low PSS (solid line) and high PSS (dashed line). Overall, PA scores decreased over repeated tests (main effect Test Number: F[3,462]=6.37, p<.01)

**Figure 4C.** Participants classified as high relative to low PSS scored lower overall on PA (main effect PSS: F[1,154]=10.35, p<.01)

**Significant difference in overall PA levels in the PSS groups, p<.01**
EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

**Figure 5A-B.** Scores on the VAS in males (4A) and females (4B) for each VAS Test (1-4) in participants classified as low PSS (solid line) and high PSS (dashed line). Overall, VAS scores decreased over repeated tests (*main effect of Test Number*: F[3, 462]=7.40, p<.001). Separate repeated measures ANOVAs for the factor of Test Number in each PSS group revealed a significant effect only in the high PSS group (*main effect of Test Number*: F[3, 267]=12.32, p<.001, Fig. 4C); the effect was non-significant in the low PSS group (F[3,201]=.65, p>.5). For this measure, as for PA, there was no main effect of CTQ or interactions with CTQ.

**Figure 5C.** Separate repeated measures ANOVAs for the factor of VAS Test Number in each PSS group revealed a significant effect only in the high PSS group (*main effect of Test Number*: F[3, 267]=12.32, p<.001).

***High PSS group showed significant decrease in VAS scores over time, p<.001***

**Figure 6A.** Reaction time (in milliseconds) for each trial type in the MIDT across all participants. **Inc:** Incentive trials; **Non-Inc:** Non-incentive trials. The effect of condition varied in incentive compared to non-incentive trials (*Condition by Incentive Type interaction*: F[2, 302] = 46.68, p<.001).

***RTs were shortest for incentive reward and incentive punishment trials compared to control trials and non-incentive trials, p<.001***

**Figure 6B.** Reaction time (in milliseconds) for the MIDT, comparing participants in the low stress and high stress groups across trial types. Participants in the high stress group had overall longer reaction times than those in the low stress group, across conditions and incentive-types (*main effect of PSS*: F[1, 151] = 3.98, p<.05).

*High stress group had overall longest RTs across trial types relative to low stress, p<.05

**Figure 7A.** Proportion of correctly completed trials in the MIDT. Trials were considered “successful” if participants responded to the on-screen target with a button press within a limited amount of time. The effect of Condition on PC varied by Incentive Type (*Condition by Incentive Type interaction*: F[2, 302] = 89.84, p<.001), such that participants responded most accurately to Incentive Reward and Incentive Punishment conditions compared to Control and Non-incentive conditions.

***Proportion correct was highest for incentive reward and incentive punishment trials relative to control and non-incentive trials, p<.001***

**Figure 7B.** Proportion of correctly completed trials (PC) for the MIDT, comparing participants scoring in the “None”, “Low”, and “Moderate” ranges on the CTQ across trial Conditions and Incentives. Repeated-measures ANOVA revealed a significant main effect of CTQ on the PC outcome (F[2, 151] = 3.34, p<.05).
*Participants in the “none” group on the CTQ had significantly reduced PC relative to those in the “low” group, p<.05

Figure 8A. The proportion of difficult trials selected across trial types based on the Reward Probability and Reward Magnitude. Low reward probability: 12%; Medium reward probability: 50%; High reward probability: 88%.

***Proportion of difficult trials selected on the EEfRT was highest for medium and high probability amounts and high reward amounts (interaction effect), p<.001

Figure 8B. Effects of CTQ on the proportion of difficult trials selected in the EEfRT. Participants scoring in the “Moderate” range, relative to those in the “None” and “Low” ranges, selected the least amount of difficult trials, though these effects were not quite significant (F[2, 151] = 2.58, p=.08).
EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

Figure 1
## Figure 2

<table>
<thead>
<tr>
<th>CTQ</th>
<th>PSS</th>
<th>Count</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low stress</td>
<td>high stress</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>21</td>
<td>38</td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td>6</td>
<td>19</td>
</tr>
</tbody>
</table>
Figure 3

3A-B

3C-D

3E
EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

Figure 4

4A-B

4C
EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

Figure 5

5A-B

5C
Figure 6

6A

![Bar graph showing mean reaction times (ms) for Reward, Punishment, and Control Trials under Inc. and Non-Inc. conditions with Low Stress and High Stress levels.](image)

6B

![Bar graph showing mean reaction times (ms) for Reward, Punishment, and Control Trials under Low Stress and High Stress levels.](image)
EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

Figure 7

7A

![Bar chart comparing proportion successful completion across different conditions and stress levels for Reward Trials, Punishment Trials, and Control Trials.](chart1.png)

7B

![Bar chart comparing proportion successful completion across different CTQ levels and stress levels for Reward Trials, Punishment Trials, and Control Trials.](chart2.png)
Figure 8

8A

8B
APPENDICES

Appendix A: State Trait Anxiety Inventory

<table>
<thead>
<tr>
<th>SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please provide the following information:</td>
</tr>
<tr>
<td>Name __________________________ Date ________ S _____</td>
</tr>
<tr>
<td>Age ___________ Gender (Circle) M F T _____</td>
</tr>
</tbody>
</table>

**DIRECTIONS:**
A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I feel calm</td>
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<tr>
<td>2. I feel secure</td>
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<tr>
<td>3. I am tense</td>
<td></td>
<td></td>
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<tr>
<td>4. I feel strained</td>
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<td></td>
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<tr>
<td>5. I feel at ease</td>
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<tr>
<td>6. I feel upset</td>
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<tr>
<td>7. I am presently worrying over possible misfortunes</td>
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<tr>
<td>8. I feel satisfied</td>
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<tr>
<td>9. I feel frightened</td>
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<tr>
<td>10. I feel comfortable</td>
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<tr>
<td>11. I feel self-confident</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12. I feel nervous</td>
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<td></td>
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<tr>
<td>13. I am jittery</td>
<td></td>
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<td></td>
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<tr>
<td>14. I feel indecisive</td>
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<tr>
<td>15. I am relaxed</td>
<td></td>
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<tr>
<td>16. I feel content</td>
<td></td>
<td></td>
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<tr>
<td>17. I am worried</td>
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<tr>
<td>18. I feel confused</td>
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<tr>
<td>19. I feel steady</td>
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<tr>
<td>20. I feel pleasant</td>
<td></td>
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<td></td>
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</tbody>
</table>

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www.mindgarden.com
SELF-EVALUATION QUESTIONNAIRE
STAI Form Y-2

Name ___________________________ Date ____________

DIRECTIONS
A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

1. I feel pleasant
2. I feel nervous and restless
3. I feel satisfied with myself
4. I wish I could be as happy as others seem to be
5. I feel like a failure
6. I feel rested
7. I am “calm, cool, and collected”
8. I feel that difficulties are piling up so that I cannot overcome them
9. I worry too much over something that really doesn’t matter
10. I am happy
11. I have disturbing thoughts
12. I lack self-confidence
13. I feel secure
14. I make decisions easily
15. I feel inadequate
16. I am content
17. Some unimportant thought runs through my mind and bothers me
18. I take disappointments so keenly that I can’t put them out of my mind
19. I am a steady person
20. I get in a state of tension or turmoil as I think over my recent concerns and interests

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NIAAA

Five Question Set

Question 1 - (asks about frequency of past 12 month drinking)
During the last 12 months, how often did you usually have any kind of drink containing alcohol? By a drink we mean half an ounce of absolute alcohol (e.g. a 12 ounce can or glass of beer or cooler, a 5 ounce glass of wine, or a drink containing 1 shot of liquor). Choose only one:
Every day
5 to 6 times a week
3 to 4 times a week
twice a week
once a week
2 to 3 times a month
once a month
3 to 11 times in the past year
1 or 2 times in the past year
(IF RESPONDENT GIVES ANY OF THE ABOVE RESPONSES, GO TO QUESTION 2)
I did not drink any alcohol in the past year, but I did drink in the past (GO TO QUESTION 1A)
I never drank any alcohol in my life (GO TO QUESTION 1B)
1A - During your lifetime, what is the maximum number of drinks containing alcohol that you drank within a 24-hour period? (asked here only of those who did not drink any alcohol during the past 12 months)
36 drinks or more
24 to 35 drinks
18 to 23 drinks
12 to 17 drinks
8 to 11 drinks
5 to 7 drinks
4 drinks
3 drinks
2 drinks
1 drink
(DONE WITH ALCOHOL QUESTIONS)
1B - So you have never had a drink containing alcohol in your entire life. (asked only of those who say they never drank alcohol in their lives)
Yes, I never drank.
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(DONE WITH ALCOHOL QUESTIONS)
No, I did drink
(GO BACK TO QUESTION 1 AND REPEAT)

Question 2 - (asks about number of drinks on typical drinking day in past 12 months)
During the last 12 months, how many alcoholic drinks did you have on a typical day when you drank alcohol?
25 or more drinks
19 to 24 drinks
16 to 18 drinks
12 to 15 drinks
9 to 11 drinks
7 to 8 drinks
5 to 6 drinks
3 to 4 drinks
2 drinks
1 drink

Question 3 - (asks about maximum drinks in a 24 hour period in past 12 months)
During the last 12 months, what is the largest number of drinks containing alcohol that you drank within a 24-hour period?
36 drinks or more
24 to 35 drinks
18 to 23 drinks
12 to 17 drinks
8 to 11 drinks
5 to 7 drinks
4 drinks
3 drinks
2 drinks
1 drink

Question 4 - (asks about frequency of binge drinking in past 12 months)
During the last 12 months, how often did you have 5 or more (males) or 4 or more (females) drinks containing any kind of alcohol in within a two-hour period? [That would be the equivalent of at least 5 (4) 12-ounce cans or bottles of beer, 5 (4) five ounce glasses of wine, 5 (4) drinks each containing one shot of liquor or spirits - to be provided by interviewer if asked.] Choose only one.
Every day
5 to 6 days a week
3 to 4 days a week
two days a week
one day a week
2 to 3 days a month
one day a month
3 to 11 days in the past year
1 or 2 days in the past year

**Question 5 - (asks about maximum drinks in 24 hours in lifetime)**
During your lifetime, what is the largest number of drinks containing alcohol that you drank within a 24-hour period?
36 drinks or more
24 to 35 drinks
18 to 23 drinks
12 to 17 drinks
8 to 11 drinks
5 to 7 drinks
4 drinks
3 drinks
2 drinks
1 drink
### Beck Anxiety Inventory (BAI)

Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by circling the number in the corresponding space in the column next to each symptom.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Not At All</th>
<th>Mildly but it didn’t bother me much</th>
<th>Moderately - it wasn’t pleasant at times</th>
<th>Severely – it bothered me a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbness or tingling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling hot</td>
<td></td>
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<tr>
<td>Wobbliness in legs</td>
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<tr>
<td>Unable to relax</td>
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<tr>
<td>Fear of worst happening</td>
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<tr>
<td>Dizzy or lightheaded</td>
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<tr>
<td>Heart pounding/racing</td>
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<tr>
<td>Unsteady</td>
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<tr>
<td>Terrified or afraid</td>
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<tr>
<td>Nervous</td>
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<tr>
<td>Feeling of choking</td>
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<tr>
<td>Hands trembling</td>
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<tr>
<td>Shaky / unsteady</td>
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<td></td>
<td></td>
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<tr>
<td>Fear of losing control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty in breathing</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fear of dying</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scared</td>
<td></td>
<td></td>
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<tr>
<td>Indigestion</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Faint / lightheaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face flushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot/cold sweats</td>
<td></td>
<td></td>
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</tbody>
</table>
## EFFECTS OF EARLY AND CURRENT STRESS ON REWARD

Appendix D: Drug Abuse Screening Questionnaire – 10 Item (DAST-10)

<table>
<thead>
<tr>
<th>In the past 12 months...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you used drugs other than those required for medical reasons?</td>
</tr>
<tr>
<td>2. Do you abuse more than one drug at a time?</td>
</tr>
<tr>
<td>3. Are you unable to stop abusing drugs when you want to?</td>
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<tr>
<td>4. Have you ever had blackouts or flashbacks as a result of drug use?</td>
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<tr>
<td>5. Do you ever feel bad or guilty about your drug use?</td>
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<tr>
<td>6. Does your spouse (or parents) ever complain about your involvement with drugs?</td>
</tr>
<tr>
<td>7. Have you neglected your family because of your use of drugs?</td>
</tr>
<tr>
<td>8. Have you engaged in illegal activities in order to obtain drugs?</td>
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<tr>
<td>9. Have you ever experienced withdrawal symptoms (felt sick) when you stopped taking drugs?</td>
</tr>
<tr>
<td>10. Have you had medical problems as a result of your drug use (e.g. memory loss, hepatitis, convulsions, bleeding)?</td>
</tr>
</tbody>
</table>