Associations Between Trait Irritability and Temporal Discounting in a
Community Sample of Adults

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Abstract

This senior thesis in psychology aims to investigate one potential mechanism of an impairing clinical symptom: irritability. Irritability is commonly defined as an elevated proneness to anger (Leibenluft et al., 2011). Clinically significant irritability in youth is predictive of depression, anxiety, and suicidality up to twenty years into adulthood (Brotman et al. 2006), meaning that a childhood presentation of irritability could lead to a lifetime of clinically significant symptoms.

Studying the mechanisms that underlie irritability may aid in the identification of potential treatments for problematic irritability. The present study focuses on the role of a subdomain of reward processing: temporal discounting (TD) in adult irritability. TD is defined as the tendency to devalue reward as a function of time (Critchfield & Kollins, 2001). Studying TD as a potential mechanism of irritability may help explain associations between irritability and impulsive decision making and reactive aggression (Blair, 2018; Dambacher et al., 2015). The study hypothesized that trait irritability would be associated with increased TD, and not with deficits in response inhibition.

The present study of a community sample of adults ($N=362$) found no significant association between trait irritability and TD. There was also no significant relation between trait irritability and response inhibition, as predicted.
Associations Between Trait Irritability and Temporal Discounting in a Community Sample of Adults

Irritability is most commonly defined as an elevated proneness to anger that is continuously distributed across the population (Leibenluft et al., 2011). High levels of irritability are clinically significant and impairing, especially in children (Leibenluft & Stoddard 2013; Brotman et al., 2017). Clinically significant irritability in youth is predictive of depression, anxiety, and suicidality up to twenty years into adulthood (Brotman et al. 2006; Copeland et al. 2014; Dickstein et al. 2015; Leibenluft et al. 2006; Stringaris et al. 2012), meaning that a childhood presentation of severe irritability could lead to a lifetime of clinically significant symptoms. Irritability also worsens outcome in adults, for example, by increasing risk for suicidality in adults with major depressive disorder (Malhi et al., 2019). Studying the mechanisms that underlie irritability can aid the identification of potential treatments and interventions for clinically significant irritability. Conceptual writing hypothesizes that irritability is caused by dysfunction in three major cognitive systems: reward, threat, and facial identification, each of which contains multiple subsystems (Brotman et al, 2017). The present study focuses on one potential mechanism of irritability within the reward system: temporal discounting. Temporal discounting is defined as the tendency to devalue reward as a function of time (Critchfield & Kollins, 2001). The neural correlates of the decision-making processes engaged during temporal discounting are well studied (Lempert et al., 2018, Peters & Büchel, 2011), and the rate at which an individual devalues a reward as a function varies according to an individual’s trait impulsivity and psychiatric symptoms (Peters & Büchel, 2011). Studying temporal discounting as a potential mechanism of irritability is a valuable field of research.
because it may help explain outcomes of irritability rooted in impulsive decision making and reward valuation, such as reactive aggression, suicidality, and poor life outcomes.

Trait Irritability

Irritability can be measured in two ways: using clinical diagnoses, such as disruptive mood dysregulation disorder (DMDD), a psychiatric disorder characterized by severely impairing irritability (DSM-5), or dimensionally, as a trait. Trait irritability can be measured on a spectrum that ranges from typical and non-impairing to clinically-significant and extremely impairing (Vidal-Ribas, 2016). Trait irritability is a feature of traits like neuroticism (Witiger & Oltmanns, 2017) and reactive aggression (Fite, Raine, Stouthamer-Loeber, Loeber, & Pardini, 2009; Stoddard, Scelsa, & Hwang, 2018; Xu, Farver, & Zhang, 2009). In addition, elevated irritability is a transdiagnostic symptom found in many psychiatric disorders, especially mood disorders, in adults and children (Beauchaine & Tackett, 2020). These disorders include major depressive disorder (MDD; Costello, Copeland, & Angold, 2016; DSM-5, Vidal-Ribas & Stringraris, 2021, Zisner & Beauchaine, 2016), generalized anxiety disorder (GAD; Cardinale et al., 2019, Read et al., 2020), and attention-deficit hyperactivity disorder (ADHD; Maire et al., 2020; Shaw et al., 2014). Therefore, a better understanding of irritability and its mechanisms may help researchers better understand the mechanisms of and identify effective treatments for a variety of psychiatric disorders and related traits

Reward Processing

Some of the best-studied mechanisms of irritability involve aspects of reward processing (Brotman et al., 2017). Reward processes motivate our behavior, causing us to move towards desired goals, alter our behavior in response to feedback, and respond to unfair or unexpected outcomes (Insel et al., 2010; National Institute of Mental Health, 2022). Reward processing
consists of several subdomains including reward learning, reward responsiveness, reward satiation, reward valuation and frustrative nonreward (Insel et al., 2010; National Institute of Mental Health, 2022). Probing each domain requires specific tasks, which can help isolate the specific neural circuitry and cognitive processes that underlie trait irritability’s association with aberrant reward processing.

**Reward Learning**

Reward learning is a type of reinforcement learning in which humans gain knowledge about actions, behaviors, and stimuli that predict positive outcomes (Insel et al., 2010; National Institute of Mental Health, 2022). The most classic example of reward learning is B.F. Skinner’s work in operant conditioning, where he placed animals in a ‘Skinner Box’ and taught them to press a lever in exchange for a reward (1948). In humans, reward learning is measured by performance on computerized behavioral tasks such as the probabilistic reward task, where participants are asked to distinguish between two stimuli. The task rewards certain responses over the other, causing typical adults to form a bias in favor of the reward-producing stimulus (Kangas et al., 2020). When participants’ reward learning systems are dysfunctional, participants will not form a bias in favor of the reward-producing stimulus as quickly or accurately as their healthy peers (Kangas et al., 2020). Reward learning dysfunction has been observed in a variety of psychiatric disorders and symptoms. For example, participants with MDD show decreased ability to form a reward bias on the task, suggesting deficiencies in reward learning (Pizzagalli et al., 2008). The association between MDD and deficits in reward learning suggests that irritability may have a similar relation with reward learning. One study (Dickstein et al., 2010) tested reward learning in youth with clinical levels of irritability (with pediatric bipolar disorder and severe mood dysregulation). Reward learning was measured by performance on a probabilistic
reversal reward task, a task in which participants are guided to form a stimulus/behavior relationship, and without warning, the relationship is reversed, forcing participants to adapt their understanding of the stimulus/behavior relationship. Relative to healthy controls and youth with other psychiatric diagnoses, youth with clinically significant irritability demonstrated deficits in reward learning (Dickstein et al., 2010). This deficit in reward learning in youth with severely impairing irritability may stem from cognitive inflexibility and dysfunctions in error monitoring driven by abnormalities in the caudate and inferior frontal gyrus (Adelman et al., 2011).

Individuals with high levels of irritability can anticipate rewards, but may be unable to form an association between reward and the behavior necessary to receive it, leading to blocked goal attainment and frustration.

**Reward Responsiveness**

Reward responsiveness is a category of processes that governs the neurological and cognitive responses to possible reward. Reward responsiveness can be assessed by measuring reward positivity (RewP) in event-related potential (ERP) studies. RewP amplitudes are a neurological index of reward responsiveness that are commonly measured in response to gain and loss trials in a monetary reward task (Burkhouse et al., 2017; Nelson et al., 2016). Monetary reward tasks used in RewP studies generally ask participants to choose one of two doors shown on a computer screen, with one of the doors leading to a gain of a small amount of money (e.g., $0.50) and the other leading to a loss of a small amount of money (e.g., $0.25, Burkhouse et al., 2017). Higher RewP amplitudes signify greater reward responsiveness and have been shown to be lower in individuals with depressive symptoms (Burkhouse et al., 2017; Nelson et al., 2016; Proudfit, 2014). One study in young adult females found trait irritability to be unassociated with RewP amplitudes, but positively associated with feedback-related negativity following blocked
reward (Deveney, 2019). However, in one longitudinal study, irritability and other symptoms of DMDD during preschool correlated with increased RewP in preadolescence, suggesting greater responsiveness to reward feedback (Kessel et al., 2016). Another study found that in young adults, RewP amplitude was positively correlated with trait anger, a concept closely related to irritability (Tsypes et al., 2019). Although results are mixed regarding the relation between RewP amplitude and irritability, the present body of research on reward responsiveness, irritability, and concepts related to irritability suggest that reward responsiveness may be aberrant in individuals with high levels of irritability, especially because of the documented association between irritability and aberrant neural responses to blocked reward (see Frustrative non-reward, Deveney, 2019; Rich et al., 2007; Tseng et al., 2019).

**Reward Anticipation**

When imagining a future incentive, neurological and behavioral processes anticipate its receipt (Insel et al., 2010; National Institute of Mental Health, 2022). During reward anticipation tasks, participants view a cue that indicates that they will either win or lose money during the trial. In healthy adults, activation of the nucleus accumbens increases during the reward anticipation stage (Knutson et al., 2001). Studies of reward anticipation in irritability have focused on functional connectivity rather than activation of specific brain regions and the exact connectivity patterns vary by age. In adolescents, irritability has been found to be associated with decreased functional connectivity between the ventral striatum and the anterior cingulate cortex during the reward anticipation stage (Kryza-Lacombe et al., 2021). Children with greater levels of irritability in preschool also exhibited differences in connectivity amongst the ventral striatum and other key regions in the reward system during reward anticipation. (Dougherty et al., 2018). Research in adolescents suggests that a stronger functional connectivity between the amygdala
and striatum causes irritable adolescents to have more rigid reward anticipation than their non-irritable peers, and react negatively if the reward is blocked (Mukherjee et al., 2021; Badre & Wagner, 2007). One recent study found the connectivity pathways between the amygdala and other regions of the brain to function differently in irritable versus typically-developing youth (Hodgdon et al., 2021). These findings together support the characterization of irritability of having ‘rigid’ reward anticipation and inducing greater frustration if that reward is blocked.

**Reward Satiation**

Finally, as a reward is repeatedly received over time, the reward satiation sub-construct of reward responsiveness diminishes the subjective value of the reward (Insel et al., 2010; National Institute of Mental Health, 2022). For example, if a child receives a cookie every day after school, the neurological and cognitive systems that drive reward responsiveness may decrease the subjective value of the cookie because the child receives it every day. The majority of reward satiation research has been conducted within the context of substance use, which is beyond the scope of this literature review. One fMRI study of healthy participants found that natural satiation of hunger after fasting reduces activation in reward-related brain regions such as the ventromedial prefrontal cortex (VmPFC), nucleus accumbens, and orbitofrontal cortex (Thomas et al., 2015). As previous sections have explained, irritability is associated with differences in activation in these regions during reward tasks, so further study into reward satiation and irritability is warranted. Future research should examine the relation between reward satiation and irritability, especially because childhood presentations of irritability predict substance use in adolescence and adulthood (Silver et al., 2021; Tarter et al., 1995) and because irritability is associated with dysfunctions in other subdomains of the reward system.

**Frustrative Non-reward**
Perhaps the best researched reward subdomain in populations with irritability is frustrative non-reward, which refers to the negative reactions elicited from a blocked goal or reward (Insel et al., 2010; National Institute of Mental Health, 2022). Some studies of frustrative nonreward use the Affective Posner task, an attentional task that is commonly used to induce frustration in participants. During that task, participants identify the location of a target stimulus. Frustration is induced when participants are told that they responded too slowly and lost money.

Rich et al. (2007) administered the Affective Posner task to children diagnosed with bipolar disorder and severe mood dysregulation in an ERP study. Increased frustration was associated with lower N1 amplitudes, reflecting impairments in automatic visual attention in individuals with severe mood dysregulation. However, post-hoc analyses in this study found that these differences were found to be associated with irritability in the context of oppositional defiant disorder severity as opposed to strictly trait irritability (Rich et al., 2007). Similarly, an fMRI study of children and adolescents with distributed irritability (some individuals had non-impairing levels of irritability, but mean levels of irritability were severe) using the Affective Posner task found that severe trait irritability was associated with increased frontal-striatal activation during attention-orienting following induced frustration. These regions mediate attention orienting and top-down inhibition, suggesting increased effort to inhibit frustrated responses (Tseng et al., 2019). In one similar study of a community sample of young adults, greater severity of trait irritability was associated with less negative feedback-related negativity following frustration (Deveney, 2019). Feedback-related negativity, originating in the anterior cingulate cortex, occurs when an individual receives feedback that is different than expected, such as losing money when they expected to gain it (Crowley, 2013). The findings from Deveney (2019), Tseng et al. (2019), and Rich et al. (2007) suggest that neural disruptions
in attention and feedback following frustrative non-reward are present in youth with clinical levels of irritability, as well as in non-clinical populations of young adults. Deveney (2019) in particular suggests that neural differences in the reward system exist even in those with non-impairing irritability.

*Reward Valuation*

Reward valuation is a category of processes by which a reward is assigned a subjective value (Insel et al., 2010; National Institute of Mental Health, 2022). Factors such as the probability of receiving the reward, the delay of receipt, and the effort needed to get the reward are all considered during this process. Individual differences in prior experiences, reward learning, stimuli, and the environment can also affect reward valuation (Insel et al., 2010; National Institute of Mental Health, 2022). According to functional connectivity data from healthy young adults, the VmPFC and posterior parietal cortex function as “comparator” regions that employ the executive functioning and reward valuation systems to weigh the delay and magnitude of reward when making subjective reward-driven decisions (Loganathan et al., 2021). An fMRI study found that the vmPFC is activated when an individual is deciding between objects or actions to gain a reward, whereas the dorsal anterior cingulate cortices drive decisions about punishment (Blair et al., 2006).

*Temporal Discounting*

The present study aims to (1) build on past findings about differences in the reward system in irritability and (2) focus on the sub-domain of reward valuation. When the neural mechanisms underlying reward valuation are combined with decisions about delay and choice, individuals engage in temporal discounting (Peters and Büchel, 2011; Liu et al., 2012). Temporal discounting, also called delay discounting, is the tendency to devalue a reward as a function of
time, such that the greater the delay the lesser the value (Richards, Zhang, Mitchell, & de Witt 1999; Critchfield & Kollins, 2001). Temporal discounting tasks ask participants to choose between two monetary amounts, one available immediately and the other delayed (e.g., “Would you prefer $10 now or $15 in a week?”).

An individual’s choices on the temporal discounting task compute $k$, which is a value that measures the extent to which they discount delayed rewards and would choose the smaller immediate reward over the larger delayed reward. Healthy individuals subjectively devalue reward as its receipt is delayed, but the extent of devaluation varies across certain psychiatric disorders and symptoms (Amlung et al., 2019). Higher $k$ values reflect a greater tendency to devalue delayed rewards, which may contribute to impulsive decision-making. Temporal discounting rate may potentially serve as a behavioral marker of psychopathology and cognitive dysfunction (Lempert et al., 2018), reward valuation (Gui et al., 2016), and executive control (Loganathan et al., 2021). The present study examines temporal discounting because it is a measure of reward valuation and decision making that may help explain the risk-taking and impulsive actions of people with high levels of irritability.

Temporal discounting has been found to vary across many psychiatric disorders (Bickel et al. 2012; Castellanos-Ryan et al. 2016). For example, greater temporal discounting is associated with disorders including ADHD (Barkley et al., 2001; Scheres & Sumiya, 2007), major depressive disorder (MDD; Pulco et al., 2014), generalized anxiety disorder (GAD; Xia, Zhang, & Luo, 2017), and schizophrenia (Amlung et al., 2019; Barkley et al., 2001; Critchfield & Kollins 2001; Mason et al. 2012). Anorexia nervosa is associated with less impulsive temporal discounting compared to healthy controls (Decker, Figner, & Steinglass, 2015), suggesting that temporal discounting varies according to self-control and function of neurobehavioral
decision-making systems (Bickel et al., 2012). Because children with clinically significant irritability often display impulsive behaviors such as reactive aggression (Connor et al., 2017) and irritability is a symptom of several disorders and traits associated with greater temporal discounting rates (DSM-5), the present study hypothesizes that trait irritability will positively predict greater TD.

To date, only one study has explored the relation between temporal discounting and irritability (Blair et al., 2020). In this study, the authors measured temporal discounting task performance in adolescents diagnosed with conduct disorder (CD)—a disorder characterized by problems with impulse control and destructive behavior (DSM-5)—living in a residential treatment facility. The researchers compared the TD performance of the youth with CD to adolescents with different psychiatric disorders and a healthy control group. The adolescents with CD showed greater preference for immediate reward on the temporal discounting task (i.e., greater TD) compared to the control group, although they did not differ from the psychiatric comparison group. The authors further explored whether greater temporal discounting was related to specific traits exhibited by these adolescents. Therefore, they examined between three dimensional symptoms: irritability, self-reported impulsivity, and callous-unemotional traits. Researchers analyzed the relations between symptoms and performance on the TD task across the CD, psychiatric, and control groups. Greater TD was associated with higher irritability levels, but not self-reported impulsivity or callous-unemotional traits. These findings suggest that irritability will be associated with TD in our study; however, as discussed below, limitations to this study and the irritability-related research suggest additional explorations are necessary.

Temporal Discounting and Trait Irritability in Adults
Although the one prior study on temporal discounting (Blair et al., 2020) suggests that elevated irritability is associated with greater temporal discounting in an adolescent sample, it is not appropriate to apply Blair’s findings to a broader population because the participants in this study had severe behavioral and mental impairments in addition to irritability, such as callous-unemotional traits.

Much of what is known about the mechanisms of irritability comes from research conducted in children and adolescents; relatively little research has explored irritability-related mechanisms in adults. Although adults suffer from irritability, they are often misdiagnosed and receive inappropriate treatments due to a lack of understanding and attention paid towards irritability in adulthood (Yager, 2020). Although irritability has significant stability across time (Caprara et al., 2007; Roberson-Nay et al., 2015) and the mechanisms of irritability may be consistent across the lifespan, it is also possible that they vary across different developmental stages. For example, several irritability-related mechanisms undergo significant development and change across the lifespan, including reward responsivity (Galván, 2010) and temporal discounting (Göllner et al., 2018). Therefore, it is important to explore irritability-related mechanisms in adulthood and it is inappropriate to apply Blair et al. (2020)’s findings in adolescents to an adult population. Investigations of irritability in adulthood may help clinicians understand the cognitive processes that drive irritability’s association with relatively poor life outcomes (Witiger & Oltmanns, 2017), why adults engage in reactive aggression, and common neural abnormalities that underlie disorders associated with irritability.

The aim of the present study is to investigate the relationship between trait irritability and temporal discounting in a community sample of adults in order to better understand the mechanisms that drive irritability. Although we are unaware of any studies that link trait
irritability in adults with greater temporal discounting, studies of related populations suggest that there is a link between these two constructs. First, trait irritability is closely related to the emotion of anger both conceptually and empirically (Deveney et al., 2019). Therefore, studies of trait anger and TD may inform predictions about irritability. One study in adults found that anger, along with several other emotions, increase preference for immediate rewards on temporal discounting tasks (Calluso, Devetag, & Donato, 2021). In contrast, however, one study found that trait anger predicted larger and more delayed choices on a temporal discounting task (Song et al., 2021). Therefore, although conclusions are mixed about the role of anger on temporal discounting, trait irritability may be associated with a preference for immediate rewards on a temporal discounting task.

Two additional concepts that share close theoretical similarities with irritability, emotional lability and reactive aggression, are also associated with greater rates of TD (Chester et al., 2019; Childress & Sallee, 2015). Emotional lability is defined as sudden changes in emotion and behavior to an inappropriate intensity (Marwaha et al., 2013). Irritability and emotional lability are both characterized by inappropriate and sudden shifts in affect, but in irritability, changes are unidirectional toward negative valenced emotions (Beauchaine & Tackett, 2020; Leibenluft & Kircanski, 2021). Emotional lability is associated with dysfunction in so-called “hot” domains of executive functioning, including temporal discounting (Childress & Sallee, 2015). Chester and colleagues studied the association between choices on a temporal discounting task, reward valuation, and reactive aggression in a recent fMRI study. Participants completed a novel intertemporal aggression paradigm, where they were asked to choose to enact immediate and less severe or delayed and more severe aggression to a same-sex opponent. Results indicated that individuals with higher rates of reactive aggression chose more immediate
aggressive reactions on the task. Preference for delayed aggression on the task was correlated
with increased activity in the vmPFC, a region that drives reward valuation (Blair et al., 2006),
suggesting that decreased vmPFC activity and the resulting lack of top-down inhibitory control
could be a mechanism of reactive aggression and impulsive decision making (Blair et al., 2006;
Chester et al., 2019). Given links between irritability and reactive aggression, irritability is likely
to be associated with similar preferences for immediate over delayed rewards: greater temporal
discounting.

*Isolating the Effects of Irritability and Temporal Discounting*

Irritability is a trait that is related to many other traits, symptoms, and psychiatric
diagnoses which are also associated with temporal discounting (Amlung et al., 2019; Chester et
al., 2019; Childress & Sallee, 2015). Therefore, it is important to ensure that the present study is
measuring trait irritability as well as related concepts such as depression, neuroticism, and
reactive aggression. This study is designed to examine the relation between trait irritability and
temporal discounting, while controlling for related traits and disorders that may also have an
association with greater temporal discounting. To address this concern, participants will
complete questionnaires that measure depression, anxiety, ADHD, neuroticism, and reactive
aggression and these covariates will be included in statistical analyses.

In addition, it is important to clarify whether irritability’s associations with greater
temporal discounting are due to reward valuations at different delays or whether they reflect
problems with impulsive responding, including difficulty inhibiting motor responses. In pediatric
populations, greater severity of irritability predicts poorer performance on a go/no-go task during
a frustration manipulation (Deveney et al., 2018). However, results for irritability and response
inhibition are mixed, and many studies in children have found associations between irritability
and deficits in response inhibition only during frustration conditions (Fishburn et al., 2019) or not at all (Grabell et al., 2017). No known research has been done on the relationship between trait irritability and response inhibition in adults, but some research exists about trait anger and response inhibition. A 2015 study of trait anger and response inhibition found that accuracy on the response inhibition task did not differ between angry and non-angry groups, but individuals with higher trait anger had greater activation in the prefrontal cortex during the task. fMRI data suggest that participants with higher levels of anger require more effort and cognitive control to withhold responses on this task (Lin et al., 2015). If we expand these findings about trait anger to the related concept of irritability, we would expect individuals with greater levels of irritability to perform the task with the same accuracy as healthy individuals. To explore this possibility, participants will complete a behavioral measure of impulsivity (a go/no-go task) as well as a self-reported measure of impulsivity (the Barratt Impulsiveness Scale 11).

Present Study

The present study seeks to explore whether trait irritability in adults is associated with greater temporal discounting by exploring associations between self-reported trait irritability and performance on a TD task. We hypothesize that trait irritability in adults will be associated with greater TD. Participants will also complete the go/no-go task to measure response inhibition, and we do not expect irritability to predict deficits in response inhibition. We hypothesize that the association between trait irritability and TD will exist even after accounting for covariates (neuroticism, depression, anxiety, reactive aggression, and ADHD symptoms).
Methods

Participants

426 adults (55.16% male) participated in this study. In order to be eligible for the study, participants were required to be: (1) at least 18 years old; (2) currently living in the United States, as the temporal discounting task uses United States Dollars (USD); and (3) fluent in English, as all of the testing materials were in English. The participants were recruited through Testable Minds, an online crowdsourcing platform. Participants were compensated $6.75 for approximately 30 minutes of participation in the study.

In addition to excluding participants who do not meet the age, country, and English proficiency eligibility criteria, we excluded data from any participant who: (1) failed to complete the temporal discounting or go/no-go task; (2) missed one or more items on the BITe, (3) reported English proficiency of 3 or lower on a 5-point likert scale; or (4) failed to report gender or age.

Procedure

Following informed consent, participants reported their age and gender identity. Next, participants were randomly assigned to complete either the temporal discounting task or go/no-go task first, followed by the other task. Following the completion of the two behavioral tasks, participants then completed the mood and personality questionnaires described below (order randomized across participants). Finally, participants completed sociocultural questionnaires for a related study, additional demographic questions, reported their English proficiency and prescribed psychotropic medications.
Questionnaires

We evaluated the inter-item reliability for each questionnaire to identify measures with sufficient inter-item reliability to use in subsequent analyses. Questionnaires with Cronbach’s $\alpha$ < .70 were excluded from subsequent analyses.

Primary Variables

Brief Irritability Test (Holtzman et al., 2015)

The BITe is a five-item questionnaire that measures trait irritability (Holtzman et al., 2015). Participants are asked to respond to statements (e.g., “I have been feeling like I might snap”) on a six-point Likert scale from 0 (“Never”) to 5 (“Always”). Reliability was acceptable ($\alpha = 0.89$). The BITe served as our primary measure of trait irritability. The BITe is a useful measure of trait irritability because it measures irritable behavior and mood among non-clinical community sample like the ones in the present study.

Affective Reactivity Index (Stringaris et al., 2012)

The ARI is a seven-item questionnaire developed to measure clinically significant irritability. Participants are asked to respond to statements (e.g., “I often lose my temper”) with response options of “not true,” “somewhat true,” or “certainly true.” The ARI was used as an exploratory measure of irritability because it was designed to measure clinically significant irritability and has significant floor effects that may make it less able to assess variations in trait irritability in our non-clinical sample (Stringaris et al., 2012). Reliability was acceptable ($\alpha = 0.85$). This study aimed to use the ARI in an exploratory analysis in which the primary regressions were repeated with the ARI, rather than the Brief Irritability Test (BITe) as the measure of irritability.
Covariates

Barratt Impulsiveness Scale 11 (Patton, Stanford, & Barratt, 1995)

The Barratt Impulsiveness Scale 11 (BIS-11) is a 30-item questionnaire that measures self-reported impulsivity. Participants are asked to read phrases and choose the applicable response in a four-point likert scale ranging from 1 (“rarely”) to 4 (“almost always/always”). Three subscales, attentional impulsiveness (e.g., “I am restless at lectures or talks”), motor impulsiveness (e.g., “I do things without thinking”), and nonplanning impulsiveness (e.g., “I plan tasks carefully”) make up the questionnaire. Because of the widespread distribution of a trial version of the BIS-11, BIS-11A, the BIS-11A was mistakenly presented to participants in this study. Of the thirty total items in the BIS-11A, 24 are identical to the BIS-11. Because using the BIS-11A in place of the BIS-11 is a common error among researchers, Barratt and Lijffijt designed a prorating procedure to transform BIS-11A into BIS-11 score (Barratt & Lijffijt). The BIS-11A was scored by summing responses to 24 items (excl. questions 9, 17, 22, 23, 24, and 26), dividing by 24 (number of items shared between BIS-11A and BIS-11), then multiplying by 30 (total number of items in BIS-11). The present study used total impulsivity score ($\alpha = .83$) in an exploratory analysis of correlation between temporal discounting rate and trait irritability. Although scores on the subscales were not intended to be used in the analysis, reliability was calculated for all subscales. Low reliability on the motor ($\alpha = .69$) and attentional ($\alpha = .63$) subscales prevented them from being used in any post-hoc analyses, but the non planning subscale had acceptable reliability ($\alpha = .72$) and was used in exploratory analysis five.

Reactive-Proactive Aggression Questionnaire (Raine et al., 2006).

The Reactive-Proactive Aggression Questionnaire (RPQ) is a 23-item questionnaire designed to measure reactive (e.g., “Gotten angry when frustrated”) and proactive (e.g., “Yelled
at others so they would do things for you”) aggression with possible responses on a three-point likert scale (0, 1, or 2). The total aggression score is the sum of proactive and reactive scores. The reliability of the reactive subscale is $\alpha = .83$. Although participants completed all 23 items, the present study used the reactive subscale in our analyses due to its close association with irritability (Fite, Raine, Stouthamer-Loeber, Loeber, & Pardini, 2009).

**Short Scale Eysenck Personality Inventory-Revised (Eysenck, & Barrett, 1985)**

The Short Scale Eysenck Personality-Revised (EPQ-R Short Scale) consists of 48 questions, with response options of “yes” or “no.” This questionnaire has four subscales: Extroversion/Introversion (E), Neuroticism (N), Psychoticism/Tough-Mindedness (P), and Lie (L). The present study only administered items from the Neuroticism (N) subscale, which contains twelve questions (e.g., “Does your mood often go up and down?”) and has acceptable internal consistency ($\alpha = .87$).

**Depression Anxiety Stress Scales 21 (Lovibond & Lovibond, 1995)**

The Depression Anxiety Stress Scales 21 (DASS21) is a questionnaire that measures depression, anxiety, and stress using a dimensional model. Participants respond to prompts with a 4 point likert scale from 0 (“Did not apply to me at all”) to 3 (“Applied to me very much, or most of the time”). The depression subscale includes seven questions (e.g., “I found it difficult to work up the initiative to do things”) and is scored by multiplying responses by two. The anxiety subscale includes seven questions (e.g., “I was worried about situations in which I might panic and make a fool of myself”) and is scored by multiplying responses by two. Responses were collected for all three subscales of the questionnaire, but only the anxiety and depression subscales were analyzed. This measure was chosen for the present study because of its high validity in measuring dimensional depression and anxiety. The short, 21 item version is
recommended for research (Lovibond & Lovibond, 1995). Reliability of depression ($\alpha = 0.90$) and anxiety ($\alpha = 0.82$) subscales were acceptable.

**Adult ADHD Self-Report Scale (Adler et al., 2012)**

The Adult ADHD Self-Report Scale (ASRS-1.1) is an 18-item questionnaire (e.g., “When you have a task that requires a lot of thought, how often do you avoid or delay getting started?”) that measures ADHD symptoms in adults. Responses consist of a 5-point Likert scale, from 0 (“never”) to 4 (“very often”). The present study administered Part A only, as these items are most predictive of ADHD symptoms (Adler et al., 2012). Results from Part A were summed to form an ADHD traits score that were used in the analysis. Reliability was acceptable ($\alpha = 0.72$).

**Behavioral Tasks**

**5-Trial Adjusting Delay Task (Koffarnus & Bickel, 2014)**

The 5-Trial Adjusting Delay Task was used to measure temporal discounting. During the task, participants choose between receiving two hypothetical rewards: $500 now or $1000 at varying delays, starting with 3 weeks in trial one. In each successive trial, the instrument increases or decreases the delay according to the participant’s previous response, with possible delays ranging from one hour to 25 years. By trial five, the instrument arrives at the indifference point (i.e., the ED50), the delay at which the participant subjectively values both hypothetical rewards equally. The logarithmic inverse of the indifference point is the rate of temporal discounting, $k$, which is the primary dependent variable in the primary analysis. Because the distribution of $k$ is highly skewed in most temporal discounting studies (Koffarnus & Bickel, 2014), a natural logarithmic transformation was applied to $k$ prior to any of the analyses. Regressions were conducted and results are presented for $\log(k)$ as a measure of temporal
discounting rate. For ease of interpretation, regression coefficients were exponentially transformed after analysis ($e^\beta$), which yielded multiplicative change of the median of the dependent variable and were denoted by $\beta^*$ in regression tables. From this value we determined the directionality of the regression—values less than 1 represent a negative association between predictor and dependent variable (Benoit, 2011; Ramsey, 1997).

**Go/No-Go Task (Donders, 1868)**

A go/no-go task served as the behavioral measures of response inhibition. During the task, participants were asked to respond by pressing a key when they see a “go” signal (a yellow square; 48 trials) and withhold response when they see a “no-go” signal (a blue square; 12 trials). In each trial, the signal is shown for one second. Accuracy for go and no-go trials were calculated, separately. The commission error was calculated as the ratio of incorrect no-go responses divided total no-go signals and served as the dependent measure of response inhibition in our analyses.
Statistical Analysis

This study was preregistered through Open Science Framework prior to the collection of data. Analyses for this study were conducted using R, version 4.1.2 (R Core Team, 2021), and the R packages dplyr, tidyverse, psych, Hmisc, car, effectize, ggplot2, and rstatix. We used the standard $p < .05$ criteria for determining the significance of our findings. We also calculated and reported confidence intervals and effect sizes.

First, we conducted a series of preliminary analyses to (1) measure the reliability of each questionnaire; (2) identify possible covariates based on correlations (3) evaluate multicollinearity. Only those variables that showed a significant correlation ($p < .05$) with TD outcomes were to be included as covariates in the primary analyses.

Our primary hypothesis that higher trait irritability will be associated with greater temporal discounting, was tested using a multiple regression with rate of temporal discounting ($\log(k)$) as the dependent variable and BITe score as the predictor. Age and gender identity were included as covariates. BITe score and age were centered for this analysis.

To test whether trait irritability was associated with response inhibition deficits, we conducted a multiple regression predicting commission error on the go/no-go task using BITe (centered) as the predictor and age and gender as covariates.

Exploratory Analyses

Due to concerns about small numbers, people who identify as non-binary ($N = 3$) or did not specify gender were excluded from the main analysis described above. However, in our first exploratory analysis, we repeated our primary multiple regression using three levels of the gender variable (male, female, non-binary). In another exploratory analysis, we repeated the
primary analyses after excluding outliers. Outliers were excluded using the mean absolute difference method (Leys et al., 2013). Our third exploratory analysis aimed to understand if psychotropic medication is correlated with temporal discounting rate given findings that stimulants and selective serotonin reuptake inhibitors (SSRIs) have been shown to reduce TD rate (Carlisi et al., 2016). We conducted four one-way ANOVA tests between participants who reported taking and not taking four classes of medication: SSRIs, stimulants, non-SSRI antidepressants, and antipsychotic or mood stabilizers. Participants were asked to report if they are prescribed SSRIs, other antidepressants, stimulants, or antipsychotic/mood stabilizer medications. As one of the medication classes (non-SSRI antidepressants) was significantly correlated with TD rate, we repeated the primary regression analysis after removing that medication class. We expected that the relation between TD and irritability would become stronger if we controlled for statistically significant medication.

In the fourth exploratory analysis, we conducted a Pearson correlation to test whether trait irritability was correlated with score on the Barratt Impulsiveness Scale-11. This measure was used as an exploratory analysis as opposed to a covariate because of mixed findings about the association between self-reported impulsivity and trait irritability—some studies have used BIS-11 score to validate TD tasks (Germine et al., 2012), whereas others have found no relation between the two measures (McLeish & Oxoby, 2007, Vasconcelos et al., 2014), and one has found trait irritability to be associated with TD but not self-reported impulsivity (Blair et al., 2020).
Results

Participants

A total of 426 participants consented to the study. One participant (0.23%) was excluded due to a priori exclusion criteria for not completing the TD task; 13 did not complete the go/no-go task (go Accuracy=0), 3 (3.05%) failed to report gender; 7 (2.14%) failed to report age; 1 (0.23%) failed to complete the BITe; 44 (13.50%) did not meet the English proficiency criteria. As noted above, the 3 (0.70%) participants who reported gender as ‘nonbinary’ were excluded from the main analyses. Therefore, 362 participants were eligible for main analyses. The demographic characteristics of these participants are described in Table 1. For exploratory covariate analysis, participants who did not complete all covariate questionnaire items were excluded. The total number of eligible participants for exploratory covariate analysis was 240.

Preliminary Analyses to Assess Reliability, Correlations and Multicollinearity

The Affective Reactivity Index (ARI) was excluded from analysis due to poor reliability ($\alpha = 0.68$). The attentional impulsiveness ($\alpha = 0.63$) and motor impulsiveness ($\alpha = 0.69$) subscales of the BIS-11A were excluded due to poor reliability, possibly due to the transformation of scores from the BIS-11A to BIS-11. All other measures had satisfactory inter-item reliability (see Table 2). Pearson correlations between and within subscales of the mood and trait questionnaires (e.g., BITe and DASS21 anxiety) and the behavioral measures (i.e. $\log(k)$, and commission error) revealed significant associations between many covariates and behavioral measures. For correlations, see Table 3.

In an exploratory multiple linear linear regression, two covariates predicted temporal discounting rate ($\log(k)$) and the overall regression was statistically significant ($R^2 = 0.09$, $F(8,236) = 2.88$, $p = 0.0014$). Age significantly negatively predicted temporal discounting rate ($\beta$...
Hypothesis One: Associations between trait irritability and temporal discounting

Contrary to our hypothesis, trait irritability was unrelated to temporal discounting rate (log($k$)). The main linear regression indicated that age ($\beta = -0.05, \beta^* = 0.89, p < .001$), but not BITe score predicted log($k$) values ($\beta = 0.00, \beta^* = 1.00, p = 0.88$) (see Table 4, Figure 2). Older participants displayed lesser temporal discounting. Although trait irritability did not significantly predict temporal discounting rate, the regression analysis was repeated with all covariates as an exploratory analysis (Table 6) in order to further understand the relationship between trait irritability and TD (see Discussion for details). The results of the covariate analysis showed that age ($\beta = -0.05, \beta^* = 0.89, p < .001$) and ADHD symptoms ($\beta = -0.13, \beta^* = 0.74, p = .009$) negatively predicted temporal discounting.

Hypothesis Two: Associations between trait irritability and response inhibition

In a multiple linear regression, age ($\beta = -0.24, p < .001$), but not trait irritability ($\beta = 0.09, p = .50$) or gender ($\beta = -2.14, p = .09$), predicted commission error. As age increases, commission error decreases, suggesting improved response inhibition (see Table 5, Figure 3) and lower motor impulsivity.

Exploratory Analysis One: Inclusion of non-binary individuals in analysis

In the main analysis, non-binary individuals ($N = 3$) were excluded a priori due to concerns about small sample size. Repeating the analyses using three levels of gender (male, female, and non-binary) did not alter the results. Specifically, trait irritability was unrelated to temporal discounting rate (log($k$)). In the multiple linear regression with log($k$) as the dependent
variable, age significantly negatively predicted temporal discounting rate as in the main analysis ($\beta = -0.04$, $\beta^* = 0.91$, $p < .001$). In the multiple linear regression predicting commission error, age continued to significantly negatively predict commission error ($\beta = -0.23$, $p < .001$). In addition, no gender effects emerged in either analysis.

*Exploratory Analysis Two: Exclusion of outliers*

The findings remain unchanged even after excluding 98 participants whose data were identified as outliers using the mean absolute different method (Leys et al., 2013). Trait irritability did not significantly predict log($k$) or commission error in the subsample of 264 participants whose data were not outliers (all $\beta$s < .1 and $p$s > .1).

*Exploratory Analysis Three: Effects of medication on temporal discounting rate*

The third exploratory analysis aimed to determine whether psychotropic medication is correlated with temporal discounting rate. Temporal discounting rate did not differ significantly between unmedicated individuals and those taking SSRI, stimulant, or antipsychotic/mood stabilizers. However, individuals taking non-SSRI antidepressants had a significantly lower rate of temporal discounting (log($k$)) than did individuals not taking antidepressants other than SSRIs ($F(2, 359) = 3.24$, $\eta^2 = 0.02$, $p = .04$). See Table 7, Figure 5.

*Exploratory Analysis Four: Associations between ARI and temporal discounting rate*

This exploratory analysis sought to determine if score on the ARI, a measure of clinically-significant irritability, predicted greater rates of temporal discounting. A multiple linear regression showed that the ARI did not significantly predict TD rate ($\beta = 0.03$, $\beta^* = 1.03$, $p = .55$). See Table 8.

*Exploratory Analysis Five: Associations between trait irritability and self-reported impulsivity*

In an exploratory analysis of participants, we found trait irritability to be significantly
positively correlated with BIS-11 total score ($r = 0.14, p = .008$) and negatively with the non-planning subscale ($r = -0.28, p < .001$). See Table 9.
Discussion

The present study aimed to contribute to the existing literature on mechanisms of irritability by exploring a subdomain of the reward processing system that had not previously been explored in adults—reward valuation. One prior study on this topic was conducted in adolescents diagnosed with conduct disorder and found a positive association between irritability and greater temporal discounting (Blair et al., 2020). In the present study, we predicted that trait irritability in adults would be positively associated with greater temporal discounting but not motor impulsiveness or total impulsivity, due to associations between temporal discounting and irritability-related traits and disorders such as depression (Pulco et al., 2014), anxiety (Xia, Zhang, & Luo, 2017), ADHD (Barkley et al., 2001; Scheres & Sumiya, 2007), neuroticism (Augustine & Larsen, 2011), and reactive aggression (Chester et al., 2019), and mixed evidence linking irritability with response inhibition deficits (Deveney et al., 2018; Lin et al., 2015). In our sample of 362 eligible adults, trait irritability did not significantly predict temporal discounting rate or commission error, a measure of response inhibition. When interpreting this finding, we considered several explanations for these null findings—namely, that irritability is truly not associated with a tendency to make impulsive decisions on the TD task, that this association may exist in individuals with clinically-significant but not low-levels of irritability, or that these findings might be explained by methodological factors.

A True Lack of Association Between Irritability and Temporal Discounting

Irritability has been associated with deficits in other reward processing domains (reward learning, Dickstein et al., 2010; reward responsiveness, Kessel et al., 2016; reward anticipation, Mukherjee et al., 2021; Badre & Wagner, 2007; Kryza-Lacombe et al., 2021; frustrative nonreward, Rich et al., 2007; Tseng et al., 2019; Deveney, 2019). Additionally, several traits and
disorders characterized by high levels of irritability such as MDD (Pulco et al., 2014), reactive aggression (Chester et al., 2019), and ADHD (Barkley et al., 2001; Scheres & Sumiya, 2007) demonstrate greater temporal discounting in adult samples; and one study in an adolescent clinical population linked irritability with higher rates of temporal discounting (Blair et al., 2020). However, the present study failed to identify a significant association between trait irritability and greater TD in a community sample of adults. This suggests that, unlike many of its associated traits and disorders, trait irritability is unrelated to greater valuation of immediate over delayed rewards.

There is reason to believe that our results reflect a true lack of association between trait irritability and temporal discounting in a non-clinical sample of adults. First, our measure of temporal discounting, the 5-Trial Adjusting Delay Task (Koffarnus & Bickel, 2014), is a well-supported measure of temporal discounting rate (Miranda et al., 2018). Initially validated in 111 undergraduate students and shown to generate $k$ values that are comparable to longer adjusting delay tasks (Koffarnus & Bickel, 2014), the task has been cited 231 times and is commonly used as an abbreviated but accurate task for calculating temporal discounting rate (Amlung et al., 2016) in both community and clinical populations (Stein et al., 2018; Strickland et al., 2017). Because of the widespread support and use of the 5-Trial Adjusting Delay Task, there is evidence that suggests that the null findings in the present study were not caused by errors in measuring TD rate.

In addition to evaluating the reliability of the TD task, we also considered that a lack of association between trait irritability and TD could be caused by errors in measuring trait irritability. This is especially notable because Blair et al. (2020) measured irritability using the ARI, while the present study administered both the BITe and ARI, neither of which predicted TD
rate. The Brief Irritability Test (BITe) is also a reliable and valid measure of trait irritability in community samples. During its design, it was administered to over 1,000 participants and demonstrated negligible overlap with related concepts (such as depression, anxiety, anger) and had strong psychometrics (Holtzman et al., 2015). In their 2017 review, Toohey and DiGiuseppe conclude: “Of the existing irritability scales, the BITe scale developed by Holtzman et al. (2015) appears to be the best” (Toohey & DiGiuseppe, 2017, p. 106). Additionally, in a similar study of trait irritability in a community sample of adults recruited from a different online platform, mean BITe score was 11.73, close to the mean BITe score of the present study, 12.83 (Deveney et al., 2019). Because of the widespread support of the BITe and the similarity of our population characteristics to other studies that have detected associations between BITe scores and irritability-related mechanisms, we believe that the null findings in the present study were not caused by errors in measuring irritability.

Additionally, associations between other variables and temporal discounting were in the expected direction. For example, age significantly negatively predicted temporal discounting rate which aligns with developmental models of impulsivity—adolescents and young adults generally show greater rates of temporal discounting, self-reported impulsivity, and risk-taking behavior due to incomplete neural development relative to older adults (Green, Myerson, Ostazewski, 1999; de Water, Cillessen, & Scheres, 2014; Göllner et al., 2018; Steinberg et al., 2009).

One compelling reason for a lack of association between TD and trait irritability is that the association exists only at a clinical level— for example, individuals with impairing psychopathology may have neural abnormalities that drive both irritability and TD (Blair et al., 2020). In participants with non-impairing but still relatively high levels of irritability, this neural abnormality may not exist, and TD rates may not reflect neural differences in reward valuation.
Blair et al. (2020) studied adolescents in a residential psychiatric treatment facility, a sample with significant symptoms and impairment. The mechanisms that drive the abnormal functioning of their reward systems, including reward valuation, could simply not be present in subclinical levels of irritability as in this study’s sample.

Together, these findings suggest that the lack of relation between trait irritability and temporal discounting represents a true lack of association between these variables, at least within non-clinical samples.

**A False Lack of Association Between Irritability and Temporal Discounting**

However compelling the evidence for a true null finding, it is also possible that our null findings represent the failure to detect an existing association between trait irritability and temporal discounting. First, the mean $k$ value ($M = 0.32$) in our study was noticeably higher than the one ($M = 0.00259$) reported in Koffarnus & Bickel (2014). While the discrepancy may exist due to the fact that our participant group represented a range of ages ($M = 30$ years, 18-72) whereas Koffarnus & Bickel (2014) tested undergraduates (ages 18 to 24, $M = 111$), an exploratory analysis in our data suggests that this is not the case. The mean $k$ value for participants aged 24 and younger in our sample was 0.34 ($M = 105$) which is larger than the reported value from Koffarnus & Bickel (2014). In addition, a study which recruited similarly aged participants from a similar online platform to Testable (Strickland et al., 2017), MTurk, reported mean $k$ values among their participants, including cannabis users, that were similar to the ones reported in Koffarnus & Bickel (2014): 0.02 for both the cannabis user and control groups. Together, these findings raise the possibility that the task was not a valid measure of temporal discounting in our sample and may therefore have failed to identify TD as a mechanism of irritability.
Second, although we replicated established associations between age and temporal discounting, we failed to replicate other established associations between psychiatric traits and temporal discounting. Specifically, while ADHD is typically associated with greater temporal discounting (Barkley et al., 2001; Scheres & Sumiya, 2007), the present study revealed a negative association between ADHD symptoms and temporal discounting. In addition, an exploratory analysis revealed that depression, neuroticism and reactive aggression were unrelated to temporal discounting in the present sample. This contradicts prior findings linking each of these traits with increased temporal discounting (Amlung et al., 2019; Bickel et al. 2012; Castellanos-Ryan et al. 2016). For example, while numerous studies have observed associations between depression (Pulco et al., 2014), anxiety (Xia, Zhang, & Luo, 2017), ADHD (Barkley et al., 2001; Scheres & Sumiya, 2007), neuroticism (Augustine & Larsen, 2011), and reactive aggression (Chester et al., 2019) and increased temporal discounting, these measures were not correlated with temporal discounting in the present sample. These findings again suggest that TD was not correctly measured in the current study.

The lack of relationship between trait irritability and temporal discounting rate may be due to the inclusion of the go/no-go task in our study which is not used in many other TD studies. After answering brief demographic questions, half of the participants completed the temporal discounting task first, while the other half completed the go/no-go task first. Although the go/no-go task is only one minute in duration, it was described as tedious and frustrating during pilot testing in our lab. It is possible that individuals who completed the go/no-go task first became frustrated, then either made more impulsive decisions on the TD task, or rushed through it without carefully reading the questions. An exploratory analysis comparing mean $k$ values between participants who completed the go/no-go task first vs. participants who
TRAIT IRRITABILITY AND TEMPORAL DISCOUNTING

completed the TD task first supports this hypothesis. Mean $k$ value in the go/no-go-first group ($N = 173$) was 0.53 and mean $k$ value in the TD task-first group ($N = 147$) was 0.09. This is a major discrepancy, with the go/no-go-group preferring immediate rewards significantly more than the TD task-first group. Whether caused by a genuine preference for immediate rewards following the go/no-go task or participants wishing to quickly skip through the TD task, this finding presents a significant challenge in our interpretation of the results. To verify that a lack of association between trait irritability and TD was not caused by task order, an exploratory analysis tested hypothesis one in the TD task-first group. The results of the regression reveal that trait irritability does not significantly predict TD ($\beta = 0.00, \beta^* = 1.00, p = .99$) in the sample of participants who completed the TD task first. While task order did influence mean $k$ value, it did not change the results of the study.

Temporal Discounting and Self-Reported Impulsivity

Although temporal discounting is a specific type of non planning impulsivity that has established neural correlates (McLeish & Oxoby, 2007) and is most accurately assessed through behavioral rather than self-report measures, an exploratory analysis conducted Pearson correlations between self-reported impulsivity and TD. The BIS-11, this study’s measure of self-reported impulsivity, is used to validate certain temporal discounting tasks (Germine et al., 2012). Total impulsivity, but not non planning impulsivity, was significantly positively correlated with $\log(k)$ ($r = 0.14, p < .001$). Consistent with the BIS-11 being used to validate some TD tasks, TD and self-reported impulsivity are correlated. In addition to the lack of expected correlations between TD and non planning impulsivity, exploratory analyses found that trait irritability is significantly positively correlated with self-reported total impulsivity ($r = 0.14, p < .01$) and negatively with non planning impulsivity ($r = -0.28, p < .01$). Although non planning impulsivity
is not the same specific behavioral concept as TD, this negative correlation does conceptually support a lack of association between trait irritability and TD. Blair et al. (2020) failed to find a significant correlation between irritability and self-reported impulsivity, although this study used different measures than the present study (Björk et al. (2009) as the temporal discounting task, ARI as the irritability questionnaire, Conners 3 (2008) as the impulsivity questionnaire).

Taken together, conclusions drawn from these results are that there is no consistent relationship between trait irritability and temporal discounting. In their 2020 paper, Blair et al. argued that “the current data are at least consistent with the suggestion that a specific form of pathophysiology increases the risk both for greater temporal discounting and irritability and that this form of pathophysiology is seen in individuals with a variety of psychiatric conditions” (p. 546). Based on the results of the present study, we can draw two potential conclusions: (1) this specific neural mechanism that drives the association between irritability and temporal discounting is present only in individuals with impairing psychiatric traits (clinical populations), not community samples, or (2) this association between irritability and temporal discounting exists at subclinical levels, but the present study was unable to confirm or reject this hypothesis. Although the 5-Trial Adjusting Delay task is well-validated and widely used, it failed to produce a $k$ value comparable to past reported $k$ values (Koffarnus & Bickel, 2014; Strickland et al., 2017) in this study, preventing us from drawing a definite conclusion from these results. Trait irritability’s correlation with self-reported total impulsivity lends some support to this hypothesis but, as discussed earlier, does not provide the full answer as to whether trait irritability predicts temporal discounting, and if it does, if it represents a specific mechanism that underlies many psychiatric conditions.
In the coming months, a future study will re-examine the relation between temporal discounting and trait irritability. This study will remove the go/no-go task in case it was causing frustration and aberrant responses on the temporal discounting task. The future study will re-administer the 5-Trial Adjusting Delay Task in order to compare mean $k$ values between studies, as well as a longer, non-adjusting temporal discounting task such as Björk (2009) or the Monetary Choice Questionnaire (Kirby et al., 1999). For now, we can conclude that trait irritability is not associated with increased rates of temporal discounting in community samples, but emphasize that this finding does not preclude the possibility that a significant association could be found in future studies.

*Trait Irritability and Response Inhibition*

As hypothesized, no significant relationship existed between trait irritability and response inhibition, measured by commission error on the go/no-go task. Irritability and response inhibition have not been widely studied in adults, and findings in pediatric populations are mixed (Chaarani et al., 2020; Liuzzi et al., 2020). Presently, no studies have found an association between irritability and deficits in response inhibition in non-frustrative conditions. Deveney et al. (2019) found that children with high levels of irritability (4-7 years) exhibited deficits in response inhibition on a go/no-go task only during frustrating task conditions, suggesting that trait irritability is associated with poor performance on emotional, but not non-emotional, cognitive tasks. Not enough research has been conducted to definitely state whether irritability is associated with deficits in response inhibition in adults and/or individuals with subclinical levels of irritability. The present finding suggests that in non-frustration conditions, trait irritability does not predict response inhibition, measured by commission error on the go/no-go task.

*Limitations*
Whether or not internet crowd-sourcing platforms provide reliable results in psychological studies is debated by the field (Chmielewski & Kucker, 2019; Hauser & Schwarz, 2015). Because the present study was conducted online with minimal oversight over participant performance, it is possible that the following limitations may have influenced the results. Participants may have been tempted to rush through the TD task, or may not have paid it their full attention. Differences in mean $k$ values show that task order impacted performance on the TD task. The participants were asked to select their responses by pressing ‘1’ or ‘0’ on their keyboards, and some may have repeatedly pressed keys to move quickly through the task without carefully considering their answers. Although participants were urged to “pay close attention to the amount and time frame of each option, and choose accordingly,” and to take their time on the task, the ease of quick response may have discouraged them from carefully selecting their reward preference. If participants were supervised during the administration of the study, perhaps they may have completed the TD task more carefully.

Despite explaining in the study advertisement that participants were only eligible if they were fluent in English, a large number ($N = 42$) of participants reported only moderate proficiency with English and were therefore excluded from the data analyses. A small number ($N = 28$) of additional participants were excluded due to missing age, gender and irritability data or for not having completed the TD or go/no-go task. This resulted in a final sample size of 362, which is smaller than our target sample size of 400 participants, which was derived from a power analysis conducted in G*power using the effect size from a similar previously published study of temporal discounting and ADHD (Mostert et al., 2015). Because the study was underpowered, it is possible that a relation did exist between study variables, but the effect was insignificant due to inadequate power.
Final Conclusions

The aim of this study was to investigate one potential mechanism of trait irritability within the reward valuation system, temporal discounting. Although we failed to find a significant relation between temporal discounting and trait irritability in our community sample, the findings add further dimension to the existing affect and TD literature, including Blair et al. (2020). Due to the mixed conclusions drawn from these results, including the possibility of methodological error, a future study will re-investigate the main hypothesis.
### Tables and Figures

Table 1 *Characteristics of Eligible Participants*  
(*N* = 362)

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<td>Southeast Asian</td>
<td>37</td>
<td>10.22</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 *Inter-Item Reliability of Self-Report Measures*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>N of Items</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARI</td>
<td>6</td>
<td>0.85</td>
</tr>
<tr>
<td>ASRS Part A</td>
<td>6</td>
<td>0.72</td>
</tr>
<tr>
<td>BITe</td>
<td>5</td>
<td>0.89</td>
</tr>
<tr>
<td>BIS-11A</td>
<td>24</td>
<td>0.83</td>
</tr>
<tr>
<td>Attentional</td>
<td>5</td>
<td>0.63</td>
</tr>
<tr>
<td>Non Planning</td>
<td>10</td>
<td>0.72</td>
</tr>
<tr>
<td>Motor</td>
<td>9</td>
<td>0.69</td>
</tr>
<tr>
<td>EPQ-R Neuroticism</td>
<td>12</td>
<td>0.87</td>
</tr>
<tr>
<td>DASS 21 Depression</td>
<td>7</td>
<td>0.90</td>
</tr>
<tr>
<td>DASS 21 Anxiety</td>
<td>7</td>
<td>0.82</td>
</tr>
<tr>
<td>RPQ Reactive Aggression</td>
<td>11</td>
<td>0.83</td>
</tr>
</tbody>
</table>

(ARI= Affective Reactivity Index; ASRS= Adult ADHD Self-Report Scale; BITe= Brief Irritability Test; BIS-11A= Barratt Impulsiveness Scale 11A; DASS21= Depression Anxiety Stress Scales 21; EPQ-R= Eysenck Personality Questionnaire- Revised; RPQ= Reactive-Proactive Aggression Questionnaire)
Table 3 Pearson Correlations (N = 240)

<table>
<thead>
<tr>
<th>Variables</th>
<th>M (SD)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. BITe</td>
<td>12.21 (4.20)</td>
<td>x</td>
<td>0.08</td>
<td>-0.05</td>
<td>0.07</td>
<td>0.08</td>
<td><strong>0.42</strong>*</td>
<td><strong>0.55</strong>*</td>
<td><strong>0.63</strong>*</td>
<td><strong>0.40</strong>*</td>
<td><strong>0.39</strong>*</td>
</tr>
<tr>
<td>2. log(k)</td>
<td>-4.77 (2.21)</td>
<td>x</td>
<td><strong>0.42</strong>*</td>
<td>-0.00</td>
<td><strong>0.16</strong>*</td>
<td>0.10</td>
<td>0.00</td>
<td>0.06</td>
<td>-0.05</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>3. k</td>
<td>0.31 (2.22)</td>
<td>x</td>
<td>0.06</td>
<td><strong>0.15</strong>*</td>
<td>0.02</td>
<td>-0.06</td>
<td>-0.07</td>
<td>-<strong>0.14</strong>*</td>
<td>-0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Commission error</td>
<td>7.69 (11.39)</td>
<td>x</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
<td><strong>0.13</strong>*</td>
<td>0.06</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. BIS-11A total</td>
<td>75.18 (4.76)</td>
<td>x</td>
<td><strong>0.15</strong>*</td>
<td>0.00</td>
<td><strong>0.15</strong>*</td>
<td>0.07</td>
<td><strong>0.14</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. DASS 21 anxiety</td>
<td>8.88 (8.21)</td>
<td>x</td>
<td><strong>0.66</strong>*</td>
<td><strong>0.38</strong>*</td>
<td><strong>0.43</strong>*</td>
<td><strong>0.34</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. DASS 21 depression</td>
<td>10.74 (9.39)</td>
<td>x</td>
<td><strong>0.51</strong>*</td>
<td><strong>0.36</strong>*</td>
<td><strong>0.25</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. EPQ-R neuroticism</td>
<td>5.50 (3.89)</td>
<td>x</td>
<td><strong>0.43</strong>*</td>
<td><strong>0.36</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. ASRS</td>
<td>8.42 (3.45)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. RPQ reactive</td>
<td>6.54 (3.79)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Bolded values are statistically significant, * p < .05  ** p < .01  *** p < .001.

(ASRS= Adult ADHD Self-Report Scale; BITe= Brief Irritability Test; BIS-11A= Barratt Impulsiveness Scale 11A; DASS 21= Depression Anxiety Stress Scales 21; EPQ-R= Eysenck Personality Questionnaire- Revised; RPQ= Reactive-Proactive Aggression Questionnaire)
### Table 4 Predictors of Temporal Discounting Rate (log(k))

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>β*</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-4.94</td>
<td>0.01</td>
<td>0.16</td>
<td>-31.57</td>
<td>&lt; .001***</td>
<td>[0.01, 0.01]</td>
</tr>
<tr>
<td>BITe</td>
<td>0.00</td>
<td>1.00</td>
<td>0.026</td>
<td>0.015</td>
<td>.88</td>
<td>[0.95, 1.06]</td>
</tr>
<tr>
<td>Age</td>
<td>-0.05</td>
<td>0.95</td>
<td>0.012</td>
<td>-3.65</td>
<td>&lt; .001 ***</td>
<td>[0.93, 0.98]</td>
</tr>
<tr>
<td>Gender</td>
<td>0.38</td>
<td>1.46</td>
<td>0.24</td>
<td>1.62</td>
<td>.11</td>
<td>[0.92, 2.34]</td>
</tr>
</tbody>
</table>

R^2 = 0.04

F_{3,358} = 5.09**

Note. Bolded values are statistically significant, * p < .05  ** p < .01  *** p < .001. CI* = Exponentiated confidence interval. β* = exponentiated β.

(BITe = Brief Irritability Test)
Table 5 *Predictors of Commission Error on the Go/No-Go Task*  
(*N = 362*)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>9.60</td>
<td>0.83</td>
<td>11.61</td>
<td>&lt;.001***</td>
<td>[7.97, 11.22]</td>
</tr>
<tr>
<td>BITe</td>
<td>0.09</td>
<td>0.14</td>
<td>0.68</td>
<td>0.50</td>
<td>[-0.18, 0.36]</td>
</tr>
<tr>
<td>Age</td>
<td>-0.24</td>
<td>0.06</td>
<td>-3.60</td>
<td>&lt;.001***</td>
<td>[-0.36, -0.11]</td>
</tr>
<tr>
<td>Gender</td>
<td>-2.14</td>
<td>1.25</td>
<td>-1.71</td>
<td>0.09</td>
<td>[-4.61, 0.32]</td>
</tr>
</tbody>
</table>

R^2 0.05

F\textsubscript{3,358} 6.34***

Note. Bolded values are statistically significant, * p < .05 ** p < .01 *** p < .001. CI = Confidence Interval. (BITe= Brief Irritability Test)
Table 6 Exploratory Analysis: Covariate Predictors of Temporal Discounting Rate (log(k)) (N = 245)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>β*</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-4.93</td>
<td>0.01</td>
<td>0.19</td>
<td>-26.12</td>
<td>&lt;.001***</td>
<td>[0.01, 0.01]</td>
</tr>
<tr>
<td>BITe</td>
<td>0.05</td>
<td>1.05</td>
<td>0.05</td>
<td>1.00</td>
<td>0.32</td>
<td>[0.96, 1.15]</td>
</tr>
<tr>
<td>Age</td>
<td>-0.05</td>
<td>0.95</td>
<td>0.01</td>
<td>-3.49</td>
<td>&lt;.001***</td>
<td>[0.92, 0.98]</td>
</tr>
<tr>
<td>Gender</td>
<td>0.35</td>
<td>1.42</td>
<td>0.29</td>
<td>1.21</td>
<td>0.23</td>
<td>[0.76, 2.41]</td>
</tr>
<tr>
<td>DASS21 anxiety</td>
<td>0.03</td>
<td>1.03</td>
<td>0.02</td>
<td>1.43</td>
<td>0.15</td>
<td>[0.98, 1.09]</td>
</tr>
<tr>
<td>DASS21 depression</td>
<td>-0.03</td>
<td>0.97</td>
<td>0.02</td>
<td>-1.45</td>
<td>0.15</td>
<td>[0.92, 1.01]</td>
</tr>
<tr>
<td>EPQ-R neuroticism</td>
<td>0.02</td>
<td>1.02</td>
<td>0.05</td>
<td>0.37</td>
<td>0.71</td>
<td>[0.92, 1.12]</td>
</tr>
<tr>
<td>ASRS</td>
<td>-0.13</td>
<td>0.88</td>
<td>0.05</td>
<td>-2.61</td>
<td><strong>0.009</strong></td>
<td>[0.80, 0.97]</td>
</tr>
<tr>
<td>RPQ reactive</td>
<td>0.04</td>
<td>1.04</td>
<td>0.04</td>
<td>0.86</td>
<td>0.39</td>
<td>[0.95, 1.12]</td>
</tr>
<tr>
<td>R²</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F&lt;sub&gt;8,236&lt;/sub&gt;</td>
<td>2.88**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Bolded values are statistically significant, * p < .05  ** p < .01 *** p < .001. CI* = Exponentiated confidence interval. β*= Exponentiated β.  
(ASRS= Adult ADHD Self-Report Scale; BITe= Brief Irritability Test; DASS21= Depression Anxiety Stress Scales 21; EPQ-R= Eysenck Personality Questionnaire- Revised; RPQ= Reactive-Proactive Aggression Questionnaire)
Table 7 *Exploratory Analysis Three: Effects of Medication on Temporal Discounting Rate (N = 362)*

<table>
<thead>
<tr>
<th>Medication class</th>
<th>Medicated</th>
<th>Unmedicated</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>log(k) M (SD)</td>
<td>n</td>
</tr>
<tr>
<td>Antidepressant</td>
<td>6</td>
<td>-6.72 (1.08)</td>
<td>355</td>
</tr>
<tr>
<td>Antipsychotic</td>
<td>6</td>
<td>-4.77 (2.41)</td>
<td>353</td>
</tr>
<tr>
<td>SSRI</td>
<td>22</td>
<td>-5.30 (2.10)</td>
<td>340</td>
</tr>
<tr>
<td>Stimulant</td>
<td>1</td>
<td>-3.23</td>
<td>340</td>
</tr>
</tbody>
</table>

Note. Bolded values are statistically significant, * p < .05  ** p < .01 *** p < .001. Unmedicated= not taking this medication class, but these individuals could be taking other medications. Antidepressant= antidepressants other than SSRIs. (SSRI= Selective Serotonin Reuptake Inhibitor)
Table 8 Exploratory Analysis Four: ARI as a Predictor of Temporal Discounting Rate (log(k))
(N = 360)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>β*</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-4.93</td>
<td>0.01</td>
<td>0.16</td>
<td>-31.51</td>
<td>&lt;.001***</td>
<td>[0.01, 0.01]</td>
</tr>
<tr>
<td>ARI</td>
<td>0.03</td>
<td>1.03</td>
<td>0.04</td>
<td>0.59</td>
<td>0.55</td>
<td>[0.94, 1.12]</td>
</tr>
<tr>
<td>Age</td>
<td>-0.04</td>
<td>0.96</td>
<td>0.01</td>
<td>-3.62</td>
<td>&lt;.001***</td>
<td>[0.94, 0.98]</td>
</tr>
<tr>
<td>Gender</td>
<td>0.38</td>
<td>1.46</td>
<td>0.24</td>
<td>1.60</td>
<td>0.11</td>
<td>[0.92, 2.34]</td>
</tr>
</tbody>
</table>

R² 0.04

F_{3,356} 5.14**

Note. Bolded values are statistically significant, * p < .05  ** p < .01  *** p < .001. CI* = Exponentiated Confidence Interval. β* = exponentiated β.
(ARI= Affective Reactivity Index)
Table 9 Exploratory Analysis Five: Pearson Correlations between Trait Irritability and Impulsivity Measures
(N = 354)

<table>
<thead>
<tr>
<th>Variable</th>
<th>M (SD)</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.BITe total</td>
<td></td>
<td></td>
<td>0.14**</td>
<td>-0.28***</td>
<td>-0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>2.BIS-11A total</td>
<td>63.64</td>
<td>(10.97)</td>
<td></td>
<td>0.44***</td>
<td>0.13*</td>
<td>0.14**</td>
</tr>
<tr>
<td>3.BIS-11A Non-planning</td>
<td>22.76</td>
<td>(4.74)</td>
<td></td>
<td>0.11*</td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>4.k</td>
<td>0.26</td>
<td></td>
<td></td>
<td></td>
<td>0.40***</td>
<td></td>
</tr>
<tr>
<td>5.log(k)</td>
<td>-4.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Note. Bolded values are statistically significant, * p < .05  ** p < .01 *** p < .001.
(BITe= Brief Irritability Test; BIS-11A= Barratt Impulsiveness Scale 11A)
Figure 1 Logarithmic Transformation of $k$

Figure 1: The distribution of discounting rate ($k$) was highly skewed (Panel A) therefore, a natural log transformation of the $k$ values (Panel B) was used in the analyses.
Figure 2 Trait Irritability and Age as Predictors of Temporal Discounting $\log(k)$ 
($N = 362$)

Figure 1: Irritability did not predict temporal discounting rate (Panel A), however, higher age was associated with reduced temporal discounting rate (Panel B).
Figure 3 Trait Irritability and Age as Predictors of Commission Error

Figure 3: Trait irritability did not significantly predict commission error (Panel A). Participant age significantly negatively predicted commission error, suggesting that response inhibition improves with age (Panel B).
Figure 4: ADHD symptoms, measured by ASRS, significantly negatively predicted TD in an exploratory analysis.
Figure 5: TD rates are significantly lower in participants taking non-SSRI antidepressants compared to participants not taking non-SSRI antidepressants.
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https://doi.org/10.1017/S0954579416000754