The Trade-Off Between Fear and Reward: An Ethobehavioral Study of Avoidance

Rosemary S.W. Walker

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Reading Committee:

Lori A. Zoellner, Chair

Jeansok Kim

Mary E. Larimer

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Department of Psychology

University of Washington

Abstract

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Rosemary S. W. Walker

Chair of the Supervisory Committee:

Lori A. Zoellner

Department of Psychology

A hallmark feature of anxiety is maladaptive avoidance (Pittig, Treanor, LeBeau, & Craske, 2018) and women have higher rates of both anxiety and pathological avoidance than men (Kessler et al., 2005; Seedat et al., 2010). Avoidance can be problematic not only because it blocks corrective learning about what is and is not dangerous but also because it sacrifices rewards. Indeed, conflict between avoidance and approach motivation is common, and, yet, in humans, simultaneous manipulation of threat and reward has rarely been studied. Rewards for approach and individual characteristics that impact appraisal of rewards, such as anhedonia, may contribute to maladaptive avoidance. Accordingly, this study takes a reverse translational approach, emphasizing ecological validity, to investigate responding in a dynamic approach-reward and avoid-threat conflict, examining the role of anhedonia and gender. The sample (N = 80) was comprised of 41 participants in the low anhedonia group (68.3% female) and 39 in the high anhedonia group (61.5% female). Participants completed a novel approach-avoid conflict task: the Dynamic Avoidance Task (DAT). Participants were tasked with the goal of retrieving coins in the face of a threatening robot. Threat and reward level were simultaneously manipulated: coin retrieval was either incentivized with monetary reward (reward) or was not incentivized with monetary reward (no reward) and threat was manipulated by varying the coin-to-threat distance (low, moderate, high threat). Avoidance was operationalized as longer response latency for first coin retrieval and fewer total coins retrieved, and higher fear responding as higher subjective distress and higher physiological arousal. Participants with high anhedonia retrieved fewer coins than those with low anhedonia ($d = 0.46$), but only when they were not incentivized with monetary reward. Additionally, women did not avoid more than men overall but did show slightly greater decreases in coins retrieved than men when comparing low threat to high threat (women: $d = 1.57$; men: $d = 1.42$). Anxious traits predicted subjective distress ($b = .38$) and physiological arousal ($b = -.36$) whereas reward propensity did not. In addition, reward, in general, lead to decreased avoidance and increased fear responding and, critically, rewards for approach blocked increased avoidance at higher threat during initial responding to the approach-avoid conflict (partial eta^2 = .06 - .35). Thus, individuals with high anhedonia may be at greater risk for avoidance compared to those with low anhedonia, but only when approach is not maximally rewarding. Whereas anxiety impacts avoidance through fear responding, hedonic deficits can impact avoidance through a reward pathway. Thus, leveraging rewards by helping individuals identify rewarding properties and benefits of approaching anxiety-provoking situations may improve clinical outcomes for individuals with pathological avoidance.

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The Trade-Off Between Fear and Reward: An Ethobehavioral Study of Avoidance

Anxiety and traumatic-stressor disorders are highly prevalent and represent major disease burden. Indeed, estimates of global prevalence rates of anxiety disorders range from 3.6%-7.3% (Baxter, Scott, Vos, & Whiteford, 2013; WHO, 2017) and posttraumatic stress disorder (PTSD) is estimated to occur in 4% of the global population (Liu et al., 2017). Anxiety disorders and PTSD are the sixth leading cause of disability and non-fatal health loss worldwide (Baxter et al., 2013; WHO, 2017). Anxiety and traumatic-stressor disorders are reportedly on the rise, with a 14.9% increase in people living with an anxiety disorder from the years 2005 to 2015 (WHO, 2017). Women are disproportionately affected by anxiety and traumatic-stressor disorders, with risk for some anxiety disorders, including PTSD, as great as two to three times higher for women compared to men (Breslau, Schultz, & Peterson, 1995; Kessler, Chiu, Demler, & Walter, 2005; Olff, 2017; Seedat et al., 2009). Accordingly, better understanding of the causal factors involved in the development of anxiety and traumatic-stressor disorders will serve to help the approximately the 264 million individuals living with an anxiety disorder at any given time (WHO, 2017).

An important clinical consideration relevant for understanding, preventing, and treating anxiety and traumatic-stressor disorders is the frequent co-occurrence of anxiety and depression. Indeed, an estimated 51-73% of patients with major depressive disorder (MDD) have a co-occurring anxiety disorder (Fava et al., 2000). In particular, 70% of individuals with generalized anxiety disorder (GAD) and 52% with posttraumatic stress disorder (PTSD) are estimated to have a co-occurring current diagnosis of MDD (Rytwinski, Scur, Feeny, & Yojngstrom, 2013). Anxiety symptoms were shown to predict later depression symptoms and depression symptoms were found to predict later anxiety symptoms (Beesdo et al., 2007; Jacobson & Newman, 2014;

Meier et al., 2015). There are also significant adverse consequences of anxiety and depression co-occurrence, including higher levels of disability, functional impairment, and treatment utilization (Fichter, Quadflieg, Fischer, & Kohlboeck, 2010). Thus, examining core dysfunction across nosological boundaries is needed to better characterize the likely functional relationship between symptoms of anxiety and depression. This transdiagnostic approach has the potential to identify interactions amongst co-occurring symptoms and point to causal pathways, ultimately opening new and more targeted avenues for intervention.

A transdiagnostic focused approach is in line with the Research Domain Criteria (RDoC) initiative, instigated in the past decade by the National Institute of Mental Health (Insel & Cuthbert, 2009; Kozak, & Cuthbert, 2016). The RDoC initiative emphasizes discrete constructs across units of analysis, including genes, molecules, cells, circuits, physiology, behaviors, and self-reports. These constructs correspond with dysfunction related to specific, clinical phenomena, rather than broad diagnostic categories. As a result, this has pushed the field to consider broader treatment targets identifying specific, maladaptive behavioral processes (Insel & Cuthbert, 2009; Kozak & Cuthbert, 2016). The RDoC initiative not only encourages a transdiagnostic approach but also an approach that focuses on shared processes across symptom presentations, which potentially aids in the development of more precise interventions.

A hallmark clinical feature of anxiety and traumatic-stressor disorders is maladaptive avoidance (Barlow, 2004; Craske et al., 2009). Avoidance has been defined as a response (either internal or external) that minimizes or prevents contact with perceived threat or an aversive event (Pittig et al., 2018; Ledoux, Moscarello, Sears, & Campese, 2017). Although avoidance is a remarkably adaptive response in the face of threat, maladaptive avoidance represents a primary theoretical pathway through which anxiety disorders are thought to emerge and persist (Pittig, Treanor, LeBeau, Craske, 2018). *Maladaptive* avoidance has been defined as satisfying one of the following: "a) limits daily activities and impairs general functioning; b) can be provoked by stimuli, which do not pose any objective threat to the individual's health or well-being; c) is associated with a high level of distress" (Arnaudova, Kindt, Fanselow, & Beckers, 2017, p. 4). For example, individuals with social anxiety persistently fear being negatively evaluated or rejected, which might lead to dropping a class to avoid public speaking. Individuals with PTSD tend to avoid stimuli, situations, people, and places that remind them of their traumatic event; for example, a sexual assault survivor might stop watching television or reading the news to avoid content related to sexual assault. Common feared and avoided situations for individuals with panic disorder include places that cannot be escaped easily, such as crowds, elevators, and bridges. Across anxiety and traumatic-stressor disorders, pathological avoidance is often extremely impairing, making it difficult for people to work, leave home, and engage in activities that bring them joy. Indeed, greater maladaptive avoidance is associated with increased psychopathology, including anxiety, impairment, and depression (Beesdo et al., 2007; Wittchen et al., 2011).

A prominent early model of avoidance was the two-factor theory, which proposed that avoidance is acquired by Pavlovian fear conditioning, in which an antecedent stimulus is associated with an aversive event, and reinforced by fear reduction (Hull, 1943). This theory was called into question by Bolles' Species-Specific Defense Reactions theory (Bolles, 1971), which argued that Pavlovian and reinforcement learning were not necessary for the acquisition of avoidance. Instead, Bolles' theory argued that organisms are predisposed to perform species-specific defense responses (SSDR), which include an organism's innately determined defensive behaviors (e.g., fleeing, freezing, or fighting; Bolles, 1971). Accordingly, avoidance responses that fall outside of SSDRs are learned after SSDRs are positively punished by failing to result in avoidance of the aversive event. Building on SSDR theory, predatory imminence theory highlights the role of defensive behavior, including avoidance responses, and suggests that anxiety responses fall along a predatory imminence continuum, with responses differing in correspondence with level of threat imminence (Fanselow & Lester, 1988). Maladaptive avoidance in anxiety disorders has been proposed as inappropriate defensive responding due to augmented perception of threat (Craske, 1999; Fanselow & Lester, 1988; Perusini & Fanselow, 2015). More recently, informational factors, such as expectations about outcomes and stimuli, have been acknowledged in avoidance learning. The expectancy model of avoidance states that information is acquired about the outcomes of avoidance as well as non-avoidance, and this, in turn, impacts future behavior (Lovibond, Saunders, Weidemann, & Mitchell, 2008). Most recently, Krypotos, Effting, Kindt, and Beckers (2015) developed an integrated model of avoidance, which suggests avoidance learning occurs on multiple pathways, including a learned Pavlovian component with responses taking the form of an SSDR. Instrumental learning, which entails learning of a specific action necessary for the delivery or omission of an outcome, maintains SSDRs or the learning of non-SSDRs, with many forms of reinforcement, including omission of an expected aversive event or fear reduction. This model also incorporates informational components of avoidance learning, with knowledge about responses acquired (e.g., learning that a response leads to non-occurrence of an aversive event).

Avoidance is theorized as an important mechanism related to the development of anxiety because persistent avoidance in the absence of realistic threat blocks an individual from correcting their maladaptive beliefs about what is and is not dangerous. Emotional processing theory proposes that fear reduction results from integrating fear-incongruent information into existing beliefs, shifting beliefs to be more adaptive and accurate (Foa, Huppert, & Cahill, 2006; Foa & Kozak, 1986). A second well-established theory, inhibitory learning theory, is based on models of Pavlovian fear conditioning, in which a previously neutral stimulus comes to elicit a conditional fear response through association with an aversive stimulus (LeDoux et al., 2017; Pittig et al., 2018). Conditioned fear reduces through a process called extinction learning, in which the conditioned stimulus is repeatedly presented in the absence of the aversive stimulus (LeDoux et al., 2017; Pittig et al., 2018). Inhibitory learning theory posits that the key to extinction is inhibitory learning, which involves secondary new inhibitory learning that the conditioned stimulus no longer predicts the aversive stimulus and is gated by internal and external contexts (Bouton, Westbrook, Corcoran, & Maren, 2006; Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). Thus, approach of feared stimuli, which individuals with anxiety inaccurately believe are dangerous, leads to the development of new inhibitory associations with the feared stimulus, which results in extinction learning and a reduction of fear (Craske et al., 2014). Avoidance blocks extinction learning and is therefore a primary pathway through which anxiety is thought to emerge and persist.

Utilizing the process of fear extinction, cognitive-behavioral treatments (CBT) for anxiety disorders often focus on targeting avoidance, encouraging approach of fear-related stimuli, so that corrective, inhibitory learning can occur (Hofmann & Smits, 2008; Olatunji, Davis, Powers, & Smits, 2010; Watts, Turnell, Kladnitski, Newby, & Andrews, 2015). Although these treatments show efficacy with large effect sizes for both anxiety and co-occurring depression symptoms (Acarturk, Cuijpers, van Straten, & de Graaf, 2009; Cuijpers et al., 2014; Emmrich et al., 2012; Mitte, 2005), a substantial proportion of patients do not show clinically significant improvement: non-response rates are as high as 34-46% (Taylor, Abramowitz, &

McKay, 2012) and dropout rates are around 16-20% (Fernandez, Salem, Swift, & Ramtahal, 2015; Swift & Greenbert, 2012). A potential pitfall of current CBT-based interventions for anxiety disorders is a failure to fully account for the interactional nature of co-occurring, transdiagnostic symptoms (Pittig et al., 2018). Anxiety frequently co-occurs with other disorders, such as depression and substance use disorders (Kessler et al., 2005), and shared processes related to other disorder entities may impact avoidance. Advancing understanding of how common clinical features impact avoidance and translating these findings to interventions may optimize cognitive-behavioral treatments for anxiety disorders. This science-driven, translational approach will help model how clinical complexities impact mechanisms of avoidance, minimizing potential pitfalls of existing therapies by addressing co-occurring processes that have the potential to thwart effective extinction learning and recovery (Pittig et al., 2018).

Avoidance, both adaptive and maladaptive, has primarily been conceptualized as a fear-based response (e.g., LeDoux et al., 2017). However, avoidance often goes hand-in-hand with forgoing rewards for approach (e.g., Aupperle et al., 2011; Schlund et al., 2011). Indeed, a desired incentive can be the very reason for approach, rather than avoidance, of anxiety-eliciting situations. Thus, understanding avoidance from the framework of threat and fear alone likely does not account for outcome conflict and the related dynamic environmental and individual processes that contribute to avoidance. In particular, rewards for approach and individual characteristics that impact appraisal of rewards, may be important in either buffering against or causing and maintaining maladaptive avoidance.

Given significant co-occurrence and symptom overlap, models of anxiety and traumatic-stress related disorders should, in particular, account for symptoms of co-occurring depression (Pittig et al., 2018). Anhedonia is one of two required features of a DSM-5 depression diagnosis

(APA, 2013) and is usually defined as diminished interest or pleasure in usual activities (Cooper, Arulpragasam, & Treadway 2018; Treadway & Zald, 2013). Conceptually, anhedonia can include both deficits in response to hedonic rewards ("consummatory anhedonia") and a diminished motivation to pursue them ("motivational anhedonia;" Treadway & Zald, 2013). Anhedonia is also commonly experienced by individuals with anxiety disorders (Bedwell, Gooding, Chan, & Trachik, 2016). Indeed, 28.3% of individuals with obsessive-compulsive disorder met criteria for clinically significant anhedonia (Abramovitch, Pizzagalli, Reuman, & Wilhelm, 2014); and, after controlling for depression, an estimated 63-75% of patients with PTSD showed clinically significant anhedonia (Carmassi et al., 2014; Franklin & Zimmerman, 2001). Further, excessive social anxiety was associated with significant anhedonia, which was not accounted for by depression (Kashdan, 2004). Thus, anhedonia clearly spans diagnostic boundaries and may be a mechanism also implicated in anxiety. Anhedonia may also play a role in bridging anxiety with co-occurring depression.

Hyposensitivity to reward is theorized to be a trait-like characteristic that predisposes individuals to depression (Alloy et al., 2016). More specifically, anhedonia has been proposed as an endophenotype of depression, arising from the effects of stressors on the mesocorticolimbic dopamine (DA) pathways, reducing motivation to pursue rewards and engage in pleasurable activities, which, in turn, maintains or exacerbates depression (Pizzagalli, 2014). Anhedonia is characterized by attenuated responsiveness to rewards across self-report (Treadway & Zald, 2013), behavioral (Pizzagalli, Jahn, & Shea, 2005), and neural (Epstein et al., 2006; Keedwell, Andrew, Williams, Brammer, & Phillips, 2005; Shankman, Klein, Tenke, & Bruder, 2010) measures, above and beyond depression severity more generally. Due to loss of opposing approach motivation, anhedonia may play an important role in maladaptive avoidance responding. Avoidance may be more likely when individuals have lost interest in or the ability to experience pleasure when engaging in anxiety-provoking activities. Specifically, anhedonia may cause individuals to under-appraise rewards in anxiety-provoking situations and therefore lead to avoidance, which results in the loss of potential rewards (Kashdan, Barrios, Forsyth, & Steger, 2006; Trew, 2011).

Although models of avoidance have evolved significantly over the past several decades, the role of an opposing reward system has not been well accounted for and neither have the mixed outcomes of behavior or costs of avoidance (Pittig et al., 2018). Despite significant progress in models of avoidance, the translational power of these models is hindered by the oversimplification of response scenarios explained. Models are generally derived from laboratory studies involving an isolated fear-eliciting stimulus (e.g., Delgado, Jou, LeDoux, & Phelps, 2009; Ledoux et al., 2017; Lovibond et al., 2008). Thus, avoidance models have held the most explanatory power for scenarios which involve unambiguous threat. In the natural world, however, an action, behavior, or choice often has possible threatening and rewarding consequences and these outcomes are often ambiguous. Approaching a desired outcome can require tolerating distress or the risk of an aversive consequence, such as the possibility of getting attacked after leaving the house or a plane crashing when flying to a vacation. Conversely, avoidance often goes hand in hand with forgoing a reward, such as skipping enjoyable time with friends to avoid the potential threat of being attacked when leaving the safety of one's house. Conflict occurs when these opposing drives to avoid threat and approach incentives are incompatible with one another (Aupperle & Paulus, 2010). The magnitude and probability of rewards and threat can range from minimal to substantial, and one must assess and integrate this information in order to respond. Adaptive balance across avoidance and approach systems is essential for survival because, while avoidance of threat is important, an organism must also meet other primary needs such as obtain resources. Thus, adaptive functioning involves regulation of avoidance by an opposing approach system (Arnaudova et al., 2017); maladaptive avoidance and approach deficits have more recently been proposed as a dysregulated, imbalanced, integrated fear-reward system (Aupperle & Paulus, 2010; Stein & Paulus, 2009).

The idea that behavior is guided by two competing motivational systems is consistent with Gray's theory of behavioral inhibition and behavioral activation: the behavioral activation system is proposed to motivate approach behavior and the behavioral inhibition proposed to motivate withdrawal (Gray, 1990). The two systems are theorized to have inhibitory or antagonistic impacts on the other. Similarly, McNaughton and Corr (2004) proposed that defensive responding corresponds to two categorical dimensions, one which removes an organism from danger and the other which moves an organism towards danger. Decisions to approach or avoid are considered a net sum across both systems resulting in goal directed behavior (McNaughton & Corr, 2004). Thus, behavioral outcomes in the face of threat are thought to be impacted not only by threat-related variables, but also by variables that impact motivation to approach. Inaccurate assessment of risk or the value of various outcomes can shed light on how avoidance becomes maladaptive.

Overlapping neural structures involved in approach and avoidance further argue for a functional relationship across these systems (Aupperle & Paulus, 2010). Evidence from imaging, lesion, and stimulation studies indicate that the amygdala is essential in fear responding (e.g., Davis & Whalen, 2001; Lavond, Kim, & Thompson, 1993; LeDoux, 2000; Rosen, 2004). However, the amygdala has also been shown to respond to rewarding stimuli and to activate during reward learning (e.g., Baxter & Murray, 2002; Gottfried, O'Doherty, & Dolan, 2002; O'Doherty, 2004; Schlutz, 2006). On the other hand, the striatum is well-established as key in reward processing and responding (e.g., Bayer & Glimcher, 2005; Costa, Lang, Sabatinelli, Versace, & Bradley, 2010; Schultz, Dayan, & Montague, 1997), with striatal dopamine (DA) neurons coding unpredicted reward delivery using phasic bursts of dopamine (Bayer & Glimcher, 2005; Schultz et al., 1997). However, there are again parallels across fear and reward structures, with the striatum also implicated in punishment and response to aversive stimuli (Delgado, Locke, Stenger, & Fiez, 2003; Jensen et al., 2007; Jensen et al., 2003). The insula is also thought to play a role in responding to both aversive and rewarding stimuli (Singer, Critchley, & Preuschoff, 2009; Nielen et al., 2009) and predicting outcomes in response to affective stimuli (Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Paulus & Stein, 2006). The prefrontal cortex, and particularly the orbitomeatal frontal cortex (OFC), has also been implicated in approach and avoidance responding, with evidence suggesting the OFC inhibits limbic responses during fear responding (Quirk, Likhtik, Pelletier, Pare, 2003; Ohira et al., 2006) and activates during reward responding (O;Doherty, 2004; O'Doherty, Deichmann, Critchley, & Dolan, 2002). Thus, on the neural level, Aupperle and Paulus (2010) argue that, in particular, the OFC, amygdala, insula and striatal regions play a role in avoidance responding and that pathological avoidance is not only related to threat processing but, instead, can be related to either an over-representation of threat, an under or over representation of reward, or deficits in the integration of threat and reward valuation across recruited neural regions.

The relationship across avoidance and approach systems is especially important in approach-avoid conflict situations, characterized by opposing approach-reward and avoid-threat motivation (Aupperle & Paulus, 2010). In approach-avoid conflict, individuals must decide if they will prioritize incentives for approach above potential threatening outcomes. For example, just as a foraging mouse decides to leave her nest to acquire food at the risk of encountering a threatening predator, a survivor of sexual assault may leave her house to spend rewarding time with friends, despite anxiety about the risk of another attack outside of her house. Indeed, it is the possibility of rewarding outcomes that often motivates approach behavior despite the potential for threatening encounters or psychological distress inherent to many aspects of daily functioning. Thus, the study of avoidance in isolated fear situations or approach in relationship to only rewards is not sufficient for understanding real world behavior.

Growing recognition of the historical oversimplification of human avoidance paradigms has led to a recent study of human approach-avoid conflict (for review, see Kirlic, Young, & Aupperle, 2017). To date, human approach-avoid paradigms have taken various forms. Risk-based reward paradigms involve advantageous and disadvantageous choices, with the former paired with threat-relevant stimuli (e.g., CS+ or fear-relevant picture), creating a conflict (e.g., Pittig, Brand, Pawlikowski, & Alpers, 2014; Pittig, Pawlikowski, Caske, & Alpers, 2014; Pittig, Schulz, Craske, & Alpers, 2014). Approach-avoid decision tasks, on the other hand, give explicit information about reward and threat contingencies, which creates decision conflict (e.g., Aupperle, Sullivan, Melrose, Paulus, & Stein, 2011). Finally, computerized gaming paradigms task participants with the goal of pursuing rewards, that require strategic decisions to obtain reward and avoid threat (e.g., Bach et al., 2014; Rattel, Miedl, Blechert, & Wilhelm, 2017). Across these differing paradigms, converging results have begun to provide evidence for a functional relationship across fear-related avoidance and approach-related reward, showing that avoidance behavior is not only increased at higher levels of threat (e.g., Schlund et al., 2016; Schlund et al., 2017; Sierra-Mercado et al., 2015) but also at lower levels of reward (Aupperle et al., 2011; 2015; Sierra-Mercado et al., 2015; Talmi, Dayan, Kiebel, Frith, & Dolan, 2009). Importantly, a majority of approach-avoid conflict paradigms either manipulate reward level (e.g., Aupperle et al., 2011; Talmi et al., 2009) or threat level (e.g., Bach, 2014; Pittig et al., 2014; Schlund et al., 2011), precluding investigation of the interaction across threat and reward level. One study that did examine simultaneous manipulation of reward and threat level in humans, showed that, at low probability of threat, when avoidance rates were lower overall, avoidance did not differ across reward magnitudes, whereas, at high probability of threat, avoidance was lower when reward was higher compared to lower (Sierra-Mercado, 2014). Thus, preliminary evidence suggests that there may be important interactions across threat and reward, with reward being able to buffer against avoidance when avoidance rates are higher due to higher threat.

Approach-avoid studies using these various designs have started to move the field forward significantly by investigating threat and reward processes simultaneously (e.g., Aupperle et al., 2011; Pittig et al., 2014a; 2014b; 2014c; Schlund et al., 2016). However, there are several critical gaps in the human approach-avoid conflict literature. To begin with, there is often a lack of ecologically valid threat used in human approach-avoid conflict paradigms. Computerized paradigms (e.g., Pittig et al., 2014c; Aupperle et al., 2011; Schlund et al., 2016) do not adequately parallel *in vivo* confrontation with threat perceived as dangerous or potentially harmful. Even paradigms requiring virtual navigation representing threat to participants as a "predator" or 'spaceship attack" only resulted in point loss (Bach et al., 2014; Schlund et al., 2016), which falls short of eliciting a sense of threat to personal integrity. Monetary loss, viewing an aversive image, and receiving a mild shock, are criticized for not eliciting ecologically valid fear, but rather annoyance or disgust (Beckers et al., 2013). These "threats" may not be generalizable to responding in real life. Of the few studies that do examine the relationship between self-reported avoidance in real life and approach-avoid task responding have found only weak associations (e.g., Pittig et al., 2014b; van Meurs et al., 2014). A lack of convergence across task performance and self-report behavioral avoidance in real life brings to question whether or not these paradigms are capturing the construct of interest, namely behavioral avoidance, in paradigms to date. Laboratory responding will be most informative when it maps on to real-life behavior. The field needs convergent validity, showing that those who avoid more on approach-avoid tasks are similarly more frequent avoiders in real life. In sum, human avoidance paradigms typically have not incorporated ecologically valid threats that parallel dynamic, unpredictable, interactive threats encountered in real life.

The presence of actual threat, such as when a foraging rat faces a looming predator, is a neglected extrapolation from ethobehavioral rodent paradigms to human approach-avoid conflict paradigms. Indeed, in contrast to human research, there is a growing emphasis on ethobehavioral paradigms in rodent approach-avoid conflict studies (Mobbs & Kim, 2015; Pellman & Kim, 2016). One such paradigm is Choi and Kim's (2010) prey-predator robogator paradigm, which exposes foraging rats to a predator-like robot that surges when approached. Critically, the threat mimics predatory threat and is highly controllable, allowing for quantifiable manipulation. Findings from this task suggest that rats approached the food as a function of both decreasing distance between the safe nest and food and increasing distance between the food and the robot (Choi & Kim, 2010). This suggests that rats may systematically decide whether to approach or avoid based on threat level, consistent with continuum models such as predatory imminence theory (Fanselow & Lester, 1988; Perusini & Fanselow, 2015). The likelihood of approaching food in this task increased via lesioning/inactivating the amygdala and decreased via disinhibiting the amygdala (Choi & Kim, 2010). Importantly, the prey-predator paradigm parallels evolutionarily primed exposure to threat by modeling a naturalistic, dynamic fear environment, rather than requiring conditioning to acquire fear or arbitrary appetitive behaviors, which have substantially less real-world generalizability.

Theories of avoidance have largely ignored individual differences (Krypotos et al., 2015); using laboratory approach-avoid conflict paradigms, there is a particular deficit in examining reward system variables. Reward-related constructs may decrease valuation of reward, leading to decreased approach or increased avoidance. Still, reward-related processes have been largely overlooked in the approach-avoid conflict literature. With anhedonia associated with reward hyposensitivity (Pizzagalli, 2014), anhedonia may be particularly relevant in approach-avoid conflict contexts. The Probabilistic Reward task (PRT), a signal detection task that uses a differential reinforcement schedule to assess reward propensity (Pizzagalli et al., 2005), has been proposed as an objective measure of anhedonia. Individuals with higher anhedonia show attenuated reward propensity on the PRT (Pizzagalli et al., 2008a; Webb et al., 2016). Further, administration of a dopamine agonist reduced reward propensity on this task in both humans and in rats (Pizzagalli et al., 2008b). Finally, on the PRT, a threat-of-shock stress induction decreased reward propensity and self-report anhedonia predicted greater decreases (Bogdan & Pizzagalli, 2006). Thus, reward propensity may be another reward-related construct that could help explain individual differences in avoidance.

Another key individual difference that may alter avoidance responding is trait anxiety, broadly defined as a relatively stable predisposition to respond to one's environment, particularly perceived threats, with anxiety (Spielberger, 1966; Endler & Kocovski, 2001). Trait anxiety has been found to modulate approach-avoid responding, with higher trait anxiety associated with more avoidance and less approach (Loh et al., 2017; Pittig et al., 2014c). Trait anxiety is thought to impact perceived defensive distance, defined as perceived distance from threat. Augmented perceptions of threat may lead to increased avoidance behavior in approach-avoid conflict (Perusini & Fanselow, 2015). There also may be important interactions effects across emotional responding and trait-level variables. Pittig et al. (2014a; 2014c) found that avoidant responses were especially pronounced in participants who were high on trait anxiety, who also exhibited higher physiological responses, compared to those high on trait anxiety who did not exhibit higher physiological responses. Thus, trait anxiety may be particularly important when there is a matching physiological fear response. Although several approach-avoid conflict studies have measured fearful arousal across task responding (e.g., Pittig et al., 2014c; 2014b; Schlund et al., 2016; Talmi et al., 2009), none have simultaneously assessed subjective distress on a trial by trail basis. Subjective distress is a vague yet discernable and aversive feeling that individuals are motivated to reduce (Davis & Ollendick, 2005). Thus, subjective experience of distress may be an important predictor of avoidance behavior missed in extant literature. Measurement across units of analysis in approach-avoid conflict is necessary, particularly because, in defensive responding to threat, there is considerable discordance across subjective, behavioral, and physiological indices (Lang, Bradley, & Cuthbert, 1998; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005).

Gender may also impact avoidance responding, with women more likely to avoid than men. Indeed, recent human studies have reported women show more avoidance than men in approach-avoid conflict (Aupperle et al., 2011; Myers et al., 2016; Pittig et al., 2014c; Sheynin et al. 2014; Sheynin et al., 2013). Whether this difference is due to decreased responsivity to reward, increased threat responding, or both, has not been investigated. Recently, using a variant of Kim et al.'s prey-predator paradigm (2010), female rats exhibited greater fear responding and avoidance than males, operationalized as being more reluctant to enter the foraging space, greater hesitancy to leave the safe nest, and failed attempts to procure the food pellet, after exposure to the threat (Zambetti, Schuessler, & Kim, 2019). These findings suggest that perhaps women may be more responsive to threat, leading to increased avoidance, at the cost of reward. One of the most consistent findings in epidemiologic studies of anxiety and mood disorders is the higher prevalence of both anxiety and depression in women (Kessler et al., 2005; Seedat et al., 2010). Yet, the underlying causes of this difference are not well understood. Increased responsivity to threat leading to a downward pattern of avoiding and decreased rewarding experiences, may put women at higher risk for both anxiety and depression.

In sum, the human avoidance literature thus far has not prioritized ecological validity, calling to question how well laboratory avoidance findings explain responding in dynamic, naturalistic settings and how readily highly controlled experimental findings can be translated to explain complex clinical phenomenon. Further, important individual differences above and beyond anxiety and fear-related processes have been ignored in the avoidance literature. Factors such as reward-related psychopathology and gender may be crucial in understanding individual differences in avoidance behavior. Accordingly, the current study takes a reverse translational approach, capitalizing on recent advances in the development of ecologically-relevant rodent paradigms and facilitating future translation of non-human findings to clinical application. A novel approach-avoid task, the Dynamic Avoidance Task (DAT) was developed, designed to mirror Choi and Kim's (2010) prey-predator robogator paradigm. The goal of the DAT is to retrieve as many coins as possible by reaching inside a large box where the coins are placed at varying distance from the participant. Inside the box is a threatening robot, which surges when the participant reaches for coins, designed to elicit evolutionarily prepared threat responding. Unlike previous studies, reward and threat were simultaneously manipulated. Reward was manipulated by having no reward and high reward conditions. Specifically, in the no reward condition, monetary incentives were not available. In the high reward condition, coin retrieval was incentivized by giving money to participants in exchange for each coin they retrieved, representing the high reward condition. Threat was manipulated by varying participant-to-coin and coin-to-threat distance, making participants have to reach farther, which was closer to the robot, to retrieve the coins (low, moderate, and high threat conditions). The task emphasizes ecological validity by including real life, not virtual, confrontation with threating stimuli and real, rather than fictional, rewards. The task represents a paradigmatic shift, eliciting evolutionarily prepared fear (i.e., unconditioned fear), which likely maps on better to ecologically valid responses that organize avoidance behavior in real life. Unlike behavior analogue tasks, which hinder transdiagnostic investigations since idiosyncratic match with feared stimuli is often necessary, the paradigm serves to elicit behavioral threat responding across individuals without requiring disorder-specific, individualized threat stimuli.

In order to address the overlooked role of reward-related individual difference variables in avoidance behavior (Pittig et al., 2018), participants in the present study were selected for having high and low levels of anhedonia. The sample was defined in this way given interest in the role of reward system deficits more broadly, as opposed to deficits linked to distinct, categorical disorders. Selecting for this sample is consistent with current trends in the field, emphasizing specific constructs that are related to dysfunctional clinical phenomena (Insel & Cuthbert, 2009; Kozak & Cuthbert, 2016). Anhedonia was examined categorically, selecting for low and high, providing greater representation of the clinical range and facilitating comparison of people with normal and pathological levels of anhedonia.

Given the pervasiveness of anhedonia across psychiatric disorders, the relevance of findings are more broadly applicable by taking this transdiagnostic approach. Additionally, men and women were included in the sample to facilitate comparison of avoidance and fear responding in women compared to men. Characterizing gender differences in avoidance and fear responding, including differential avoidance and fear responding at varying levels of threat, reward, and degree of approach-avoid conflict, may help explain the greater prevalence of anxiety, PTSD, and depression in women compared to men (Kessler et al., 2005; Seedat et al., 2010).

Accordingly, the current study was a mixed subjects design, comparing approach-avoid conflict responding across individuals with high and low anhedonia and comparing men and women. Threat and reward level were simultaneously manipulated: coin retrieval was either incentivized with monetary reward (reward) or was not incentivized with monetary reward (no reward) and threat was manipulated by varying the coin-to-threat distance (low threat, moderate threat, high threat). Time was included as a within-subjects variable given that fear reduction occurs as a function of exposure/experience with threat (Craske et al., 2014; Foa, Huppert, & Cahill, 2006). Thus, time was necessary to examine differential responding across the task, from initial exposure to repeated exposure to the threat.

Key outcomes variables included (1) latency for first coin retrieval, or time it took for participants to retrieve a first coin during each trial; (2) total coins retrieved, representing how many total coins participants retrieved during the trial period; (3) peak subjective distress, assessed via self-report immediately after each trial; (4) and physiological responding (skin conductance level; SCL) during each trial. Response latency and total coins retrieved were chosen as outcome indices to parallel behavioral outcome indices used in the rodent version of the approach-avoid paradigm (Choi & Kim, 2010). Additionally, subjective distress and physiological arousal were included as gold-standard self-report and physiological measures of fear responding, in order to examine how constructs of interest impacted fear responding on the DAT. Avoidance was operationalized as slower latency for first reward retrieval and fewer coins obtained and higher fear responding as higher subjective distress and higher physiological responding. Finally, given their link to avoidance and/or approach behavior, reward propensity, as measured by the PRT, trait anxiety, self-report behavioral avoidance, and PTSD symptoms were examined as important individual difference characteristics that potentially have an indirect effect on approach-avoid conflict responding.

Hypotheses

Effect of anhedonia. Given that anhedonia is characterized by decreased reward sensitivity and approach motivation (e.g., Alloy et al., 2016; Pizzagalli, 2014; Treadway & Zald, 2011), we hypothesized a main effect of anhedonia, such that individuals in the high anhedonia group would show longer response latency for first reward retrieval (s), fewer coins obtained (*n* total coins), higher subjective level of distress (SUDs), and higher physiological responding (SCL) in the approach-avoid task than those in the low anhedonia group.

Effect of gender. With evidence across species demonstrating that females show more avoidance in approach-avoid conflict than males (Aupperle et al., 2011; Basso et al., 2011; Sheynin et al., 2014; Sheynin et al., 2013; Zambetti, Schuessler, & Kim, 2019), we also hypothesized a main effect of gender such that women, as compared to men, would show longer response latency for first reward retrieval (s), less reward obtained (*n* total coins), higher subjective level of distress (SUDs), and higher physiological responding (SCL).

Anhedonia, reward, and threat interaction. Given that human and non-human findings may suggest an interactive relationship across fear and reward (e.g., Choi & Kim, 2011; Pittig et al., 2014c; Rattel et al., 2017; Schlund et al., 2016), we hypothesized an anhedonia by reward by threat interaction effect, such that the largest difference between the low anhedonia group and the high anhedonia group on the DAT would be observed during high reward, high threat condition. Specifically, for high reward, high threat trials, individuals in the high anhedonia group would show longer response latency for first reward retrieval (s), less reward obtained (*n* total coins), higher subjective level of distress (SUDs), and higher physiological responding (SCL) in the approach-avoid paradigm than those in the low anhedonia.

Moderators of avoidance. To better understand the individual difference characteristics that impact avoidance and fear responding, we examined the impact of pre-task moderators on the dependent variables. Because PRT propensity has been associated with anhedonia and propensity towards reward (Pizzagalli et al., 2008a), we hypothesized that lower change in reward propensity on the PRT would predict longer latency for first reward retrieval (s), less reward obtained (*n* total coins), higher subjective level of distress (SUDs), and higher physiological responding (SCL) on no reward, high threat trials and on high reward, high threat trials. Further, because several approach-avoid studies have found moderate associations between higher trait anxiety and more avoidance in approach-avoid conflict (e.g., Loh et al., 2017; Pittig et al., 2014c; Sheynin et al., 2014), we hypothesized that higher trait anxiety would predict longer latency for first reward retrieval (s), less reward obtained (*n* total coins), higher subjective level of distress (SUDs), and higher physiological responding (SCL) in the no reward, high threat trials and the high reward, high threat trials.

Mediation effect of subjective distress and physiological arousal. With previous research showing that higher trait anxiety combined with a higher state physiological response predicted higher avoidance (Pittig et al., 2014c), we hypothesized a mediation effect such that higher physiological responding and higher state self-report distress during a trial will mediate the strength of the relationship between trait anxiety and avoidance on the DAT, such that individuals with higher baseline trait anxiety, higher physiological responding (SCL), and higher state self-reported distress (SUDs) during trial responding would show longer latency for first reward retrieval (s) and less reward obtained (*n* total coins) in the DAT on no reward, high threat trials, and high reward, high threat trials.

Method

Participants

The sample ($N = 80$) was comprised of 41 participants in the low anhedonia group (68.3% female) and 39 in the high anhedonia group (61.5% female). In a large metropolitan area, participants were recruited from the community via flyers and online advertisement, which stated a research study was seeking participants who either "enjoyed things less than they used to" or "lived a fun-filled life." Required eligibility characteristics included fluency in English, between 18 and 65 years of age, and self-report normal or corrected-to-normal hearing and vision. Participants who had a past diagnosis of bipolar disorder or psychotic disorder, or who were regularly taking sedative-hypnotics, benzodiazepines, or beta-blockers, or who were pregnant were excluded due to the potential confounding impact these conditions and medications could have on approach-avoid conflict responding, limiting ability to detect the effects of interest.

Due to interest in examining a transdiagnostic construct specifically tied to the reward system as it relates to avoidance rather than this relationship within a distinct categorical disorder, participants were pre-screened online using the Snaith-Hamilton Pleasure Scale

(SHAPS; Snaith et al., 1995) and selected to be potential members of either a high anhedonia group (SHAPS ≥ 3) and a low anhedonia group (SHAPS = 0). SHAPS score was confirmed in person on the day of the study. Of the eighty-five total participants who signed informed consent, five were removed from the study due to a substantive change in anhedonia from online to in-person assessment ($n = 3$) or for not following task instructions ($n = 1$) or for discontinuing study participation ($n = 1$). The final sample ($N = 80$) were on average 31.60 years old ($SD = 13.82$). Approximately forty-five percent ($n = 36$) were Caucasian, thirty-three percent Asian ($n = 27$), nine percent Black or African American ($n = 7$) and the remainder American Indian, Native Hawaiian, other Pacific Islander, or "Other" ($n = 10$). See Table 1.

Study Design

This study used a mixed-subjects design, with between-subjects factors of anhedonia group (high, low) and gender (women, men) and manipulating within-subjects factors of reward (no reward, high reward) and threat type (low, medium, high) and time (block 1, block 2, block 3) on the primary study task: the Dynamic Avoidance Task (DAT). Primary dependent variables on the DAT included response latency for first reward retrieval (s), amount of reward obtained (*n* coins retrieved), self-report peak distress on each trial (SUDs), and physiological responding measured via skin conductance level (SCL).

Materials

Dynamic Avoidance Task (DAT). This task is an adapted, human version of the prey-predator robogator paradigm for rodents, developed by Kim and colleagues (Choi & Kim, 2010; Kim et al., 2014; see Figure 1). The DAT is designed to model ecologically valid approach-avoid conflict scenarios by incorporating *in vivo* confrontation with a threat and manipulating juxtaposed reward and threat levels. In a semi-dark room illuminated by a red light, participants sat in a chair with adjustable height, in front of a rectangular box (60" x 36" x 24"; DAT Box), which was placed on top of a table, 28.5 in. tall. The walls of the DAT box were painted black. On the side of the box adjacent to the participants, there were two openings. One of the openings (6” x 2”) was at eye level and covered by black, opaque felt attached via Velcro, which can be easily detached from the box by pulling and detaching the Velcro. Eight inches below the top opening was a second opening (12” x 5”), covered by a black curtain, with a slit down the middle. Through this slit, participants could reach inside the box with their dominant hand to retrieve rewards in the form of coins. The inside of the box was dimly illuminated by a small, red light. Inside the box, at the opposite side from the participant, 50 in. from the opening where the participant reached inside the box, a Kamigami robot was placed at the start of each trial. The Kamigami robot was 2.56 x 11.97 x 7.95 in. See Figure 1. The robot had a black external plastic shell, two eyes, and a tail that extends above the back of its body, with six legs and makes a rapid, buzzing sounds as it moves.

At the start of each trial, participants pulled down the felt eye covering and reach inside the box with their dominant hand to retrieve as many coins as possible within 20s, one at a time. Each time a coin was retrieved, the participant placed the coin in a bowl attached to the table in front of the DAT box, located on the side of the participants’ dominant hand. Each trial, a maximum of 12 coins, with a circumference of 1 in., were available for retrieval. Participants were told before each trial whether the upcoming trial was a “reward trial” or a “no-reward” trial. On reward trials, participants could earn monetary rewards based on the number of coins retrieved ($0.35 cents for each coin for maximum possible earning of $4.20 per trial). During “no-reward” trials, monetary rewards could not be earned. Coins used in high-reward trials and coins used in no-reward trials varied visually: high reward coins were unmarked, orange, and glow-in-the-dark; no-reward trials were also orange glow-in-the-dark but were labeled with an "X" the full length of the coin diameter.

At the start of each trial, once the participant placed the felt eye-hole cover on the table beside them, the Kamigami robot began one of three, pre-programed, 20s surge patterns. The surge program included a straight-forward movement, curved-forward movement, backward movement, 1-2 s pauses, and left and right rotation, with movement speed variability. Three distinct surge programs were used, systematically counterbalanced across trials and participants, in order to make the movement appear unpredictable to participants.

Across trials, participant-to-reward distance and reward-to-threat distance inside the box (low, moderate, high threat) was manipulated. Specifically, during low threat trials, the twelve coins were placed in rectangular formation (6 coins each), closest to the participant, 18 in. apart and 9 in. from the box opening, where the participant reached inside the box. At moderate threat, the coins were placed in the same formation, 14 in. apart and 14 in. inside the box. At high threat, the coins were placed farthest from the participant in the same formation, 14 in. apart and 19 in. inside the box, requiring the participant to move their hand considerably closer to, and at some points past, the robot.

Accordingly, there were six trial type across reward and threat types: low reward, low threat trials; low reward, moderate threat trials; low reward, high threat trials; high reward, low threat trials; high reward, moderate threat trials; and high reward and high threat trials. Three blocks of six trials were conducted, for a total of eighteen trials, with trial order counterbalanced across reward and threat within each of the three blocks (e.g., one of each of the 6 trial types, in each block, counterbalanced across participants). Key dependent variables were response latency for first reward retrieval (s) defined as time from when the eye cover was placed on the table to when first coin was placed in the bowl and total reward value obtained, operationalized as the number of coins collected during each trial (0-12 coins), self-report peak distress on each trial (SUDs), and physiological responding measured via skin conductance level (SCL).

Probabilistic Reward Task (PRT; Pizzagalli et al., 2005). The probabilistic reward task (PRT) has been used to assess reward propensity across species (e.g., Der-Avakian et al. 2013; Pizzagalli et al., 2005; 2008a; 2008b; Webb et al., 2016). This task has been proposed as a behavioral measure of anhedonia and was included to have an objective, in addition to self-report, measure of our primary independent variable of anhedonia. In this task, participants must identify which of two difficult-to-differentiate stimuli was presented. Stimuli were simplified line faces. At the start of the trial, the face had no mouth. After a delay, either a straight mouth of 11.5 mm or 13 mm was presented for 100 ms. Participants were instructed to press the "V" or the "M" key (counterbalanced across participants) to indicate whether the short mouth or the long mouth was presented. Within each block, 40 correct trials were followed by reward feedback: "Correct! You won 5 cents!" Correct identification of one stimulus, the "rich" stimulus, was rewarded three times (30 trials) more frequently than the other stimulus, the "lean" stimulus (10 trials), an asymmetrical reinforcer ratio shown to produce a response bias. However, in individuals with higher anhedonia this reinforcement schedule leads to an attenuated response bias (i.e., a preference for the more frequently rewarded stimulus) compared to those with lower anhedonia (Pizzagalli et al., 2008; Pizzagalli et al., 2005). The task consisted of 200 trials, divided into two blocks, and the stimulus serving as the more frequently rewarded stimulus was counterbalanced across participants. Participants were pre-determined to earn $5.80 or $6.20, counterbalanced across participants, and this pre-determined amount was displayed on the screen at the end of the task.

The degree of response bias toward the more frequently reinforced alternative was used to operationalize reward propensity. Response bias was calculated using the following equation: $\log b = \frac{1}{2} log \left(\frac{Rich_{correct} * Lean_{incorrect}}{Rich_{incorrect} * Lean_{correct}}\right)$. The output variable was response bias change, operationalized as the increase in response bias during the second block relative to the first block [DResponse Bias = Response Bias(Block 2) - Response Bias(Block 1)], with higher scores indicating a greater increase in response bias and greater reward propensity. The PRT shows good convergent validity, being associated with anhedonia (*r* = -.52) and reduced response bias in depressed patients (Pizzagalli et al., 2008a).

Measures

Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995). The SHAPS is a 14-item self-administered instrument that measures level of anhedonia, defined as diminished interest or pleasure in usual activities. Items are rated for "the last few days" on a 4-point Likert scale (1 = *definitely agree*, 4 = *strongly disagree*). The four response categories are recoded into dichotomous categories (0 = *agree*, 1 = *disagree*), and total scores result from the sum of the 14 items, with total scores ranging from 0 to 14. A higher total SHAPS score indicates higher anhedonia. The SHAPS has demonstrated good convergent validity with other measures of mood, and group differences are found for those who score 0 or 1 vs. 2 or 3 on the pleasure/enjoyment item of the Inventory of Depressive Symptomatology (Snaith et al., 1995). Participants were pre-screened online using the SHAPS and, if eligible, preliminarily classified to be potential members of either the low anhedonia group (SHAPS = 0) or high anhedonia group (SHAPS ≥ 3; Franken et al., 2007). On the day of study participation, anhedonia level was re-assessed using the SHAPS. Given strong test-retest reliability (test-rest *r* = .70; Franken et al., 2007; Langvik et al., 2018), participants remained eligible for their potential group if their score moved within 1-point of the pre-screen cut-off (low anhedonia group: SHAPS ≤1; high anhedonia group: SHAPS ≥ 2). Depression severity (QIDS-SR) was used to arbitrate potential group membership for participants whose SHAPS score on the day of study participation moved beyond this 1-point cut-off.

Quick Inventory of Depressive Symptomatology Self-Report (QIDS-SR; Rush et al., 2003). The QIDS-SR is a 16-item self-report measure that assesses diagnostic criteria items for MDD, including mood, vegetative, psychomotor, and cognitive symptoms. Items are rated on a 4-point scale with anchors that vary with the question (e.g., 0 = *I do not feel sad*, 3 = *I feel sad nearly all of the time*). The QIDS-SR has good convergent validity with the 30-item Inventory of Depressive Symptomatology Self-Report IDS-SR (r = .96) and the clinician-rated Hamilton Rating Scale for Depression (r = .84; Rush et al., 2003). Given strong relationship between anhedonia and depression (r = .55, Snaith et al., 1995), for participants whose SHAPS score on the day of study participation moved beyond the 1-point cut-off (n = 15), QIDS-SR severity was used to confirm group membership. Specifically, based on Rush et al. (2003), if the clinical cut-off for moderate depression or higher was met (QIDS-SR ≥ 10), participants were included in the high anhedonia group (n = 8). Participants with scores indicating the absence of depressive symptoms (QIDS-SR ≤ 5) were included in the low anhedonia group (n = 4). A QIDS-SR indicating mild depression (5 < QIDS-SR < 10) rendered participants ineligible (n = 3).

State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushen, 1983). The STAI is a 40-item self-administered measure that assesses both state anxiety (STAI-S), asking participants to report how they in the current moment on feelings of apprehension, tension, nervousness, worry, and arousal, and also trait anxiety (STAI-T), asking participants about relatively stable tendencies to respond to the environment with anxiety and nervousness rather than calmness and confidence. The STAI-S asks participants to rate how they feel "right now" whereas the STAI-T asks participants to rate how they generally feel. Items are rated on a four-point Likert scale (1 = *not at all*, 4 = *very much so*). Total scores range from 20-80, with higher scores indicating greater anxiety. The STAI-T has demonstrated good test-retest reliability (r = .73 - .87; Spielberger et al., 1983) and good convergent validity with other measures of trait anxiety (r = .52 - .80; Spielberger et al., 1983). Given literature showing a stronger relationship between trait anxiety and avoidance, as compared to state anxiety and avoidance, STAI-T was used in the moderation analysis (e.g., Bach 2015; Loh et al., 2017; Pittig et al., 2014c).

PTSD Scale-Self-Report for DSM-5 (PDS-5; Foa et al., 2016). The PDS-5 is a 24-item self-report measure used to assess prior trauma exposure and DSM-5 symptoms of PTSD, including intrusion, avoidance, negative alterations in cognitions and mood, and alternations in arousal and reactivity. The PDS-5 uses a trauma screen to identify prior exposure to DSM-5 Criterion A traumatic events and assesses the severity of DSM-5 PTSD symptoms related to the event causing the most distress in the last month. The trauma screen asks participants whether they have experienced a traumatic event (e.g., serious life threatening illness, physical assault, sexual assault, military combat/lived in a war zone, child abuse, serious accident, natural disaster, or other traumatic event, which participants are asked to specify). For those who have Criterion A exposure, the PDS-5 includes 20 questions assessing symptom severity on a 5-point Likert scale (0 = *not at all*, 4 = *six or more times a week/severe*), and scores are calculated by summing responses, with higher scores indicating higher PTSD severity. The PDS-5 also includes two questions assessing distress and interference and two questions assessing symptom onset and duration. This measure has good test-retest reliability (r = .90) and is highly correlated with PTSD interview measures (r = .85, Foa et al., 2016). For analysis, participants who had not experienced a Criterion A traumatic event were included with a score of 0, indicating the presence of no PTSD symptoms.

Subjective Units of Distress (SUDs; Wolpe, 1969). This measure served to measure how much fear participants were experiencing prior to beginning the DAT and during each trial of the DAT . Ratings were based on a 100-point scale (0 = *most relaxed you've ever been*, 100 = *most distressed, uncomfortable, or anxious you have ever been*). SUDs ratings are correlated with measures of physiological arousal (heart rate, r = .39; peripheral vasoconstriction, r = .84; Thyer, Papsdorf, Davis, & Vallecorsa, 1984). Prior to the start of the DAT, participants were asked to provide a baseline rating of their current state. Immediately after each trial of the DAT, participants were asked to rate their peak level of distress during the trial they just completed. Peak SUDs served as a dependent variable for the DAT.

Multidimensional Experiential Avoidance Questionnaire – Behavioral Avoidance Subscale (MEAQ; Gámez, Chmielewski, Kotov, Ruggero, & Watson, 2011). The behavioral avoidance subscale of the MEAQ measures the extent to which an individual tends to avoid things that might cause anxiety, discomfort, or distress. The subscale consists of 15 statements, such as "I won't do something if I think it will make me uncomfortable" and "I work hard to avoid situations that might bring up unpleasant thoughts and feelings in me". Items are rated on a 6 point-Likert scale (1 = *strongly disagree*, 6 = *strongly agree*), with total scores ranging from 0 - 90. The MEAQ demonstrated strong convergent validity with other measures of avoidance, such as the Cognitive-Behavioral Avoidance Scale (r = .54 - 60; Gámez et al., 2011).

Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). The AUDIT is a 10-item questionnaire with 3 questions on the amount and frequency of drinking, 3 questions on alcohol dependence (e.g., "how often during the last year have you needed a first drink in the morning to get yourself going after a heavy drinking session?"), and 4 questions on problems caused by alcohol (e.g., "have you or someone else been injured as a result of your drinking?"). This questionnaire was included given that alcohol use disorders have been linked to aberrant reward neural circuitry and responding (Volkow et al., 2011). Thus, exploratory analyses were conducted to examine possible associations between alcohol use disorder symptomatology and responding on the DAT. Questions are asked in regard to the last year and scored on a 5-point Likert scale, and this measure yields a total severity score ranging from 0 (*no alcohol-related risk*) to 40 (*maximum alcohol-related risk*). The AUDIT has been shown to discriminate between persons with harmful or hazardous alcohol consumption and those with non-hazardous consumption and shows good convergent validity with biochemical measures of excessive drinking (Saunders et al., 1993) and other self-report measures of drinking frequency and behavior, such as the Michigan Alcohol Screening Test ($r = .88$; Bohn, Babor, & Kranzler, 1995).

Cannabis Use Disorder Identification Test – Revised (CUDIT-R; Adamson et al., 2010). The CUDIT-R is an 8-item self-report questionnaire, with two questions each assessing domains of cannabis consumption (e.g., "how often do you use cannabis?"), cannabis problems (e.g., how often did you fail to do what was normally expected from you because of using cannabis?"), dependence, and psychological features (e.g., "have you had a problem with your memory or concentration after using cannabis?". Like the AUDIT, this questionnaire was included to conduct exploratory analyses examining the association between cannabis use and responding on the DAT, given that cannabis use has been associated with reward-related deficits (Lawn et al., 2016). Seven questions are rated on a 5-point Likert scale with 5 anchors points (0 = *Never,* 4 = *4 or more times a week*) and one question, related to cutting down or stopping cannabis use, is rated on a five-point Likert scale with only three anchor-points (0 = *never,* 2 = *yes, but not in the past six months*, 4 = *yes, during the past 6 months*). Participants are asked to respond in reference to the last six months. The CUDIT-R shows high sensitivity (91%) and high specificity (90%) when predicting diagnostic status determined by structured clinician-interview and has a strong correlation with recent cannabis use frequency (r = .71; Adamson et al., 2010).

Domain-Specific Risk-Taking Scale – Financial, Health/Safety, and Recreational Subscales (DOSPERT; Weber, Blais, & Betz, 2002). The DOSPERT is a 24-item self-report questionnaire that asks participants their likelihood of engaging in specific, risky-related activities (e.g., "Driving while taking medication that may make you drowsy"; "Engaging in unprotected sex"). Riskiness may impact avoidance responding, given that risky individuals are thought to undervalue possible negative outcomes and prioritize positive outcomes (Rosenbaum & Hartley, 2018). Items are rated on a 7-point Likert scale (e.g. 1 = *extremely unlikely*, 7 = *extremely likely*; Blais & Weber, 2006). On the DOSPERT, responses are cumulative, with a higher overall score indicating a greater propensity for risk taking behaviors. The DOSPERT has moderate to strong convergent validity with self-report scales measuring the frequency of past risky behavior and sensation-seeking (r = 0.49; Weber et al., 2002; 2009).

Short-Version of Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale (SUPPS-P; Lynam, 2013). The SUPPS-P is a 20-item self-report measure that assesses impulsivity or a tendency to have hasty and unplanned reactions without regard to the negative consequences of such reactions (Moeller, 2001; Jakuszkowiak-Wojten et al., 2015). Thus, impulsivity may impact avoidance behavior via decreased concern for threatening consequences. The SUPPS-P includes twenty items and items are rated on a 4- point Likert scale (1 = *agree strongly*, 4 = *disagree strongly*). Scores are summed across items for a total score, with higher scores indicating a higher degree of impulsivity (Cyders, Littlefield, Coffrey, & Karyadi, 2014). The SUPPS-P shows strong convergent validity with longer self-report measures of impulsivity (r = .64 -.84) as well as predictive validity with theoretically linked behavior (e.g., problematic drinking [b = 2.38, p < ,05], risky sexual behavior [b = 1.66, p < ,05]; Cyders et al., 2014).

The Snake and Spider Questionnaires – 12-item version (SNAQ-12; SPQ-12; Zsido, Arato, Inhof, Janszky, & Darnai, 2017). The SNAQ-12 asks participants to rate the fear they would feel across various situations involving snakes (e.g., "I am terrified by the thought of touching a harmless snake"). The SPQ-12 asks participants to rate the fear they would experience across various scenarios involving spiders ("If a picture of a spider crawling on a person appears on the screen during a motion picture, I turn my head away". These questionnaires were included to examine phobia-specific, rather than non-specific, responding during the DAT, given the possibility that, due to its shape and movement features, the robot in the DAT could remind participants of spiders or snakes. Both the SNAQ and the SPQ include 12-items, with dichotomous response formats (*true, false*). 'True' responses are summed to yield a total score ranging from 0-12. The SNAQ-12 and SPQ-12 are short-form versions of the SNAQ and SPQ, both of which are well-validated measures. Specifically, the SNAQ-12 and SPQ-12 are highly correlated with corresponding full-length scales (SNAQ-12: r = .89; SPQ=12: r = 0.91). Further, both scales show high discriminate validity, effectively discriminating between individuals diagnoses with corresponding spider or snake phobia and nonclinical controls (SNAQ-12: d = 2.91; SPQ-12: d = 1.58; Åhs et al., 2011; Kopp et al., 2005). and show discriminate validity for those with and without a specific phobia diagnosis (Zsido et al., 2017). The SNAQ-12 and SPQ-12 were completed at the end of study participation in order to avoid priming effects for the ATT. These questionnaires were added to the study fourteen months into data collection and were only completed by the subset of participants who had time remaining after completing other study tasks completed the SNAQ-12 and SPQ-12 (n = 40).

Physiological Arousal: Skin Conductance Level. SCL was collected to measure anxiety at the physiological level during each trial of the DAT (e.g., Beckers et al., 2013; Lipp, 2006; Bradley & Lang, 2000). SCL is a form of electrodermal activity (EDA), or automatic changes in electrical properties in the skin. SCL is the slower acting component of EDA, reflecting general changes in automatic arousal over seconds to minutes (Cacioppo, Tassinary, Berntson, 2000). During the DAT, skin conductance level was collected using Biopac's MP150 Data Acquisition System (Biopac Systems, Inc.) running Acknowledge 4.2 software. Participants' skin was prepared by asking them to gently wash their hands with water and non-abrasive soap (Boucsein et al., 2012). Two disposable electrodes (EL507-10) with isotonic gel were placed adjacently on the volar surfaces of distal phalanges on the third and fourth fingers of the non-dominant hand, reducing movement artifacts, and secured with surgical tape. A Galvanic Skin Response module (GSR100C) with gain set to 10 µΩ/V, low pass filter set to 1 Hz, and high pass filter set to DC was used to collect skin conductance data in the range of 0-100 microsiemens (µS). The signal was sampled at 1 kHz in AcqKnowledge.

A 3 min baseline SCL recording was taken prior to the DAT, before providing the task instructions. Data was examined for outliers and outliers were checked for movement artifacts and excluded when present. SCL was standardized via the following proportion: $(SCL_n - SCL_{min}) / (SCL_{max} - SCL_{min})$, with SCL_{min} representing the minimum SCL_n during baseline, SCL_{max} representing the maximum SCL across the entire task, and SCL_n representing the average amplitude during the n^{th} trial (Dawson et al., 2001). SCL data was log transformed to reduce skew and kurtosis (log [SCL +1]; Cacioppo, Tassinary, Berntson, 2000; McTeague, Lang, Laplante, & Bradley, 2011).

Procedure

A flowchart of study procedures can be seen in Figure 2. After a brief description of the study on the telephone, research assistants obtained verbal consent to conduct a phone screen and subsequently asked screening questions related to eligibility (e.g., past diagnosis of psychotic disorder). Interested participants were given a link to complete the SHAPS (Snaith et al., 1995) online. Those meeting criteria for either high or low anhedonia groups were invited to participate in the study. After written informed consent, participants completed self-report questionnaires (SHAPS, QIDS-SR, STAI, PDS-5, AUDIT, CUDIT-R, MEAQ-Avoidance, SUPPS-P, DOSPERT). Next participants completed the DAT (≈45 min) and the PRT (≈12 min; Pizzagalli et al., 2005), the order of which was counterbalanced across participants.

The room where the DAT was completed included a one-way mirror to the physiological suite. As participants entered the room, it was dimply lit with a red light. Participants sat in the chair in front of the DAT box, removed the eye hole covering, and were instructed to adjust the chair height so that their eyes were level with the eye hole. They were then asked to peer into the eye hole and confirm that they could see the six, two-by-two parallel marks where the coins would be placed. Next, participants were asked to reach inside the box and touch each of the six marks, and to move their chair closer to the box so they could easily reach each mark. The chair's settings were then adjusted so that the wheels were locked and it no longer rotated. Next, SCL sensors were attached to their non-dominant hand and a 3-min resting baseline SCL was collected. During the baseline SCL, participants were told to remain seated and to relax and stay as still as possible. Afterwards, participants were told: "*The goal of this task is to earn as much* *money as possible, by reaching inside the box and retrieving coins. While you are retrieving the coins, there will be a robot inside the box moving around*." If participants asked questions about the robot prior to starting the task, research assistant replied: *"The robot will be in the box and it will move. You will understand more when you begin the task."* Participants were next told: "*Some trials you can earn money and some trials you cannot earn money*" and were subsequently shown examples of the two types of coins and how to differentiate between reward and no-reward coins. Participants were told both the value of each individual reward coin ($0.35) and the total possible amount to be earned in the task ("*A little less than $38*"), which would be given, in cash, upon completion of the study. Participants were also instructed to use only their dominant hand to retrieve the coins, to keep their non-dominant hand (with the SCL sensors) on the table, with palm up and to move it as little as possible. Participants were also told to only retrieve one coin at a time, and to place each coin in the bowl in front of their dominant hand before retrieving another coin.

Once the DAT was explained, participants were asked to give a SUDs rating before beginning the task. The research assistant explained that the SUDs scale "*works like a thermometer with '0' being the most relaxed you have ever been and a '100' being the most distressed, uncomfortable, or anxious you have ever been.*" At the end of each trial, participants were asked for their "peak SUDs," which was explained as the "*greatest level of anxiety or distress experienced during the last trial."* At the start of each trial, participants were told either: "*This is a money trial and you can earn up to $4.20*" or "*This is a no money trial; you will not earn money for this trial.*" Then, the research assistant counted down from three and the participant removed the cover, placed it in front of them on the table, and began the trial. Eighteen trials were conducted, in blocks of six, with trial order counterbalanced across reward and threat within each of the three blocks. At the end of the DAT, sensors were removed, and participants were told their total earning for the task.

Participants completed the PRT in a private room, on a computer with an 18 in. monitor and Windows XP software, at a viewing distance of approximately 18 in. A trained research assistant read the instructions appearing on the screen out loud and then left the room during task completion. Participants were told that their task was to decide whether a face with a “big” or “little” mouth was presented by pushing the correct button as quickly and as accurately as possible. The two keys (“V” or the “M”) were marked on the keyboard with red and yellow stickers to ensure identification of the correct key. Participants were told that they would be compensated for however much they earned in the task at the end of their study visit.

After completing of the DAT and PRT, participants with study time remaining (<2.5 hr) completed the phobia questionnaires (SFQ, SPFQ). Finally, participants were debriefed and given, in cash, either their cumulative earnings from each task, or $5 per 15 min of study participation, whichever was the greater total allotted amount.

Data Analytic Strategy

Power analysis. Results from prior studies using approach-avoid conflict tasks were examined to estimate the expected effect size for the current study. In behavioral avoidance task studies in phobic versus not phobic individuals, effect sizes were large (e.g., d = 0.90 - 2.15; Olatunji et al., 2008a, 2008b; Matthews et al., 2015). In a computerized risk-based approach-avoid task, effect size was also large (d = 0.74; Pittig et al., 2014c). Finally, in the prey-predator robogator paradigm (Choi & Kim, 2010), there have been large effects (d = 1.49; Choi & Kim, 2010). Together, estimates range from d = 0.74 - 2.15. Based on this range, it was anticipated that at least a moderate effect (d = 0.50) would be observed.

Power analyses were conducted using G*Power 3.1 (Faul et al., 2007) focusing primarily on anhedonia, reward, and threat interaction hypothesis, examining an anhedonia group (2: low anhedonia, high reward) x reward (2: low reward, high reward) x threat (3: low threat, moderate threat, high threat) interaction, with between-subjects factors of anhedonia group and within factors of reward and threat. Parameters were set for a repeated measures ANOVA, with power set at .80, alpha set at .05, and assuming $r = .50$ correlation across repeated measures, $\varepsilon = 1.00$ for sphericity assumption. To detect a moderate effect ($f = 0.20$), for the anhedonia x reward x threat interaction, assuming repeated measures on threat and reward, 28 participants per group were needed.

Data Reduction. Data was screened prior to analysis to ensure accuracy of entered data and checking for missing values. Less than 2% of data was missing. For DAT dependent variables, missing values (3.3%) were estimated using regression, including other DAT dependent variables, demographic variables, and measures of psychopathology to predict missing values for incomplete cases (Tabachnick & Fidell, 2006). Data was checked for parametric test assumptions such as normality, homogeneity of variance, and independence (Tabachnick & Fidell, 2006). SCL data was standardized to control for individual differences and transformed to address skew and kurtosis (log [SCL +1]).

General analytic strategy. For the anhedonia effect, gender effect, anhedonia, reward, and threat interaction hypotheses, we conducted separate univariate repeated measures ANOVAs. Repeated measures ANOVAs were used instead of multivariate analysis of variance (MANOVA) because of expected discordance of behavioral, subjective, and physiological indices (Lang, Bradley, & Cuthbert, 1998; Mauss & Robinson, 2009). Indeed, the four dependent variables were not highly correlated and, thus, a univariate approach, examining one dependent variable at a time, was preferable (Tabachnick & Fidell, 2006). Although there were significant differences across low and high anhedonia groups (e.g., years of education, state and trait anxiety, behavioral avoidance, and impulsive behavior), analysis of covariance (ANOCOVA) was not used given that controlling for group differences is inappropriate when pre-treatment differences likely reflect meaningful differences attributable to group membership (Miller & Chapman, 2001; Strauss, 2001). Indeed, ANCOVA assumes independence between covariates and group membership, which is likely not the case when studying preexisting groups, and, thus, statistically controlling for group differences is inappropriate and risks removing considerable variance due to the independent variable. Finally, Type II sums of squares were use to account for unbalanced sample sizes when conducting the ANOVAs to examine the gender effects (Langsrud, 2002).

Separate ANOVAs were conducted for each dependent variable, including response latency for first reward retrieval, total reward obtained, subjective level of distress (SUDs), and physiological responding (SCL). The repeated measures ANOVA conducted for the anhedonia effect and the anhedonia x reward x threat interaction effect was a 2 (group: low anhedonia, high anhedonia) x 2 (reward: low reward, high reward) x 2 (threat: low threat, moderate threat, high threat) x 3 (time: block 1, block 2, block 3). Similarly, the repeated measures ANOVA conducted for the gender effect hypothesis was a 2 (group: men, women) x 2 (reward: low reward, high reward) x 3 (threat: low threat, moderate threat, high threat) x 3 (time: block 1, block 2, block 3). Significant main and interaction effects were followed-up with simple effects analyses to specify the nature of the observed effect, examining simple main effects between groups across relevant threat and reward factors and also examining across relevant reward and threat factors within conditions. Given that it was not expected that gender would moderate the relationship between anhedonia and avoidance and fear responding, a four-way interaction was not predicted.

For the moderator effects hypotheses, we used a multiple regression framework, examining the data for violation of assumptions. If variance inflation factor indicated multicollinearity, theoretically and analytically informed decisions were made about which variable(s) to consider dropping. Specifically, depression (QIDS-SR) and trait anxiety (STAI-T) were strongly correlated ($r = .79$, $p < .001$), violating the multicollinearity assumption. Based on stronger empirical support for trait anxiety as a predictor of avoidance and fear responding, compared to the depression, depression (QIDS-SR) was excluded from the regression analyses. Using four simultaneous multiple regressions, baseline predictors of reward propensity (PRT DResponse Bias), self-report anxiety (STAI-T), depression severity (QIDS-SR), avoidance (MEAQ – behavioral avoidance subscale), and PTSD severity (PDS-5) were used to predict longer latency for first reward retrieval, less reward obtained, higher subjective level of distress, and higher SCL in the no reward, high threat condition and in the high reward, high threat condition, averaging across trials and blocks. Both the no reward and high reward conditions were chosen to compare predictors in a condition where there was little conflict (no reward) and high conflict (high reward). The high threat condition was chosen in both cases because high threat was expected to elicit the greatest degree of fear responding; and, relatedly, fear and reward-related system characteristics would be expected to have the greatest impact, leading to the greatest variability of responding across participants.

For the mediation hypothesis, PROCESS macro model 4 was used (Hayes, 2013) to examine whether the moderating effect of trait anxiety on avoidance may be mediated by subjective distress (SUDs) and physiological responding (SCL) (separately) in trial responding.

Dependent variables were response latency for first reward retrieval (s) and total reward obtained (*n* coins) in the no reward, high threat condition and the high reward, high threat condition, averaged across block 1, block 2, and block 3. These conditions were chosen for similar reasons to in the above predictor analyses. The PROCESS model was set to use 5,000 bootstrap resamples, which is shown to reduce the likelihood of Type 1 and Type II errors due to small sample sizes (Hayes, 2013). The analysis yielded both coefficient and standard error estimates for the predictor, mediator, and interaction term. InterActive was used to visualize the data, examining simple slopes for the mean, and one and two standard deviations above and below the mean (McCabe, Kim, & King, 2018).

Results

For descriptive of baseline demographics and baseline psychopathology see Table 1. There were no group differences between the high and low anhedonia groups in terms of age, gender identity, race, and ethnicity. The high anhedonia group had, on average, completed fewer years of education compared to the low anhedonia group, $t(78) = 2.23$, $p = .03$, $d = 0.50$.

As expected, there were group differences between the high and low anhedonia groups on measures of psychopathology, such that individuals in the high anhedonia group had higher levels of self-report state anxiety ($t(78) = -4.92$, $p < .001$, $d = 1.10$), trait anxiety ($t(78) = -6.55$, $p < .001$, $d = 1.47$), depression ($t(78) = -7.36$, $p < .001$, $d = 1.65$), and self-report behavioral avoidance ($t(78) = -2.75$, $p < .01$, $d = 0.61$). Additionally, participants in the high anhedonia group self-reported higher on impulsive behavior ($t(78) = -3.11$, $p < .003$, $d = 0.70$). Groups did not differ on self-report posttraumatic stress disorder symptoms or symptoms related to alcohol and marijuana misuse. The high and low anhedonia groups did not significantly differ on snake fearfulness, but the high anhedonia group scored higher on spider fearfulness compared to the low anhedonia group ($t(38) = -2.13$, $p = .04$, $d = 0.66$).

Avoidance and Fear Responding Across Level of Anhedonia, Reward, Threat, and Block

Means and standard deviations for the main dependent variables on the DAT can be seen in Table 2. To examine the main hypothesis that anhedonia would impact responding on the DAT, a 2 (group: low anhedonia, high anhedonia) x 2 (reward: no reward, high reward) x 3 (threat: low threat, moderate threat, high threat) x 3 (time: block 1, block 2, block 3) repeated measures ANOVAs were conducted. Dependent variables were response latency for first reward retrieval (s), amount of reward obtained (*n* coins), self-report peak distress (SUDs), and physiological responding measured via skin conductance level (SCL).

Latency for first reward retrieval. For response latency (s) to first coin retrieval, with longer retrieval time reflecting greater avoidance, the repeated measures ANOVA showed that there was a main effect of reward, $F(1, 78) = 39.23$, $p < .001$, with longer response latency for no reward trials ($M = 3.58$, $SD = 0.85$) compared to high reward trials ($M = 3.17$, $SD = 0.74$), $d = 0.70$. There was also a main effect of threat, $F(2, 77) = 21.74$, $p < .001$. Response latency was shorter at low threat ($M = 3.28$, $SD = 0.76$) compared to high threat ($M = 3.67$, $SD = 0.99$), $d = 0.50$, and moderate threat ($M = 3.19$, $SD = 0.85$) compared to high threat, $d = 0.64$. There was also a main effect of time, $F(2, 77) = 132.81$, $p <.001$, with quicker response latencies as time went on. Specifically, response latency was slower in block 1 ($M = 4.08$, $SD = 1.1$) compared to block 2 ($M = 3.08$, $SD = 0.70$), $d = 1.32$, and slower in block 2 compared to block 3 ($M = 2.96$, $SD = 0.76$), $d = 0.22$. Thus, response latency was faster when reward was offered, compared to no reward, faster at lower levels of threat compared to higher, and faster later in the task compared to earlier.

There was no main effect of anhedonia and also no interaction effect anhedonia group among reward, threat, or time. However, the above main effects were modified by a reward x threat interaction, $F(2,77) = 9.44$, $p < .001$, reward x block interaction, $F(2,77) = 5.10$, $p = .01$, and a reward x threat x block interaction, $F(4, 75) = 13.73$, $p < .001$. Follow-up analyses examining the reward x threat interaction separately for each of the three blocks showed an interaction during early task responding. As seen in Figure 3, there was a significant reward x threat interaction, $F(2, 77) = 18.41$, $p < .001$, such that in the no reward condition, response latencies were slower as a function of threat, with longer response times at high threat ($M = 5.37$, $SD = 2.38$) compared to moderate threat ($M = 4.04$, $SD = 1.43$; $d = 0.60$) and low threat ($M = 3.83$, $SD = 1.30$; $d = 0.65$); the low and moderate threat conditions did not significantly differ. In the high reward condition, however, the opposite effect occurred, with response latency slightly slower at low threat ($M = 4.15$, $SD = 2.17$) compared to moderate threat ($M = 3.52$, $SD = 1.52$; $d = 0.25$) and low threat compared to high threat ($M = 3.58$, $SD = 1.19$; $d = 0.26$), and response latency at moderate and high threat not significantly different. However, this reward x threat interaction was not significant in block 2 and block 3. Thus, during early task responding, latencies increased or remained stable as threat increased in the no reward condition and latencies became faster or remained stable as threat increased in the high reward condition. However, in middle and late task responding, main effects of both reward and threat were maintained but there was no interaction across reward and threat.

Total coins retrieved. Fewer total coins retrieved on the DAT represented greater avoidance. When examining total number of coins retrieved on the DAT, as hypothesized, there was a main effect of reward level, $F(1, 78) = 81.16$, $p < .001$, with more coins retrieved on high reward trials ($M = 9.71$, $SD = 1.53$) compared to no reward trials ($M = 8.66$, $SD = 1.66$), $d =$

0.98. There was also a main effect of threat, $F(2, 77) = 137.30$, $p < .001$. Specifically, more coins were retrieved at low threat ($M = 9.83$, $SD = 1.54$) compared to moderate threat ($M = 9.57$, $SD = 1.52$), $d = 0.38$, and moderate threat compared to high threat ($M = 8.16$, $SD = 1.75$), $d = 1.38$. The main effect of time was also significant, with more coins retrieved in later blocks compared to earlier blocks, $F(2, 77) = 278.82$, $p < .001$. More reward was retrieved in block 1 ($M = 8.01$, $SD = 1.67$) compared to block 2 ($M = 9.55$, $SD = 1.56$), $d = 1.97$, and block 2 compared block 3 ($M = 10.00$, $SD = 1.50$), $d = 0.64$.

Examining the key hypothesis that level of anhedonia would moderate approach-avoid conflict behavior, the main effect of reward was modified by an anhedonia x reward interaction, $F(1,78) = 4.06$, $p = .047$. To examine the two-way interaction, follow-up analyses were conducted comparing high to low anhedonia groups on number of coins retrieved on no reward trials and high reward trials separately. As seen in Figure 4, simple effects analyses showed that those in the high anhedonia group retrieved fewer coins on no reward trials ($M = 8.28$, $SD = 1.79$) compared to those in the low anhedonia group ($M = 9.02$, $SD = 1.47$; $d = 0.46$); however, on reward trials, low and high anhedonia groups did not significantly differ in number of rewards retrieved. Thus, specifically when no competing reward was offered for approach, participants with high anhedonia, compared to low, retrieved fewer coins. When reward was available, high and low anhedonia groups did not differ in total coins retrieved.

Just like the effects for response latency, the main effects reward and threat were also modified by a reward x threat interaction, $F(2,77) = 42.77$, $p < .001$ and a reward x threat x block interaction, $F(4, 75) = 33.47$, $p < .001$. Follow-up analyses showed a similar pattern found as when examining number of coins retrieved (see Figure 5). Specifically, examining the reward x threat interaction, separately for each of the three blocks, showed that the reward x threat interaction occurred during initial task responding. Specifically, as seen in Figure 5, in block 1, there was a significant reward x threat interaction effect, $F(2, 77) = 74.17$, $p < .001$, where in the no reward condition, the number of coins retrieved decreased as a function of threat, with more coins retrieved at low threat ($M = 9.00$, $SD = 1.99$) compared to moderate threat ($M = 7.63$, $SD = 2.10$; $d = 0.91$) and moderate threat compared to high threat ($M = 5.61$, SD = 2.08; $d = 1.07$). In the high reward condition for block 1, the number of coins retrieved was, in contrast, slightly higher at moderate threat ($M = 9.15$, $SD = 2.14$) compared to low threat ($M = 8.27$, $SD = 2.47$; $d = 0.39$). The number of coins in the moderate threat condition was also higher than in high threat ($M = 8.43$, SD = 1.99; $d = 0.40$). Interestingly, however, the number of coins at low threat did not significantly differ from coins retrieved at high threat; thus, the pattern was not linear, but instead, increased from low to moderate threat and then decreased from moderate threat to high threat. However, in block 2 and 3, this interaction was not significant.

In sum, again, in the initial phase of the DAT, when reward was not available, number of coins decreased as a function of threat; when reward was available, number of coins stayed relatively stable when comparing low threat to high threat and, at moderate threat, the number of coins was slightly higher than at both low threat and high threat. However, in the middle and late phase of the task, again, main effects of reward and threat were maintained, with more coins retrieved at high reward compared to low and lower threat compared to higher, but the interaction between reward and threat level was no longer present.

Subjective units of distress. When examining peak subjective distress (SUDs), there was a main effect of reward, $F(1, 78) = 11.80$, $p = .001$, with higher SUDs on high reward trials ($M = 36.77$, $SD = 21.68$) compared to no reward trials ($M = 34.5$, $SD = 21.68$), $d = 0.39$. As expected, there was also a main effect of threat, $F(2, 77) = 26.04$, $p < .001$. Specifically, peak

SUDs were lower at low threat (*M* = 34.16, *SD* = 20.97) compared to moderate threat (*M* = 35.53, *SD* = 21.64), *d* = 0.43, and moderate threat compared to high threat (*M* = 37.22, *SD* = 20.84), *d* = 0.41. There was also a main effect of time, *F* (2, 77) = 6.12, *p* = .003. SUDs were higher in block 1 (*M* = 37.67, *SD* = 20.83) compared to block 3 (*M* = 33.54, *SD* = 23.14), *d* =0.29, and block 2 (*M* = 35.7, *SD* = 21.84) compared block 3, *d* = 0.31. There was no main effect of anhedonia group and no significant interaction effects. See Figure 6. Thus, like the behavioral avoidance variables, subjective distress was higher when reward was available, compared to when it was not, and higher when threat was higher, compared to lower. Subjective distress also decreased over the course of the task, with higher subjective distress at the start of the task compared to the end of the task.

Skin conductance level. Next, for SCL, again, there was a main effect of reward, *F*(1, 69) = 110.57, *p* < .001, with lower SCL on no reward trials (*M* = 0.22, *SD* = 0.03) compared to high reward trials (*M* = 0.23, *SD* = 0.03), *d* = 1.25. As expected, there was also a main effect of threat, with decreased SCL at lower threat compared to higher threat, *F*(2, 68) = 26.51, *p* < .001. Specifically, SCL was lower at low threat (*M* = 0.21, *SD* = 0.03) compared to moderate threat (*M* = 0.22, *SD* = .03), *d* = 0.33, and moderate threat compared to high threat (*M* = 0.23, *SD* = 0.03), *d* = 0.50. The main effect of time was not significant. There were no interaction effects with anhedonia.

Like response latency and coins retrieved dependent variables, the main effects were modified by a reward x threat interaction, *F*(2, 68) = 4.250, *p* < .02, and a reward x threat x block interaction, *F*(4, 66) = 7.25, *p* < .001. Follow-up analyses examining the reward x threat interaction separately for each of the three blocks were conducted. As seen in Figure 7, the pattern mirrors the interaction effect found for both total coins retrieved and response latency.

Indeed, again, in block 1, the interaction was significant, $F(2, 68) = 8.19$, $p < .001$. Follow-up comparisons showed that, on no reward trials, SCL did not significantly differ as a function of threat, with no differences found between low threat, moderate threat, and high threat. On the other hand, in the high reward condition, SCL increased as a function of threat, with lower SCL at low threat ($M = 0.21$, $SD = 0.06$) compared to moderate threat ($M = 0.23$, $SD = 0.04$; $d = 0.28$) and lower SCL at moderate threat compared to high threat ($M = 0.24$, $SD = 0.03$; $d = 0.39$). However, this interaction effect was not significant in blocks 2 or 3.

In sum, mirroring the interaction effects found for response latency and total coins retrieved, during early task responding, the results show differential effects of threat in reward compared to no reward conditions. Skin conductance levels remained relatively stable across levels of threat in the no reward condition but, in the high reward condition, SCL increased as threat level increased. Again, however, in middle and late task responding, main effects of reward and threat were still present but the interaction between threat and reward was not maintained in these later blocks.

Gender Effects of Avoidance and Fear Responding

To investigate hypothesized gender effects on the DAT, repeated measures ANOVAs were conducted again, this time with between subjects effect of gender (2: men, women) and with within subject effects of reward level (2: no reward, high reward), threat level (3: low threat, moderate threat, high threat), and time (3: block 1, block 2, block 3) across the main dependent variables of response latency for first reward retrieval (s), amount of reward obtained (*n* coins), self-report peak distress (SUDs), and physiological responding measured via skin conductance level (SCL).

Latency for first reward retrieval. Response latency for first coin retrieval was examined as the dependent variable. Results from the repeated measures ANOVA showed the main effect of gender was not significant. However, again, there were main effects of reward, $F(1, 78) = 36.66$, $p < .001$, threat, $F(2, 77) = 16.51$, $p < .001$, and time, $F(2, 77) = 118.93$, $p < .001$, the directions of which are discussed in the previous section examining the anhedonia effect hypothesis. These main effects were not modified by gender. The above main effects were again modified by a significant reward x threat interaction, $F(2,77) = 9.38$, $p < .001$, reward x block interaction, $F(2,77) = 3.80$, $p = .01$, and a reward x threat x block interaction, $F(4, 75) = 13.92$, $p < .001$, again described in the previous section.

Total coins retrieved. When examining total coins retrieved as the dependent variable, the main effect of gender was not significant. However, main effects of reward, $F(1, 78) = 65.17$, $p < .001$, threat, $F(2, 77) = 119.18$, $p < .00$, and time, $F(2, 77) = 278.82$, $p < .001$, were significant. These effects are described in the above section examining the anhedonia effect hypothesis. The threat main effect was modified by a gender x threat interaction, $F(2, 77) = 7.36$, $p = .001$, partial $eta^2 = .09$. Follow-up analyses were examined separately for men and women, comparing low, moderate, and high threat. The within-subjects effect of threat was significant for both men, $F(2, 25) = 22.15$, $p < .001$, and women, $F(2, 49) = 78.99$, $p < .001$. As seen in Figure 8, simple effects analyses showed that while total coins retrieved decreased as threat increased across both men and women, the overall effect of threat was slightly more pronounced in women. Specifically, men retrieved fewer coins at moderate threat ($M = 9.51$, $SD = 1.70$) compared to low threat ($M = 9.83$, $SD = 1.56$; $d = 0.44$) and fewer coins at high threat ($M = 8.58$, $SD = 1.71$) compared to moderate threat, $d = 1.01$. Mirroring the same pattern, women similarly retrieved fewer coins at moderate threat ($M = 9.62$, $SD = 1.43$) compared to low threat ($M = 9.82$, *SD* = 1.54; *d* = 0.34) and high threat (*M* = 7.92, *SD* = 1.71; *d* = 1.70) compared to moderate threat. Comparing effect sizes, the effect across the threat continuum, from low to high, was slightly larger in women (*d* = 1.57) compared to men (*d* = 1.42). Although men and women did not significantly differ at any level of threat, the difference in number of coins retrieved approached significance at high threat, with men retrieving more coins than women at high threat, $F(1, 77) = 2.87$, $p = .09$, $d = 0.39$. In sum, women showed a slightly greater attenuation of coins retrieved compared to men when comparing across low to high threat.

Again, the main effects reward and threat were also modified by a reward x threat interaction, $F(2,77) = 40.78$, $p < .001$ and a reward x threat x block interaction, $F(4, 75) = 29.85$, $p < .001$, the nature of which is described above.

Subjective units of distress. Next, a repeated measures ANOVA was conducted, with dependent variable of subjective distress (SUDs). The main effect of gender was not significant. Again, there were main effects of reward, $F(1, 78) = 9.99$, $p = .002$, threat, $F(2, 77) = 23.31$, $p < .001$, and time, $F (2, 77) = 5.01$, $p = .008$, which are described previously.

There was also a significant gender x reward x threat interaction, $F(2, 77) = 4.08$, $p = .02$, partial eta^2 = .05. Follow-up analyses were conducted to examine the gender x threat interaction separately for the no reward and high reward conditions. In the no reward condition, there was a significant gender x threat interaction, $F(2, 77) = 3.61$, $p = .03$, partial eta^2 = .04. In the no reward condition, men did not show increased distress from low threat to moderate threat or moderate to high threat. However, women did show significant increases in subjective distress from low threat (*M* = 32.87, *SD* = 21.16) to moderate threat (*M* = 35.37, *SD* = 21.82; *d* = 0.50) and low threat to high threat (*M* = 36.02; *SD* = 21.09, *d* = 0.93). However, in the high reward condition, the gender x threat interaction was not significant. See Figure 9.

In sum, although overall men and women did not differ on subjective distress, in the low reward condition specifically, men showed similar levels of distress across low to high threat, whereas women showed a pattern consistent with the main effect of threat, with higher subjective distress from low to high threat.

Skin conductance level. Finally, examining SCL as the dependent variable, results showed the main effect of gender was not significant. Again, there was a main effect of reward, $F(1, 69) = 104.31$, $p < .001$ and threat, $F(2, 68) = 22.36$, $p < .001$, the patterns of which were described earlier. There were no interaction effects involving gender but, again, there was a reward x threat interaction, $F(2, 68) = 4.25$, $p < .02$, and a reward x threat x block interaction, $F(4, 66) = 7.18$, $p < .001$, which were described in the previous section.

In sum, gender main effects were not found when examining DAT outcomes of response latency, total coin retrieved, SUDs, and SCL. However, examining total coins, gender modified the main effect of threat, showing that women showed a slightly greater decrease in total coins retrieved than men when comparing low threat to high threat conditions. Further, when examining subjective distress, men diverged from the typical pattern in the low reward condition, showing similar levels of distress across levels of threat.

Individual Predictors of Approach-Avoid Conflict Responding

Bivariate correlations among baseline psychopathology and individual predictors can be seen in Table 3. Individual characteristics hypothesized to moderate avoidance and fear responding were examined, specifically reward propensity on the PRT (DResponse Bias), trait anxiety (STAI-T), PTSD symptoms (PDS-5), and self-report behavioral avoidance (MEAQ). Dependent variables examined were response latency for first coin retrieval, total coins retrieved, peak subjective distress (SUDs), and physiological responding (SCL). Two conditions were examined: the no reward, high threat condition and high threat, high reward condition in each block separately (block 1, block 2, block 3).

Predictors of response latency for first coin retrieval. When examining response latency for first coin retrieval as the dependent variable, the model was not significant in block 1, block 2, or block 3, nor were any individual predictors significant. Similarly, examining response latency in the high reward, high threat condition, the model was not significant in any of the three blocks and neither were any of the individual predictors.

Predictors of total coins retrieved. When examining the above predictors for dependent variable of total coins retrieved in the no reward, high threat condition, the model was not significant in block 1, block 2, or block 3. However, individual high STAI-T predicted fewer coins retrieved in block 1, $b = -.30$, $t(75) = -2.22$, $p = .03$, block 2, $b = -.28$, $t(75) = -2.07$, $p = .04$, and block 3, $b = -.26$, $t(75) = -2.06$, $p = .04$. Examining these same predictors for total coins retrieved in the high reward, high threat condition, the models were not significant in block 1, block 2, or block 3, and the individual predictors were also not significant.

Predictors of peak subjective distress. When examining predictors of peak subjective distress in the no reward, high threat condition in block 1, the overall regression model was significant, $R^2 = .14$, $F(75) = 3.02$, $p = .02$. Specifically, higher trait anxiety (STAI-T) predicted higher peak SUDs, $b = .38$, $t(75) = 2.94$, $p = .004$. In block 2, the model was again significant, $R^2 = .13$, $F(75) = 2.73$, $p = .04$. Specifically, higher behavioral avoidance (MEAQ) predicted higher peak SUDs, $b = .26$, $t(75) = 2.07$, $p = .04$. However, by block 3, the model was not significant, nor did any of the individual predictors significantly predict SUDs in this condition in the final block.

When examining at the same set of predictors for peak SUDs in the high reward, high threat condition in block 1, again, the model was significant, $R^2 = .14$, $F(75) = 2.98$, $p = .02$. Specifically, higher behavioral avoidance (MAEQ) predicted higher peak SUDs, $b = .24$, $t(75) = 1.96$, $p = .05$, and, at a trend level, higher trait anxiety (STAI-T) predicted higher peak SUDs, $b = .23$, $t(75) = 1.80$, $p = .07$. In blocks 2, the model was not statistically significant, but higher behavioral avoidance did again individually significantly predict higher SUDs, $b = .29$, $t(75) = 2.25$, $p = .03$. In block 3, the model was not significant nor were any of the individual predictors.

Predictors of skin conductance level. Next, the above predictors were examined for SCL in the no reward, high threat condition in block 1, block 2, and block 3. In block 1, the model approached significance, $R^2 = .14$, $F(66) = 2.58$, $p = .051$, and higher behavioral avoidance significantly predicted lower SCL, $b = -.36$, $t(66) = 1.80$, $p = .01$. However, the model was not statistically significant in blocks 2 or 3, and neither were any of the individual predictors in either of these blocks. When examining these same set of predictors for the high reward, high threat condition, the model was not significant in blocks 1, 2, or 3 and the individual predictors were also not significant.

In sum, STAI-T was a significant, moderately strong individual predictor for total coins retrieved across blocks in the no reward, high threat condition only. Similarly, trait anxiety and behavioral avoidance moderately predicted higher subjective distress and lower skin conductance, particularly during early task responding. No other baseline variables emerged as strong predictors of response on the DAT.

Indirect Effect of Trait Anxiety on Approach-Avoid Conflict Responding

Finally, to test the hypothesis that higher subjective distress and higher physiological responding would mediate the strength of the relationship between trait anxiety and longer latency for first reward retrieval and less coins obtained was examined using PROCESS macro model 4 (Hayes, 2013).

Mediating effect of subjective distress. First subjective distress (SUDs) was tested as a mediator of the relationship between trait anxiety and response latency for first coin retrieval in the no reward, high threat condition, the overall model and the indirect effect were not significant. A similar model was examined for the high reward, high threat condition. Again, results of the model showed that the both the overall model and the indirect effect were not significant.

Next, similar mediation models were tested for total coins retrieved. First, for the no reward high threat condition, the mediation analysis yielded a significant overall model, $F(2, 77) = 4.83$, $p = .01$, $R^2 = .11$. The direct effect between trait anxiety and subjective distress (SUDs) was significant, such that higher trait anxiety significantly predicted higher subjective distress ($b = .45$, $p = .01$, 95% CI = [0.11, 0.79]. Higher peak subjective distress predicted fewer total coins retrieved ($b = -0.02$, $p = .04$, 95% CI = [-0.04, -.01]. While the direct effect of trait anxiety predicting total coins retrieved was not statistically significant, the indirect effect was significant ($b = -.01$, 95% CI = [-0.02, -.0003]. InterActive (McCabe, Kim, & King, 2018) was used to visualize the results of the indirect effect, indicating a mediation effect. As can be seen in Figure 10, at below the mean, subjective distress did not predict total coins obtained. However, for individuals with average trait anxiety (b = -0.02, 95% CI = [-0.04, 0]), individuals with trait anxiety one standard deviations above the mean (b = -0.03, 95% CI = [-0.06, 0]), and individuals with trait anxiety two standard deviations above the mean ((b = -0.05, 95% CI = [-0.09, 0]), higher subjective distress significantly predicted fewer total coins obtained.

Next, a similar model was tested, examining the high reward, high threat condition. The overall model was not significant and neither was the indirect effect.

Mediating effect of skin conductance level. SCL was similarly tested as a mediator of the relationship between trait anxiety (STAI-T) and response latency for first coin retrieval and total coins retrieved. First, response latency in the no reward, high threat condition was examined. The model and indirect effects were not significant. Similarly, when examining the high reward, high threat condition, the overall model and indirect effects were not significant.

Next, total coins retrieved was examined as the dependent variable. The model and indirect effects were not significant. Similarly, for the high reward, high threat condition, the model and indirect effects were not significant.

Thus, in the no reward, high threat condition, higher trait anxiety combined with higher subjective distress was associated with decreased coins retrieved. When reward was available, this effect was not present and the effect was also not significant across indices when examining higher trait anxiety combined with higher physiological arousal.

Discussion

Approach and avoidance are fundamental for survival, protecting from injury and death and enabling acquisition of reinforcers that are essential for well-being. Often, approach and avoidance motivations are in opposition, such as when a rat must leave its safe nest to search for food in a predator environment or when a sexual assault survivor must leave her house to earn a salary or spend time with friends. In an analogue approach-avoid conflict, individuals with high anhedonia showed more avoidance than those with low anhedonia when approach was not incentivized with monetary reward; yet, these groups were not different in avoidance when approach was incentivized. Thus, individuals with high anhedonia may be at greater risk for avoidance compared to those with low anhedonia, but only when approach is not maximally rewarding. Although anhedonia impacted responses to reward, anhedonia did not impact responses to threat. Furthermore, trait anxiety, but not reward propensity, was predictive of greater distress in the approach-avoid conflict. Therefore, the impacts of anhedonia on avoidance may be specifically via the reward pathway, by way of reducing motivation to approach. Notably, across all participants, avoidance was reduced when a reward was available compared to when it was not, and this effect was most pronounced during initial responding. Specifically, during first approach of threat, avoidance was higher as threat level increased when approach was not incentivized; with incentives, avoidance remained relatively stable as threat increased. Thus, approach rewards can effectively buffer initial avoidance behavior in high threat situations. Finally, while women did not avoid more than men overall, threat levels had a more significant impact on avoidance behavior among women compared to men. Increased avoidance in the context of higher threat among women may lead to decreased inhibitory learning and contact with reinforcers, potentially helping to explain greater prevalence of anxiety and depression in women compared to men.

Maladaptive avoidance in individuals with anhedonia may be related to a lesser impact of more subtle rewards across levels of threat. Anhedonia is a common feature of both depression and anxiety that is consistently associated with reduced approach/avoidance motivation (Abramovitch et al., 2014; Bedwell et al., 2014; Carmassi et al, 2014; Cooper, et al., 2018; Franklin & Zimmerman, 2001). In the present study, anhedonia impacted avoidance responding, but the effect was specific to when external incentives were not offered in exchange for approaching the threat. Specifically, individuals with high anhedonia retrieved fewer coins on trials in which monetary reward was not available compared to individuals with low anhedonia.

When monetary reward corresponded with the amount of coins retrieved, however, individuals high and low on anhedonia performed similarly. However, individuals high and low on anhedonia did not differ at either level of reward in terms of how fast they were when first approaching coins, subjective distress, or physiological arousal, suggesting the effect of anhedonia is specific to overt behavior, which translates directly to the magnitude of reward obtained. This effect was present regardless of threat level, suggesting that incentives can be used across a spectrum of threat levels to motivate approach.

Pathological avoidance in individuals with high anhedonia could be related to an attenuated impact of less overt rewards across levels of threat. Anhedonia has been consistently associated with a decreased willingness to expend effort in order to obtain reward but, interestingly, this effect is primarily found when probability of reward is low and not when probability of reward is high (Geaney, Treadway, & Smillie, 2015; Treadway, Bossaller, Shelton, & Zald, 2012; Wardle, Treadway, Mayo, Zald, de Wit, 2011). This study extends these findings to situations in which the reward is paired with threat, rather than tied to effort, and in which reward magnitude, rather than probability, is manipulated. Taken together, the impact of anhedonia may differ based on both the likelihood and nature of the reward outcome. Anhedonia may have less of an impact when approach-avoid conflict situations are highly reinforcing. On the other hand, anhedonia may diminish willingness to expend effort and endure distress when approach is minimally reinforced.

One theoretical reason why individuals with higher anhedonia engage in fewer rewarding experiences is that it allows them to avoid activities that may be difficult, punishing, or anxiety provoking (Hopko, Armento, Cantu, Chambers, & Lejuez, 2003). This is problematic because avoidance removes individuals from potential sources of positive reinforcement (Jacobson, Martell, & Dimidjian, 2011; Trew, 2011). This study suggests the impact of anhedonia may be specific to behavioral responding, rather than how distressed or fearful an individual feels when facing a difficult or anxiety-provoking situation. Further, decreased approach of such situations when rewards are minimal in individuals with anhedonia may occur across the spectrum of threat, rather than only at one end of the spectrum or the other. Many daily, difficult, or distressing activities are not maximally reinforcing but, instead, incrementally, unexpectedly, or distally reinforcing. For example, a walk can result in positive emotions or contribute to long-term health; completing taxes can contribute to feelings of mastery and relief. In the DAT, the goal was to retrieve as many coins as possible, whether monetary reward was available or not. Participants still retrieved coins, even when approach was not incentivized with monetary reward. This suggests other forms of reinforcement were at play, motivating approach of the threat even when money was not added as a reinforcer; this scenario was more motivating for individuals with low anhedonia compared to high anhedonia. Other possible reinforcers during the approach-avoid conflict task included a sense of mastery gained by performance improvement or internal satisfaction and pride. It may be that these types of secondary reinforcers were not as motivating to individuals with higher anhedonia, given the localization of the effect to the no reward condition. Individuals with anhedonia may lose interest in these non-specific reinforcers first, marking the start of a downward spiral towards decreased approach behavior. Decreased motivation to complete distressing or unpleasant tasks that involve adjacent or incidental rewards rather than maximal reinforcers could help explain why individuals with anhedonia ultimately approach distressing situations less and have comparably fewer positive experiences. In turn, anxiety persists and depression may develop (Jacobson et al., 2011; Ottenbreit & Dobson, 2004).

The attenuation of avoidance after adding monetary incentives in individuals with high anhedonia suggests that leveraging rewards may be an effective strategy for buffering against avoidance in individuals with anhedonia. Avoidance is problematic for many reasons: it blocks opportunities for inhibitory learning and potential contact with positive reinforcement, and it can exacerbate unresolved problems or create new problems (Craske et al., 2014; Jacobson et al., 2001; Martell, Addis, & Jacobson, 2001). The current findings are particularly clinically encouraging in that salient rewards may still be effective motivators for individuals with anhedonia, even when the task at hand requires facing something potentially anxiety provoking. The caveat is that individuals with anhedonia may be harder to motivate when rewards are minimal or ambiguous. Specific strategies may be needed in order to help individuals with anhedonia recognize potential rewarding outcomes of engaging in distressing situations, such as positive emotions and a sense of mastery (e.g., Craske, Meuret, Ritz, Treanor, & Dour, 2016). Through discussion of these outcomes, including why these outcomes are beneficial, these positive rewards may become more salient and desirable. In some cases, it may even be beneficial to specifically initiate an incentive schedule, such as getting to watch a favorite television show, eat at a favorite restaurant, or receive a voucher after approaching something dreaded or fear-inducing. Critically, as evidenced in the current study, individuals with anhedonia can be motivated by rewards in approach-avoid conflict situations, and it may be even more important to emphasize and leverage concrete rewards.

The impact of anhedonia on avoidance is consistent with substantial evidence and well-established theories associating anhedonia with disruption to appetitive motivation and approach deficits (Pizzagalli, 2014; Treadway & Zald, 2011). However, the current study did not find evidence to support the prediction that individuals with high anhedonia would also show augmented avoidance as a function of greater threat level. Threat was an important factor leading to increased avoidance across indices, including increased time for approach, decreased coins retrieved, increased subjective distress, and increased physiological arousal, but anhedonia did not lead to even greater avoidance or fear responding at higher threat. Therefore, anhedonia alone may not result in augmented or maladaptive threat responding; nevertheless, anhedonia can still play an important role in avoidance. Specifically, the pathway from anhedonia to maladaptive avoidance may be primarily by way of pathological reward responding, given that threat and reward are often juxtaposed and individuals have to decide to prioritize approach or avoidance based on the relative value of outcomes. On the other hand, distress-related responding in the approach-avoid conflict was predicted by anxious traits rather than reward functioning. Thus, the pathway from trait anxiety to pathological avoidance is more likely linked to the impact of anxiety on responding to threat, as supported by a dearth of previous studies (e.g., Loh et al., 2017; Klein, Schner, Ginat-frolich, Vervliet, Shechner, 2020; Pittig et al., 2014c). Notably, anhedonia and anxiety were highly correlated (r = .54) and tend to co-occur at high rates in clinical populations. Therefore, even if anhedonia does not specifically confer maladaptive threat responding, there are likely important transactions across these systems that mutually reinforce each other and potentially exacerbate maladaptive avoidance. An overactive avoidance motivation without an intact, normative push-back from the approach side may allow avoidance to kick-in when it otherwise would be inhibited by an appetitive response.

Arguably, how much reward was obtained is the most relevant outcome, representing how successful an individual was at inhibiting motivation to avoid for the sake of goal-directed behavior. In contrast to the concrete behavioral indicator of total coins retrieved, anhedonia did not differentially impact avoidance responding when examining how quickly individuals approached reward initially or how distressed or physiologically aroused individuals were. Across all participants, latencies were slower and subjective distress and skin conductance levels were higher at high reward compared to low reward, but individuals high and low on anhedonia did not differ when it came to responding across these indices. Thus, anhedonia only impacted responding measured by how many coins were retrieved, rather than deficits spanning units of analysis. This suggests that individuals with anhedonia are not slower at first response to approach-avoid conflict nor do they experience more distress and arousal. Instead, anhedonia may result in specific behavioral deficits that lead to decreased effectiveness, urgency, or efficiency when it comes to goal-directed behavior, particularly when rewards are not highly motivating.

Another critical question addressed in this study was whether women were more prone to avoidance than men in approach-avoid conflict situations. Although women and men did not differ in terms of overall avoidance, the effect of threat level was found to be slightly greater in women compared to men when examining how many coins were retrieved. Specifically, although fewer coins were consistently retrieved at higher threat compared to lower threat across participants, the difference between the number of coins collected across the low threat to high threat continuum was higher in women compared to men. However, threat levels did not differentially affect women and men in terms of how quickly they retrieved a first coin, instead, only impacting overall number of coins retrieved by the end of a trial. Women have been found to be less impulsive, less risky, and more cautious than men (Cross, Copping, & Campbell, 2011; McClean & Anderson, 2009). Thus, women's greater modulation of behavior as a function of threat may represent the adoption of a more cautious behavioral strategy as threat becomes greater and more proximal. Notably, given the trend observed in this study, with women retrieving fewer coins than men in the highest threat condition, it is possible that the effects of gender would be even stronger at even higher levels of threat, potentially leading to significant group differences in avoidance.

The slightly greater effect of increasing threat on avoidance in women compared to men found in this study is consistent with results found using the rodent version of the approach-avoid task, with female rats found to be more hesitant to leave their safe nest and enter the foraging area compared to male rats, resulting in increased latencies and greater failed attempts to procure food pellets (Zambetti et al., 2019). This finding is also consistent with human studies using other avoidance or approach-avoid conflict tasks, with women showing more avoidance of threat or anxiety-eliciting stimuli (McLean & Hope, 2010; Sheynin et al., 2014). Across species, sex hormones have been implicated in fear responding and avoidance, generally showing that lower estradiol is associated with elevated fear conditioning, increased avoidance, and fear extinction deficits (Frye & Warf, 2004; Garcia, Walker, & Zoellner, 2018; Glover, Jovanovic, & Norrholm, 2015; Maeng & Milad, 2015; Walf & Frye, 2007; Wegerer, Kerschbaum, Blechert, Wilhelm 2014). Varying estradiol levels are thought to modulate functional activation in brain regions involved in fear responding, such as the ventromedial prefrontal cortex and amygdala (Zeidan et al., 2011; Hiroi & Neumaier, 2011).Thus, sex hormones and their impact on responding to threat may play a role in the observed gender differences in modulation of avoidance across level of threat.

While men and women did not show significant differences in physiological responding to threat, men and women did show subtle differences in their overall patterns of subjective distress, but only when reward was not available. Specifically, men diverged from the overall pattern in the no reward condition: in men, when reward was not available, increasing threat imminence did not lead to corresponding increases in distress. Women showed elevated distress at high threat compared to low threat, both when rewards were available and when they were not. Thus, in the absence of reward, men appeared to be less distressed by elevated threat. For men, it may have been the presence of a competing reward that made the higher threat more distressing. Some studies show that women report greater subjective anxiety (McClean & Hope, 2010) and anxious arousal (Charak et al., 2014) compared to men. However, other studies have failed to find gender differences on these indices (Lebron-Milad et al., 2012; Zorawski et al., 2005). While this study found slight differences across men and women in patterns of subjective distress, there was little evidence to suggest major differences across men and women's distress in response to threat and no evidence to suggest women experience greater arousal. Instead, women may be more cautious when it comes to modulating their behavior in response to threat, rather than being more fearful generally.

A critical and unique undertaking of the present study was to simultaneously manipulate reward and threat to examine their potentially interactive impact on avoidance. This is in contrast to the existing literature, in which studies have either manipulated threat level or reward level, while keeping the other constant (e.g., Aupperle et al., 2011; Pittig et al., 2014; Rattel et al., 2017; Schlund et al., 2016). Important questions had therefore been left unanswered, such as whether rewards of different magnitudes differentially impact avoidance at varying levels of threat. Importantly, this study showed that threat differentially impacted avoidance behaviors when reward was not available compared to when reward was available during initial approach. In the absence of reward, during early task responding, across threat levels, number of coins retrieved decreased and initial response latency increased, suggesting that avoidance behaviors increase as a function of increasing threat. In contrast, when reward was available, number of coins actually increased slightly and response latency remained relatively stable as threat became higher. Thus, in the absence of reward, during initial approach of threat, responding was consistent with predatory imminence theory, with more avoidance at higher threat imminence (Fanselow & Lester, 1988; Perusini & Fanselow, 2015). Adding reward for approach, however, blocked this increase in avoidance at higher threat, leading to similar responding across threat levels. Schlund and colleagues (2016) suggested that there is a "tipping point" or a level of threat at which approach switches to avoidance. Rewards may shift the approach-avoidance tipping point to higher levels of threat by incentivizing approach, when otherwise avoidance would be the response of choice, particularly during first approaches of threat.

During later task responding, the effects of reward and threat were not interactive; instead, reward and threat impacted responding in line with previous findings showing that avoidance of threat increased when threat was higher compared to lower (e.g., Pittig et al., 2014; Schlund et al., 2016) and avoidance of threat decreased when reward was higher compared to lower (Aupperle et al., 2011; Talmi et al., 2009). Consistent with these prior findings, in later phases of the task, across all participants, initial approach time increased and number of coins decreased at higher reward compared to no reward and higher threat compared to lower threat. Thus, the interaction across threat and reward was localized to the initial phase of the task, suggesting rewards may be particularly effective at blocking early motivation to avoid. This early effectiveness of reward has important clinical implications given that anxiety is often at its highest the first few times an individual approach of feared consequences and, thus, motivation to avoid is likely at its peak during initial approach. Treatment uptake and engagement are major barriers to successful treatment of anxiety disorders (Becker, Boustani, Gellatly, & Chorpita, 2018). Lack of engagement in behavioral exposures was cited by clinicians as the top reason for why CBT treatments for anxiety fail to work (Issakidis & Andrews, 2007), and pre-treatment attrition in particular represents a major problem in clinical care, with many patients scheduled or recommended for anxiety treatment failing to ever begin treatment (Assakidis & Andrew, 2004; Merikangas, Nakamura, & Kessler, 2009). Rewards can block avoidance from the start, again suggesting that leveraging rewards early in treatment may be an effective strategy to inhibit initial avoidance and initiate fear extinction.

As expected, physiological responding was elevated at high threat compared to lower, but like patterns seen in response latency and number of coins retrieved, the effect of threat differed when comparing physiological responding in the no reward context to the high reward context. During initial responding in particular, when reward was not available, physiological arousal was relatively stable across levels of threat. In high reward trials, however, physiological arousal increased at each incremental rise in threat. This effect is consistent with how physiological responding was higher when reward was available compared to when it was not. Thus, during early task responding, increasing threat alone did not increase arousal. Instead, it was the additive effect of reward availability and increasing threat that resulted in increased physiological arousal. Again, this is specific to early task responding, when the threat was novel and likely more frightening. Physiological arousal is generally thought to correspond with more intense emotions (Bradley & Lang, 2000; Ledoux, 2000). In the context of threat, adding a competing reward may increase the salience of the approach-avoid conflict, helping to explain why incentives resulted in increased arousal. Along these lines, subjective distress was similarly higher when reward was available compared to when it was not, although there was no interaction effect across reward and threat when examining subjective distress. Thus, adding a reward appeared to “raise the stakes”, making the situation more anxiety provoking, as evidenced by both elevated physiological arousal and subjective distress when reward was available. Heightened distress and physiological arousal may reflect greater tension between approach and avoid motivations at higher compared to lower threat when reward is available.

Notably, the paradigm used in this study was specifically modeled after the prey-predator paradigm (Choi & Kim, 2010) and included parallel behavioral outcome indices, such as response latency and number of incentives procured. The trade-off between threat and reward found in this study converges with findings using the rodent version of the paradigm showing that retrieval of food pellets was lower and response times longer when reward was farther from a safe nest and closer to a “predator” (Choi & Kim, 2010; Pellmam & Kim, 2016). Consistent findings across parallel non-human and human models provide a promising foundation for the translation of neural, lesion, and pharmacological manipulation non-human findings to understanding and treating maladaptive avoidance behavior in humans.

Both the human and rodent version of the approach-avoid paradigm prioritize ecological validity, striving for better match between experimental manipulation and real-world response scenarios (Pellman & Kim, 2016). To date, most human approach-avoid conflict paradigms have not adequately incorporated ecologically valid threats, instead using computerized aversive or fear-conditioned images, point loss, or mild shock (e.g., Bach, 2014; Pittig et al., 2014; Sheynin et al., 2014). Further, many prior approach-avoid conflict studies measure decision making rather than behavioral responding per se, asking participants to weigh decisions based on low and high likelihood of reward and threat outcomes (Aupperle et al., 2011; Schlund et al., 2016). Thus, this study helps fill important gaps in the human approach-avoid conflict literature by showing impacts of anhedonia and gender and an interaction between reward and threat across units of analysis when studying avoidance in an unpredictable dynamic environment, mirroring the contexts individuals respond in outside the laboratory.

Better understanding of the individual differences that lead to augmented avoidance can help explain why some people are more prone to maladaptive avoidance and the development of anxiety and depression. As seen in this study, initial, elevated distress in response to threat may be an indicator or characteristic of a broader individual predisposition toward anxiety and anxiety-congruent behavioral response patterns. Importantly, trait anxiety and behavioral avoidance were moderately correlated in this study ($r = .47$); and, in general, a primary feature of anxiety is avoidance (Barlow, 2004; Craske et al., 2009). Thus, due to their association, the effects of behavioral avoidance and trait anxiety on subjective distress cannot be completely disentangled. Together, these effects point to an integral role in anxiety-related individual characteristics in predicting greater distress experienced when faced with an approach-avoid conflict.

Emotional distress has been proposed as a global index of negative affect found in mood and anxiety disorders (Pineles et al., 2013) and anxiety disorders, specifically, are characterized by difficulty downregulating anxious feelings (Niles & Craske, 2019). The effect of anxiety in predicting subjective distress was strongest in the early phase of the task and dropped off by the end of the task, suggesting that individual differences in anxiety particularly affect distress during early encounters with threat. Higher distress when first faced with an approach-avoid conflict may lead to decreased likelihood of ever approaching at all, explaining one pathway through which anxiety can be maintained. Interestingly, however, when examining reward propensity, trait anxiety, behavioral avoidance, and PTSD symptoms as predictors of physiological arousal, higher behavioral avoidance emerged as predicting lower physiological arousal rather than higher, but this effect was isolated to initial responding and only at high threat when reward was not available. It may be that individuals who are more likely to behaviorally avoid are engaging in subtle avoidance during this early phase of the task, such as safety behaviors that increase psychological distance from the threat (e.g., not looking at the threat or experiential avoidance), serving to downregulate arousal.

One of the *behavioral* indices of avoidance (i.e., coins retrieved) was significantly predicted by anxious traits, which converges with existing literature showing trait anxiety as the strongest predictor of avoidance (e.g., Loh et al., 2017; Pittig et al., 2014). However, PRT reward propensity and PTSD symptoms did not emerge as individual predictors of behavioral avoidance, subjective distress or physiological arousal. These findings are surprising given the growing literature showing that higher level of trait anxiety is associated with more behavioral avoidance in approach-avoid conflict (e.g., Bach 2015; Loh et al., 2017; Pittig et al., 2014c). However, multiple studies have also failed to find an association between trait-level measures of anxiety and depression and approach-avoid conflict behavior (e.g., Anderson et al. 2012; Aupperle et al., 2011; Rattel et al. 2017). Instead, proximal measures of task-related avoidance and goal motivation (e.g., "how motivated are you to avoid the shock?") have emerged as stronger predictors of approach-avoid conflict behavior (e.g., Aupperle et al., 2011; Claes et al., 2016). Thus, individual differences in proximal, task-specific motivation and emotional responding could suppress the impact of trait characteristics when it comes to overt behavioral responding. Indeed, situations are powerful predictors of behavior (Ross & Nisbett, 1991; Shoa, Mischel, & Wright, 1994). While threat and reward individual differences likely play some role in situational responding, other factors such as emotion regulation (Mennin et al., 2005; Tull, Barrett, McMillan, & Roemer., 2007) and distress tolerance skills (Zvolensky, Vujanovic, Bernstein, & Leyro, 2010), how rushed a person is, and subjective necessity for financial compensation also could be critical during goal-directed behavior under conditions of threat, minimizing the predictive ability of any single trait characteristic across individuals.

Across indices of avoidance, reward propensity did not emerge as predicting avoidance. Reward propensity is captured via the PRT, a behavioral task involving a differential reinforcement schedule. Reward propensity reflects the ability to learn reward contingencies and subsequently modulate behavior based on these learned contingencies. Reward propensity on the PRT has been associated with anhedonia (Pizzagalli et al., 2005; Pizzagalli et al., 2008a). Thus, given the role of reward in the approach-avoid conflict, it is surprising that, across indices, reward propensity did not predict avoidance responding, even when when reward was available. However, anhedonia is a heterogenous symptom, including deficits in the ability to experience pleasure, reduced reward motivation, or impaired learning about rewards (Cooper et al., 2018). It may be that the PRT measures an aspect of anhedonia, specifically reward learning deficits, that is less influential in an approach-avoid conflict that does not specifically involve reward learning.

Pittig et al. (2014c) proposed a stress-vulnerability model, suggesting that trait anxiety potentiates the intensity of fear conditioning, which, in turn, leads to augmented avoidance (Pittig et al., 2014c). The present results extend this hypothesis to fear responding that is not conditioned, instead involving a threat that is more evolutionarily primed. This study showed, in highly trait anxious individuals, but not lower trait anxious individuals, subjective distress led to attenuated coin retrieval specifically when incentives were not available and when threat was high. Both higher pre-task subjective distress and higher arousal and distress have been associated with greater avoidance of feared stimuli (Ollendick et al., 2011). Trait anxiety is a risk factor for anxiety disorders (Hettema, Neale, & Kendler, 2001; Hettema, Prescott, Myers, Neale, & Kendler, 2005). Rather than a direct relationship between trait anxiety and avoidance, trait anxiety may indirectly impact avoidance via higher fear responding to novel threats. Further, anxiety has been found to reduce emotion regulation strategies and the capacity to regulate distress (Mennin et al., 2005; Tull, Barrett, McMillan, & Roemer, 2007; Tull & Roemer, 2007). Thus, although distress is adaptive in threatening situations, higher distress combined with an inability to regulate distress in individuals with higher trait anxiety may explain maladaptive response patterns in approach-avoid conflict (Katz, Breznitz, & Yovel, 2019; Zvolensky, Vujanovic, Bernstein, & Leyro, 2010).

However, when reward was available and threat was high, individuals with higher anxiety and higher subjective distress did not show augmented avoidance, despite higher trait anxiety predicting higher subjective distress during these trials. This suggests that, when reward was available, individuals with higher trait anxiety and higher distress during task responding on the high threat trials were able to change their behavior to be consistent with their higher order, reward goals. Thus, the addition of reward may have motivated individuals with trait anxiety and higher distress to act against their urge to avoid in order to obtain reward. Thus, individuals with higher trait anxiety and higher distress may be most at risk for avoidance and the costs that come with avoidance when rewards are minimal.

There are several limitations to the current study, which will serve to guide future research. Uneven sample sizes across men and women in both the low and high anhedonia groups likely reduced power to detect gender effects and prevented investigation of the interaction between gender and anhedonia. This may have obscured small to moderate effects and associations. However, substantiating the current findings, the interaction of gender and threat that was found converges with an abundance of non-human and human studies (e.g., Garcia et al., 2018; Zambetti et al., 2019). A larger sample size would likely only lead to a stronger effect. The high correlation between depression (QIDS-SR) and trait anxiety (STAI-T) precluded deconstructing the independent effects of depression and anxiety as predictors of avoidance. However, it may be that this boundary is a superficial one, with growing emphasis on a transdiagnostic conceptualization of these constructs. The QIDS-SR and the STAI-T may both capture a similar dimension of negative affect (Brown, Chorpita, & Brown, 1998; Shankman & Klein, 2003). Additionally, reward was only manipulated at two levels, specifically presence and absence of reward. Although this limits the ability to examine the effect of reward on a low to high continuum, it optimized on manipulating a meaningful difference across reward conditions, addressing issues in previous approach-avoid conflict studies, which have neglected to create meaningfully distinct reward magnitudes (Aupperle et al., 2011; Schlund et al., 2017; Sierra-Mercado, 2011). Although the present study included a community sample with high anhedonia participants, we did not collect information to determine diagnostic classification, though 69.2% of participants in the high anhedonia group fell within a clinical range on depression and 84.6% in the clinical range on anxiety. Finally, concern that, given the nature of the threat, this task tapped specifically into spider or snake phobia can be assuaged by only slight to modest correlations between self-report snake or phobia across behavioral responding (r = .00 - .34) and subjective or physiological responding (r = .03 - .22) on the DAT, which are similar in strength to the relationships between trait anxiety and behavioral responding (r = .10 - .26) and subjective distress (r = .20 - .34).

Approach system deficits, such as anhedonia, may be a pivotal link in the chain across sub-clinical symptoms, such as low positive affect, anhedonia, and trait anxiety and the development of clinical levels of psychopathology. Indeed, individuals with anhedonia may be less likely to approach distressing situations unless there is a tangible, highly rewarding incentive for doing so. In turn, this pattern of avoidance can decrease the frequency of rewarding experiences, exacerbating anhedonia (Jacobson et al., 2001). At the same time, avoidance will decrease opportunities for inhibitory learning and therefore block fear extinction of maladaptive anxiety (Craske et al., 2012). Thus, anhedonia may help explain how people get stuck in patterns of avoidance, leading to increasing symptoms of both anhedonia and anxiety (Fichter, Quadflieg, Fischer, & Kohlboeck, 2010). Increased approach by leveraging incentives will not only increase the experience of positive reinforcers, buffering against depression, but also lead to the correction of maladaptive beliefs, such as overestimation of the likelihood of negative outcomes, such as failure, embarrassment, or danger, decreasing risk for pathological levels of anxiety.

Effective treatments for anxiety often involve increasing contact with feared outcomes, for example via behavioral or imaginal exposure (e.g., Craske, et al., 2012), hypothesis testing (e.g., Resick, Monson, & Chard, 2016), or acceptance and tolerance of unpleasant, anxiety-related feelings (e.g., Hayes, Luoma, Bond, Masuda, & Lillis, 2006). Treatment is thus often inherently distressing, particularly at the start of treatment, and patients are required to tolerate their distress in order to obtain higher order goals (Katz et al., 2019). Helping patients engage in treatment can be one of the most difficult parts of treatment for anxiety, since avoidance often becomes habitual and is reinforcing in the short-term, with maintained distance from threat reducing anxiety (Craske, 2009). Particularly, in the early stages of treatments for anxiety, rewards are few and far between, and, in general, incorporating or highlighting rewards for approaching fears are not specifically outlined in treatment manuals. Clinicians often rely on the motivating effects of longer-term goals, such as improved health or functioning. As demonstrated in this study, these types of non-specific rewards may reduce effectiveness for individuals with anhedonia in particular. Further, given that offering reward blocked initial avoidance in particular, this study argues introducing rewards well before the start of treatment may be an effective way to increase treatment uptake and adherence in early periods of treatment. This might simply include discussions upon referral that focus on reasons why an individual might want to approach anxiety-related outcomes and the benefits that might come from doing so, or could go so far as implementing incentives for treatment engagement, such as money, vouchers for retail or service items, free parking, and therapy discounts. Incentive-based contingency programs that have been effectively used in treatments for other disorders, such as substance use disorders (Roozen et al., 2004), and have the potential to optimize treatment for individuals with high anhedonia, anhedonia, or depression.

With significant diagnostic co-occurrence between depression and anxiety, understanding avoidance from a transdiagnostic, fear and reward perspective has important implications for treatment of these highly prevalent and costly disorders. This study highlights that deficits in positive affect are clinically relevant and may impact treatment outcome via willingness to approach distressing, fear-related stimuli when there is no strong incentive to do so. Accordingly, anhedonia should be attended to in treatments for anxiety. Currently, when patients complete these anxiety treatments, both anxiety and depression tend to attenuate (e.g., Acarturk et al., 2009; Cuijpers et al., 2014). However, dropout rates are still a barrier to treatment efficacy (Fernandez et al., 2015; Swift & Greenberg, 2012; 2014) and anhedonia or a lack of positive reinforcement may be contributing to non-adherence. Whether or not somebody engages in an exposure or willingly accepts and tolerates their anxiety may be impacted by their interest and willingness to achieve goals or engage in activities they used to enjoy. Interventions may need to target both anhedonia and anxiety so that adaptive balance can be regained across approach and avoid systems. In line with current movements towards more transdiagnostic treatments (Allen, McHugh, & Barlow, 2008; Craske et al., 2015; Craske et al., 2019), symptoms do not occur in isolation and, therefore, interventions will likely be more effective if they take into account the transactional nature of co-occurring symptoms.

It has been proposed that women may be more sensitive to punishment and less sensitive to reward, whereas men have more equal sensitivities to both (Cross, Copping, & Campbell, 2011; Sheynin et al., 2015). Thus, when faced with an approach-avoid conflict, women may be biased, specifically prone to over-assign value to an avoidance priority and under-assign value to an approach priority, whereas men may evaluate avoidance and approach outcomes more evenly. This study points more to threat-related processes involved in gender differences, with a higher sensitivity to threat potentially making women more susceptible to avoidance. In this case, women may benefit from learning to challenge initial calculations of risk and practicing overriding inclinations to avoid when approach is the more adaptive response. Overly cautious responding to threat may result in lesser rewards and decreased inhibitory learning, both of which are fundamental processes related to the development of anxiety and depression and could help explain the greater prevalence of these disorders in women compared to men (Kessler et al., 2005; Seedat, 2010).

It will be important to further characterize the effect of reward on avoidance, examining responding across lower and higher levels of reward. This will help characterize how anhedonia, anxiety, and other constructs of interest impact the trade-off between approach and avoidance across the reward and threat continuum and whether there are pathological and adaptive setpoints where approach should turn to avoidance based on relative outcome values. Generally, to date, trait level analyses characterize the field; there is a need to examine individual trajectories using more dynamic modeling approaches. Further, different types of reinforcers should be examined, both primary and secondary, internal and external, to examine if this changes how rewards impact avoidance and if anhedonia systematically devalues certain types of rewards more than others. Specific aspects of anhedonia need to be examined, given growing acknowledgment that anhedonia is a heterogeneous symptom that can include deficits in either the ability to experience pleasure, reduced approach motivation, or impaired learning about rewards (Cooper et al., 2018). Additionally, sex hormones, including progesterone, estradiol, and testosterone should be examined as a potential mechanism explaining gender differences in avoidance.

While there is general agreement that anxiety is relevant for pathological avoidance, the current study moves the field forward by showing that anhedonia can also lead to costly avoidance, likely by decreasing the subjective value of less overtly rewarding approach outcomes. Further, incentives can buffer against avoidance behavior in the context of threat, potentially by increasing willingness and engagement when first approaching anxiety-related outcomes. This is critically important given that approaching, rather than avoiding, initiates fear extinction learning when feared outcomes do not occur, and facilitates rewarding experiences. Thus, avoidance should be conceptualized as a dynamic response impacted by multiple environmental and individual difference processes related to both threat and reward. Clinical applications include helping individuals identify rewarding benefits of approaching anxiety-related situations, which, in turn, can buffer against avoidance, attenuating a major risk factor for anxiety and depression and improving clinical outcomes for individuals with pathological avoidance.

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Table 1

Baseline characteristics: high and low anhedonia groups

	Low Anhedonia (*n* = 41)			High Anhedonia (*n* = 39)		
	M	*SD*	*Range*	*M*	*SD*	*Range*
Sex (% female)	68.3			61.5		
Age (years)	33.39	*14.45*	19-65	29.71	*13.04*	18-58
Race (%)						
Caucasian	56.12			33.3		
Asian	29.3			38.5		
Black or African American	4.9			12.8		
Native Hawaiian or other Pacific Islander	2.4			5.1		
Other	7.3			10.3		
Education (Years)	16.02	*2.63*	12-24	14.72	*2.55*	10-24
Anhedonia (SHAPS)	0.36	*0.66*	0-3	4.21	*2.81*	0-12
State anxiety (STAI-S)	32.82	*9.64*	20-58	45.39	*13.04*	24-78
Trait anxiety (STAI-T)	37.03	*9.74*	20-61	52.41	*11.23*	23-75
Posttraumatic stress (PSS-SR-5)	7.76	*2.28*	0-63	15.38	*3.11*	0-69
Depression (QIDS-SR)	4.46	*3.22*	0-12	10.98	*4.60*	1-20
Behavioral avoidance (MEAQ)	35.71	*8.60*	22-58	42.15	*12.03*	22-66
Alcohol use disorder (AUDIT)	2.17	*2.27*	0-10	3.00	*3.65*	0-14
Cannabis use disorder (CUDIT)	1.61	*3.46*	0-14	2.00	*4.35*	0-17

Impulsive behavior (SUPPS-P)	37.02	*7.14*	24-56	42.57	*8.74*	29-58
Risk propensity (DOSPERT)	48.43	*14.21*	18-77	50.18	*15.71*	18-85
Spider fearfulness (SPQ-12)	3.23	*2.93*	0-11	5.60	*3.84*	*0-12*
Snake fearfulness (SNAQ-12)	3.05	*3.24*	0-10	4.91	*3.50*	0-12

Note. SHAPS = Snaith-Hamilton Pleasure Scale; STAI-S = State-Trait Anxiety Inventory-State; STAI-T = State-Trait Anxiety Inventory-Trait; PSS-SR-5 = PTSD Scale-Self-Report for DSM-5; QIDS-SR = Quick Inventory of Depressive Symptomatology Self-Report Version; MEAQ = Multidimensional Experiential Avoidance Questionnaire – Behavioral Avoidance Subscale. AUDIT = Alcohol Use Disorders Identification Test; CUDIT = Cannabis Use Disorders Identification Test; SUPPS-P = Short Version of Urgency, Premeditation (lack of), perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale; DOSPERT = Domain Specific Risk Taking. SPQ-12 = Spider Questionnaire 12-Item Version; SNAQ = Snake Questionnaire 12-Item Version; PRT = Probabilistic Reward Task. Only 50% of the sample completed the SPQ-12 and the SNAQ-12 (low anhedonia n = 17; high anhedonia n = 23).

Table 2

Approach-avoid conflict task main outcomes: latency for 1st coin retrieval, total coin retrieved, self-report peak distress, and physiological arousal for high and low anhedonia groups

	Low Anhedonia ($n = 41$)			High Anhedonia ($n = 39$)		
	M	*SD*	*Range*	*M*	*SD*	*Range*
Pre-task SUDs	28.61	*20.43*	0–80	35.92	*24.18*	0–99
Total coins retrieved (*n* coins) – no reward trials	81.19	*13.23*	51–98	74.49	*16.09*	55–107
Total coins retrieved (*n* coins)– high reward trials	88.63	*14.74*	51–108	86.22	*12.79*	40–106
Average response latency for 1st coin (*s*)						
No reward, low threat Trials	3.24	*0.80*	1.90–6.12	3.37	*0.63*	2.21–5.10
No reward, moderate threat Trials	3.21	*0.71*	2.06–4.95	3.57	*1.32*	1.87–9.50
No reward, high threat Trials	3.95	*1.27*	2.25–8.82	4.16	*1.31*	2.36–7.81
High reward, low threat Trials	3.18	*1.04*	1.55–6.92	3.34	*0.93*	2.05–6.31
High reward, moderate threat Trials	2.95	*0.81*	1.53–5.61	3.05	*0.76*	1.95–5.07
High reward, high threat Trials	3.19	*0.99*	2.06–6.78	3.36	*0.98*	1.75–6.60

Average coins retrieved (*n* Coins)						
No reward, low threat Trials	10.02	*1.64*	6.00–12.00	9.30	*1.68*	5.67–12.00
No reward, moderate threat Trials	9.38	*1.46*	6.00–11.67	8.56	*2.13*	2.00–12.00
No reward, high threat Trials	7.66	*1.61*	3.67–10.00	6.97	*2.05*	3.00–11.33
High reward, low threat Trials	10.12	*1.75*	5.67–12.00	9.85	*1.45*	6.00–12.00
High reward, moderate threat Trials	10.30	*1.62*	6.33–12.00	10.03	*1.46*	7.00–12.00
High reward, high threat Trials	9.12	*1.87*	5.00–12.00	8.86	*1.83*	4.67–12.00
Average Peak SUDs						
No reward, low threat Trials	30.65	*19.04*	2.33–80.67	35.67	*23.31*	0.00–90.67
No reward, moderate threat Trials	32.15	*19.44*	2.33–81.00	36.87	*23.11*	0.00–91.33
No reward, high threat Trials	33.24	*18.88*	4.00–80.33	38.81	*22.12*	2.00–88.33
High reward, low threat Trials	33.54	*20.27*	2.33–80.33	37.01	*22.27*	3.33–84.17
High reward, moderate threat Trials	34.89	*20.28*	3.00–81.00	38.41	*25.02*	1.33–85.50
High reward, high threat Trials	36.43	*19.97*	3.67–80.67	40.63	*23.80*	1.33–86.33
Average SCL Δ (log (μS + 1))						
No reward, low threat Trials	0.21	*0.03*	0.16–0.26	0.22	*0.03*	0.13–0.27

No reward, moderate threat Trials	0.21	*0.03*	0.13–0.26	0.22	*0.03*	0.14–0.28
No reward, high threat Trials	0.22	*0.02*	0.17–0.27	0.22	*0.03*	0.12–0.27
High reward, low threat Trials	0.22	*0.03*	0.14–0.27	0.23	*0.03*	0.16–0.28
High reward, moderate threat Trials	0.23	*0.03*	0.17–0.27	0.23	*0.03*	0.17–0.28
High reward, high threat Trials	0.24	*0.03*	0.16–0.27	0.24	*0.03*	0.13–0.28

Note. Due to equipment malfunction, sample size for SCL is n = 34 for low anhedonia group and n = 37 for high anhedonia group. SUDs = Subjective Units of Distress Scale; SCL = skin conductance level; µS = microsemens.

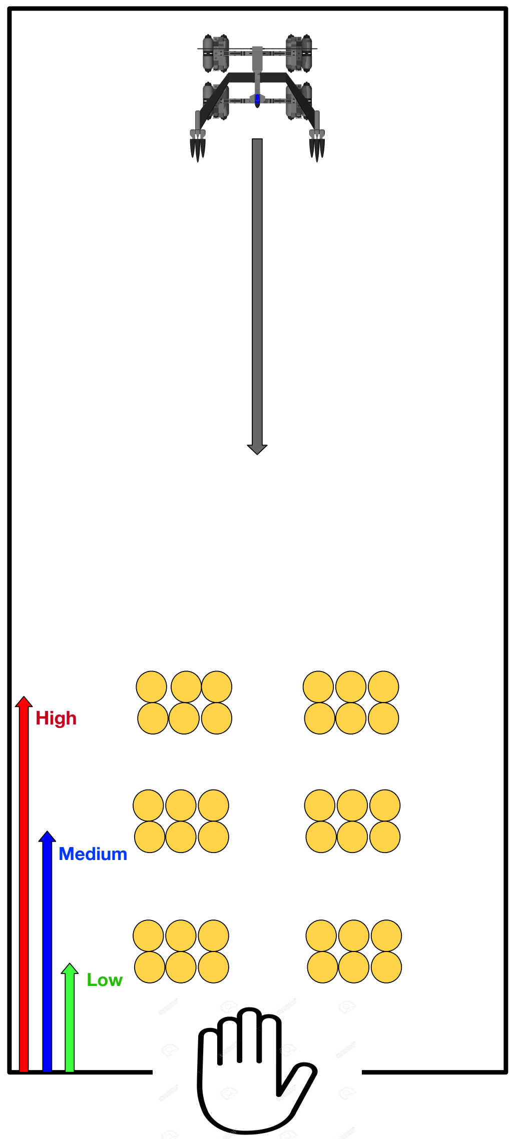
Table 3. *Associations among self-report measures of psychopathology*

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Anhedonia (SHAPS)	--												
2. Depression (QIDS-SR)	.51**	--											
3. State Anxiety (STAI-S)	.49**	.67**	--										
4. Trait Anxiety (STAI-T)	.54**	.79**	.76**	--									
5. PTSD (PSS-SR-5)	.03	.53**	.32*	.45**	--								
6. PTSD – Avoidance (PSS-SR-5)	.07	.40**	.10	.26	.80**	--							
7. Behavioral Avoidance (MEAQ)	.33**	.48**	.48**	.47**	.38*	.33*	--						
8. Alcohol Use (AUDIT)	.17	.10	.07	.16	.00	.03	-.22*	--					
9. Cannabis Use (CUDIT)	-.01	.22	-.02	.10	.22	.17	-.01	.17	--				
10. Impulsivity (SUPPS-S)	.31**	.41**	.39**	.48**	.22	.15	.27*	.00	.04	--			
11. Risk Propensity (DOSPERT)	.01	.06	-.08	.01	.09	.13	-.31**	.30**	.10	.37**	--		
12. Snake Fearfulness (SNAQ-12)	.09	.31	.41**	.30	.51*	.17	.35*	-.34*	-.17	.27	-.14	--	
13. Spider Fearfulness (SPQ-12)	.24	.45**	.56**	.43**	.50*	.17	.21	-.10	-.23	.32*	-.01	.47**	--

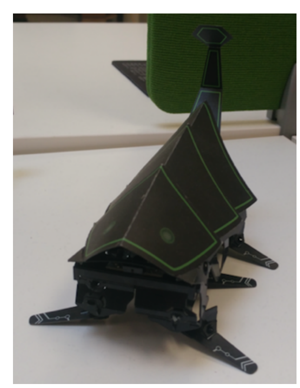
Note. SHAPS = Snaith-Hamilton Pleasure Scale; QIDS-SR = Quick Inventory of Depressive Symptomatology Self-Report Version; STAI-S = State-Trait Anxiety Inventory-State; STAI-T = State-Trait Anxiety Inventory-Trait; PSS-SR-5 = PTSD Scale-Self-Report for DSM-5; MEAQ = Multidimensional Experiential Avoidance Questionnaire – Behavioral Avoidance Subscale. AUDIT = Alcohol Use Disorders Identification Test; CUDIT = Cannabis Use Disorders Identification Test; SUPPS-P = Short Version of Urgency, Premeditation (lack of), perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale; DOSPERT = Domain

Specific Risk Taking. SPQ-12 = Spider Questionnaire 12-Item Version; SNAQ = Snake Questionnaire 12-Item Version; PRT = Probabilistic Reward Task. *p < .05 **p < .01.

Figure 1. Schematic diagram of Dynamic Avoidance Task (DAT)



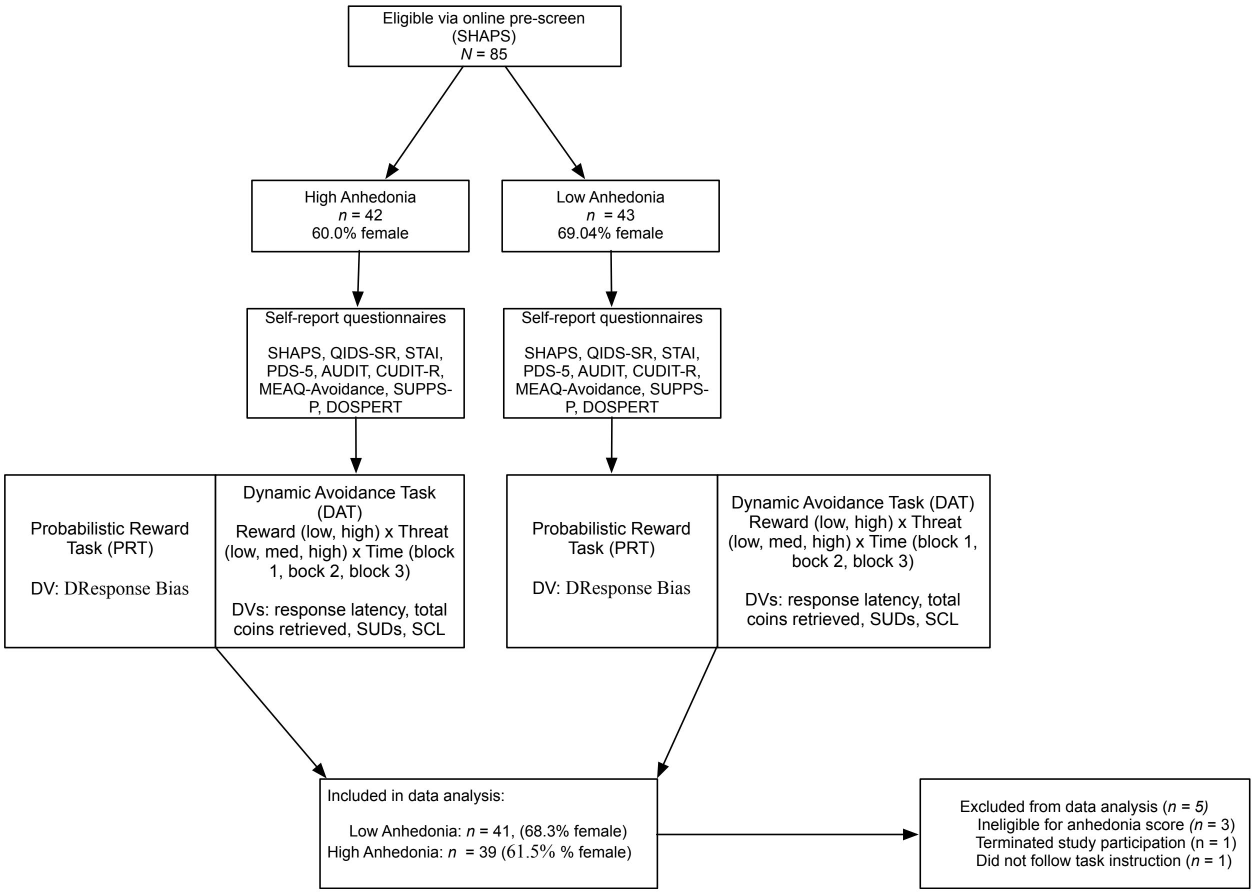
a)



b)

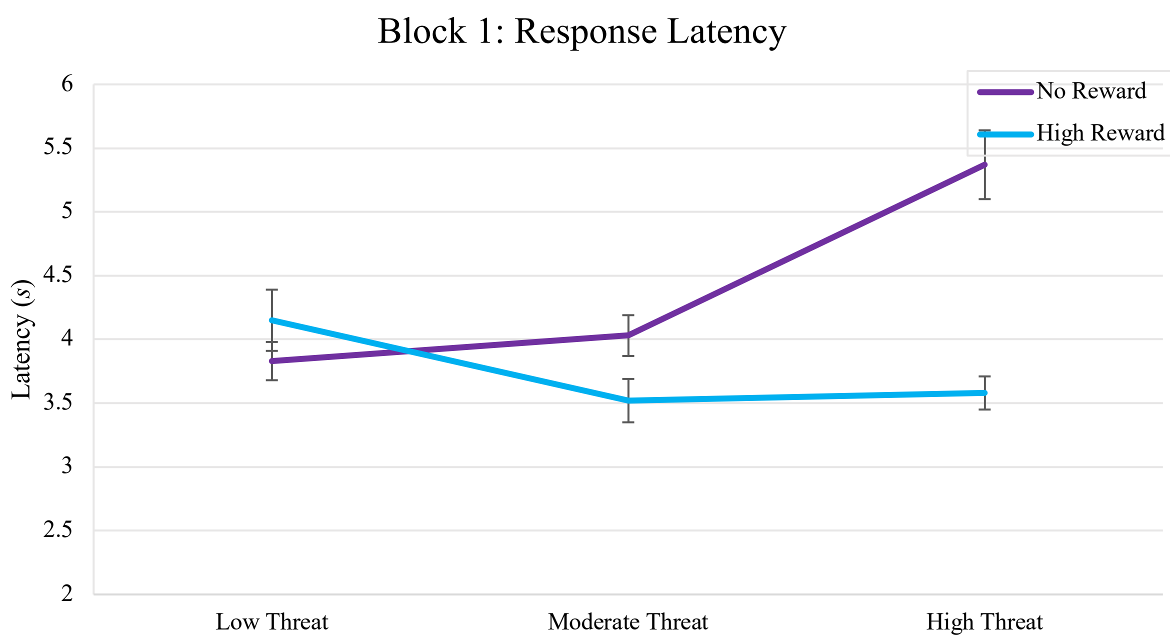
Note. (a) Bird's eye view of the Dynamic Avoidance Task (DAT) and (b) the Kamigami robot used in the DAT. Prior to each trial, participants were told if money could be earned in the upcoming trial. On reward trials, participants could earn monetary rewards based on the number of coins retrieved: $0.35 cents for each coin with maximum possible earnings of $4.20 per trial and $37.80 across the whole task. At the start of each trial, participants reached inside the box with their dominant hand to retrieve coins, one at a time. Simultaneously, the Kamigami robot began one of three, pre-programed, 20s surge patterns. Across trials, participant-to-reward distance and reward-to-threat distance inside the box (low, moderate, high threat) was manipulated. Key dependent variables were response latency for first reward retrieval (ms), total reward value obtained (*n* coins), operationalized as the number of coins collected during each trial (0- 12coins), self-report peak distress on each trial (SUDs), and physiological responding measured via skin conductance level (SCL)

Figure 2. Study flowchart

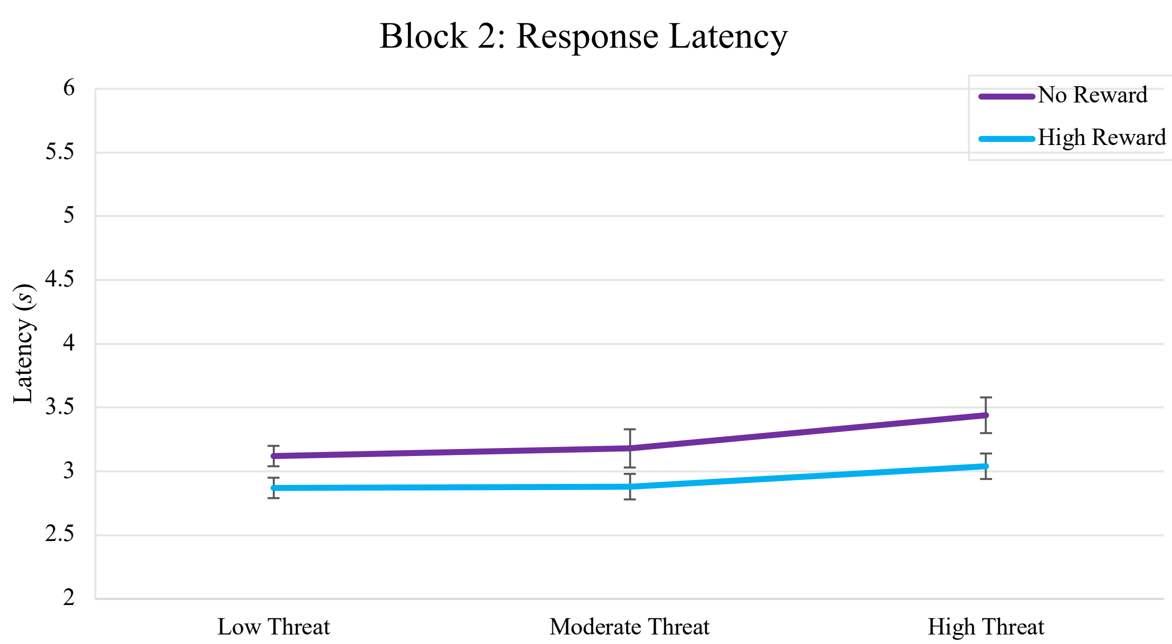


Note. Order of completing the probabilistic reward task and DAT was counterbalanced across participants.

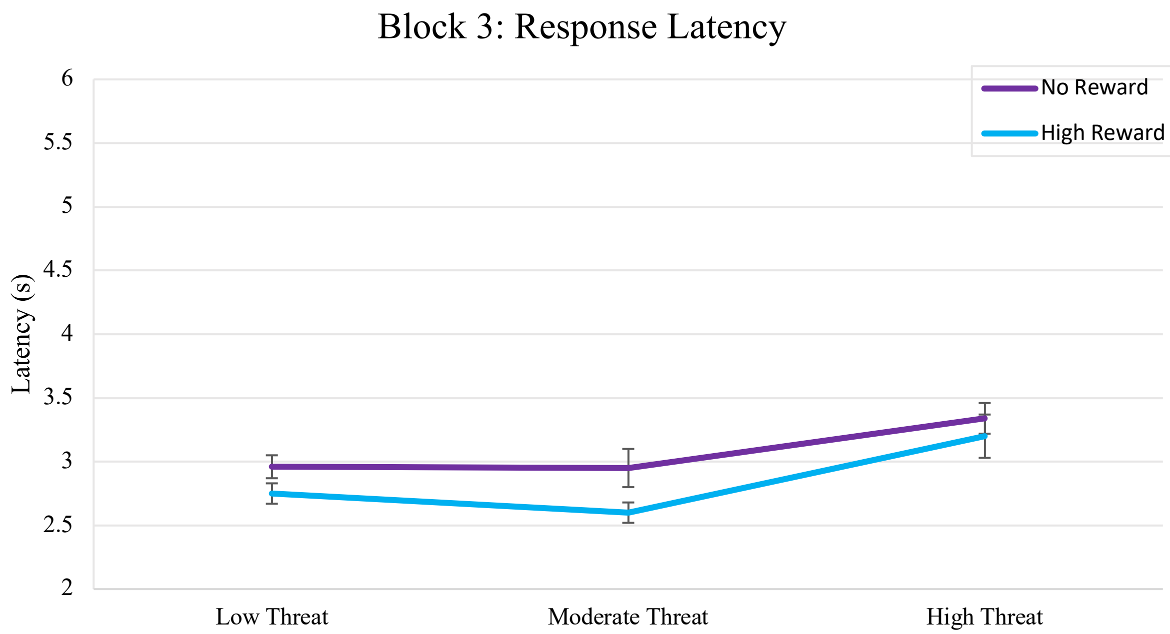
Figure 3. Interaction between threat and reward on the DAT when examining response latency for first coin retrieval in block 1 (a), block 2 (b), and block 3 (c).



a)



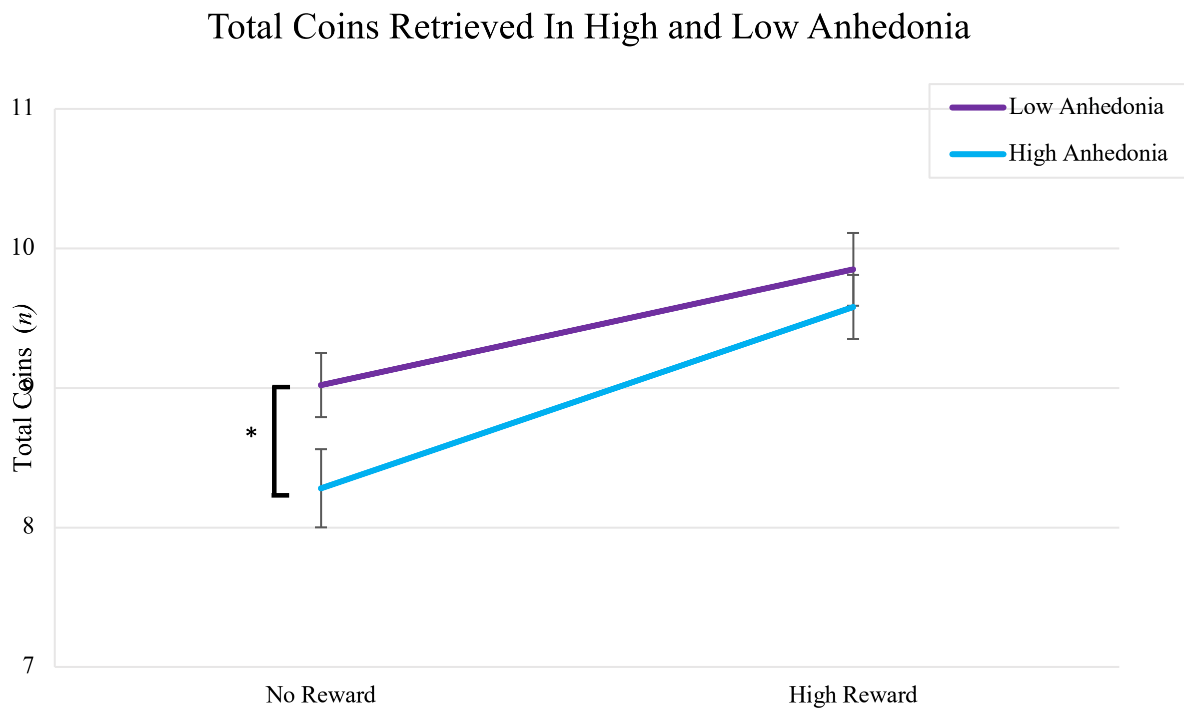
b)



c)

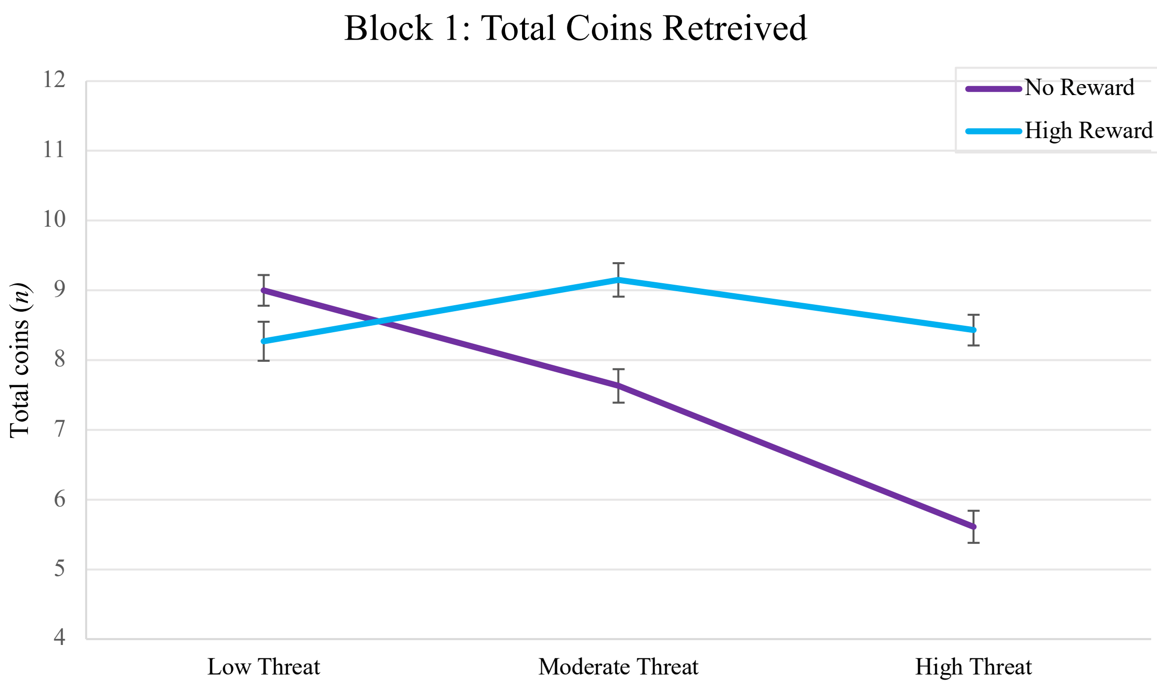
Note. Response latency was measured as the total time it took to retrieve a first coin during each trial. In block 1 of the Dynamic Avoidance Task (DAT) (a), as expected, when coins were not associated with monetary reward, mean time to retrieve a first coin was slower as threat got higher. However, when monetary reward was offered in exchange for coin retrieval, response time did not slow down as threat became more imminent. Instead, response time became slightly quicker (low to moderate threat) or stayed the same (moderate threat to high threat). Thus, reward appeared to block the slowing of response times as a function of higher threat during initial task responding. In blocks 2 (b) and block 3 (c) the pattern in block 1 was not maintained but, instead, the effect of threat was similar when reward was and was not available, with slower response times as threat increased in both conditions.

Figure 4. Average total coins retrieved on DAT in the high and low anhedonia groups during no reward and high reward trials.

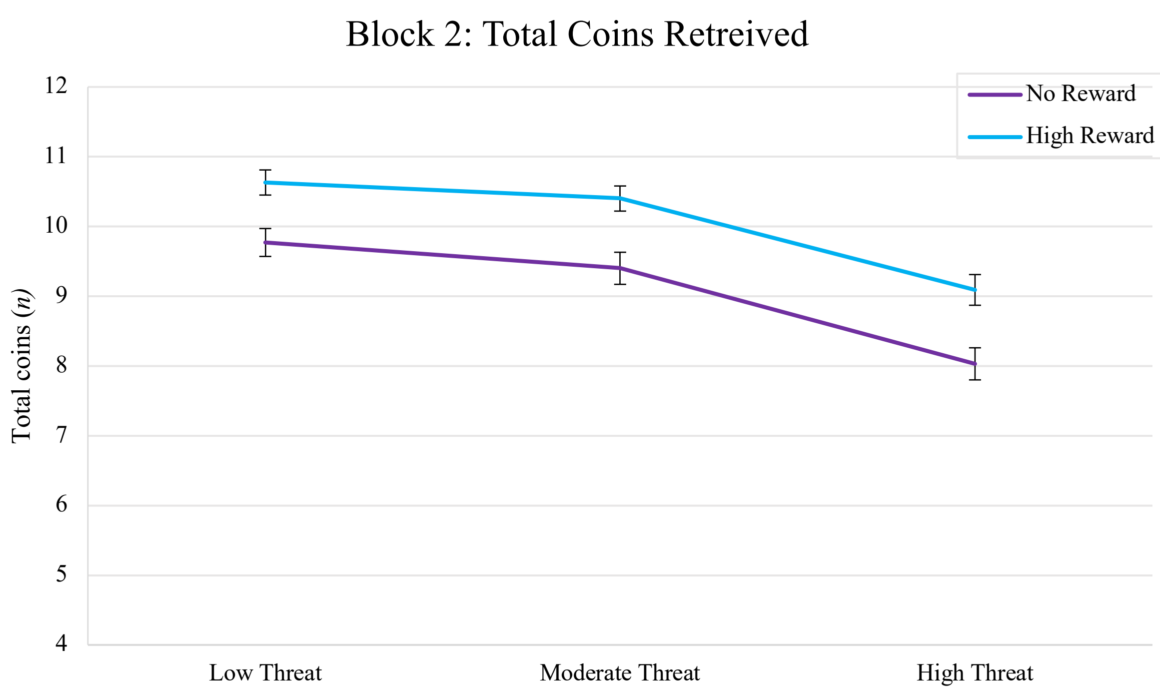


Note. *$p < .05$. The goal of the Dynamic Avoidance Task (DAT) was to retrieve as many coins as possible. Participants high and low in anhedonia performed similarly when approach was incentivized, specifically by making each coin retrieved worth monetary reward ($0.35 each). However, when coins did not correspond with monetary reward, participants with high anhedonia retrieved significantly fewer ($d = 0.46$) coins than those with low anhedonia. Thus, individuals with high anhedonia showed augmented avoidance in approach-avoid conflict when approach was not incentivized with reward.

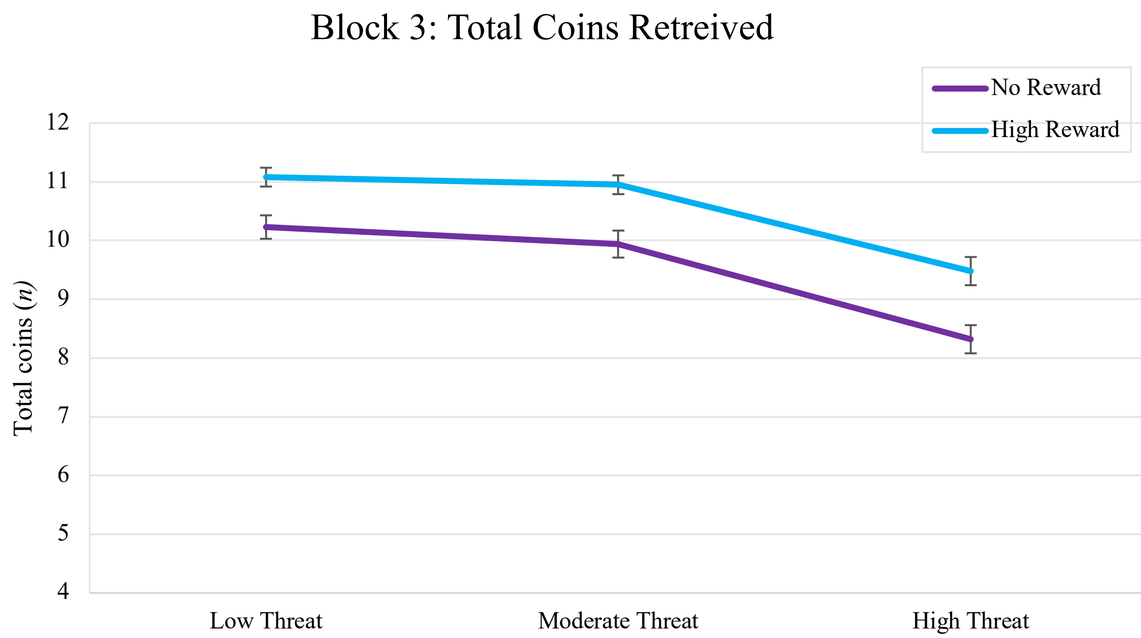
Figure 5. Interaction between threat and reward on the DAT when examining total coins retrieved in block 1 (a), block 2 (b), and block 3 (c).



a)



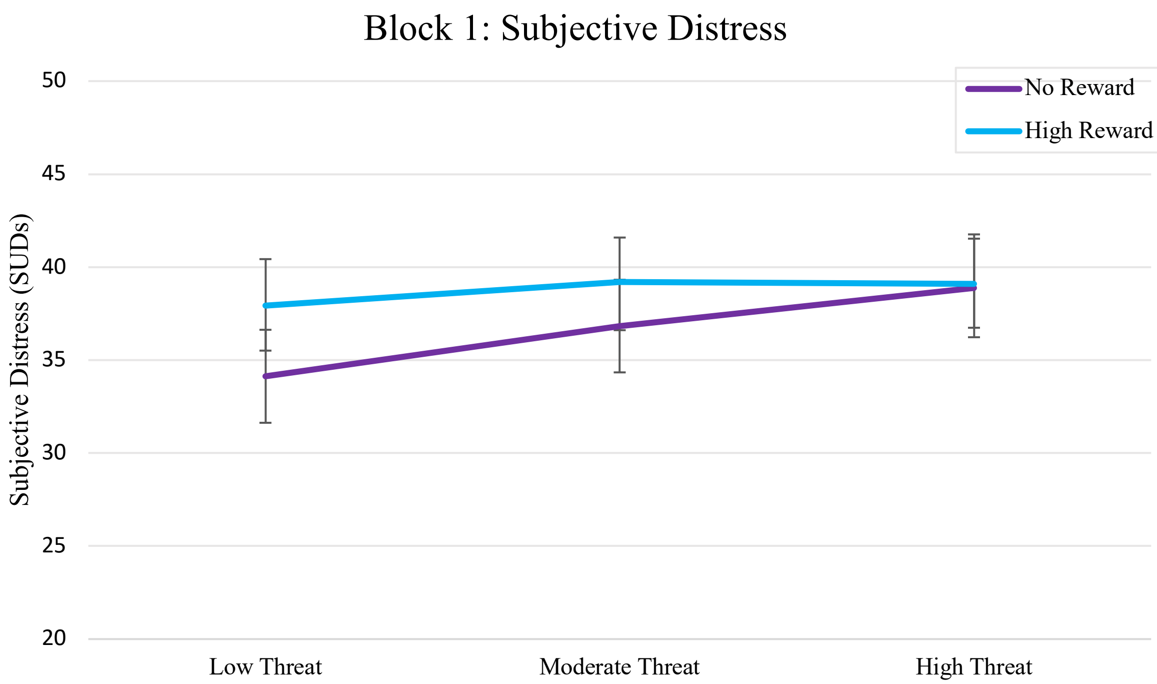
b)



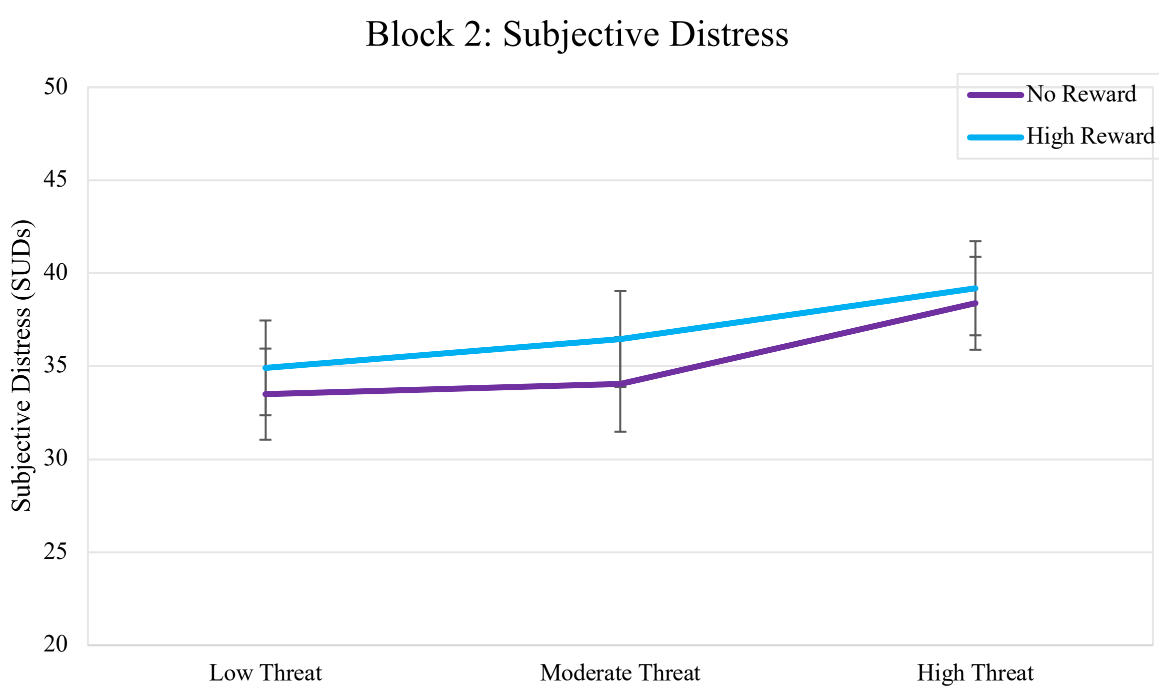
c)

Note. In block 1 of the Dynamic Avoidance Task (DAT) (a), when coins were not associated with monetary reward, as expected, the average number of coins retrieved decreased as a function of threat, with more coins retrieved when threat was low compared to high. When approach was not incentivized, however, the number of coins retrieved increased or stayed the same as threat became more imminent. Thus, during initial task responding, response to threat differed when approach was incentivized compared to when it was not, with monetary reward appearing to buffer against the effect of increasing threat leading to decreased coin retrieval. In block 2 (a) and block 3 (b), however, mean total coins decreased linearly as a function of threat both when coins were incentivized and when they were not and, in general, more coins were retrieved when coin retrieval was incentivized compared to when it was not.

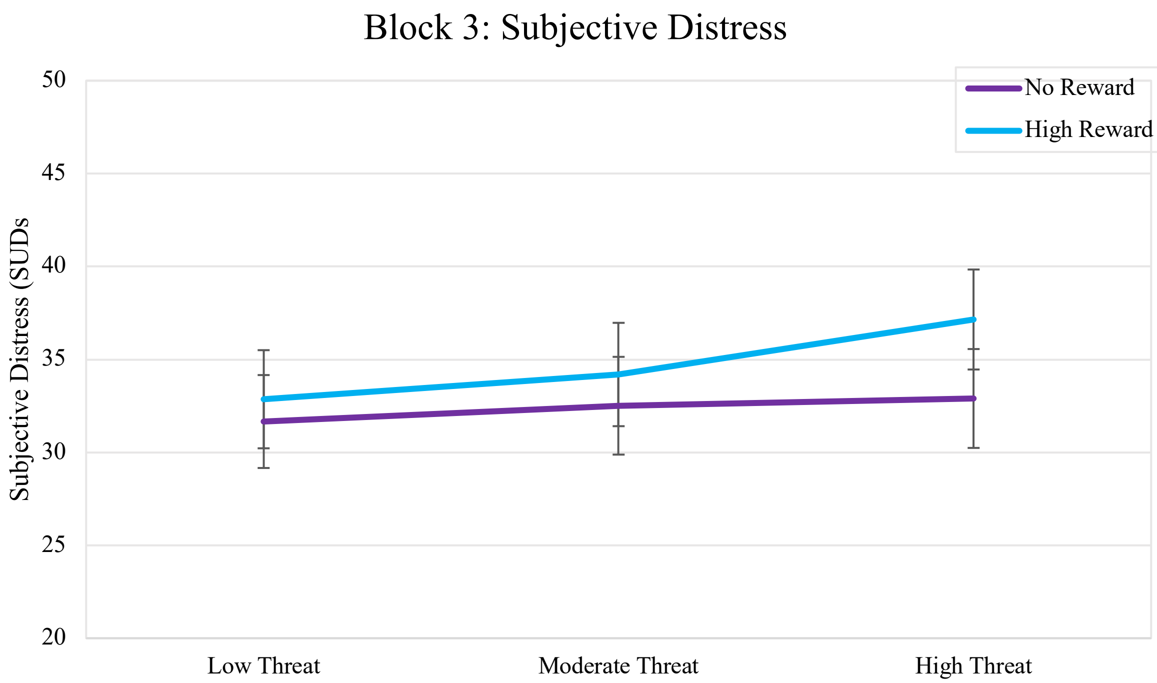
Figure 6. Subjective distress at low threat, moderate threat, and high threat in block 1 (a), block 2 (b), and block 3 (c).



a)



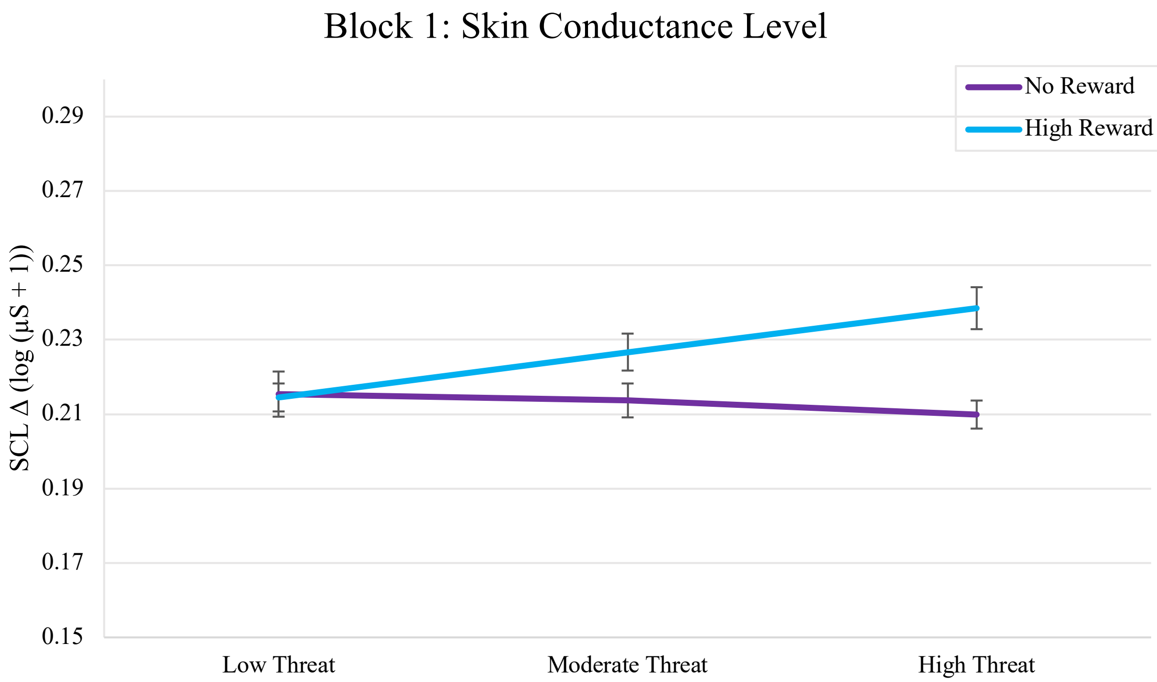
b)



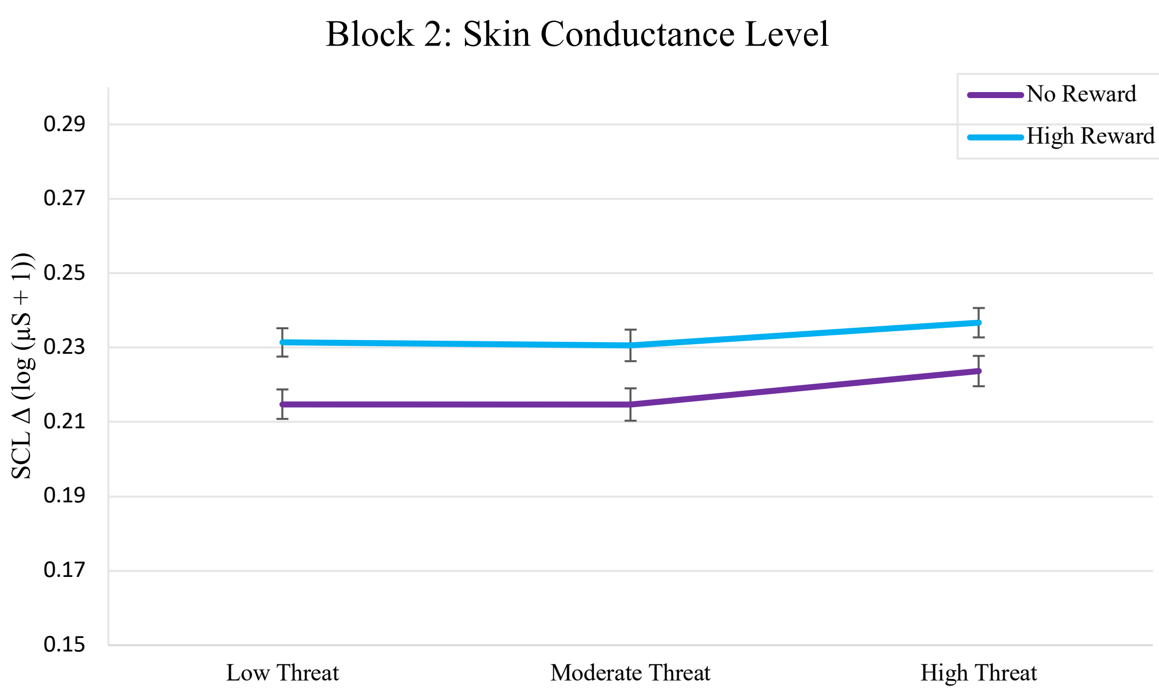
c)

Note. Peak subjective distress during a trial was assessed via self-report immediately after each trial. Similar patterns were seen in block 1 (a), block 2 (b), and block 3 (c), such that average subjective distress was higher when coin retrieval was incentivized with monetary reward, compared to when it was not, suggesting the addition of monetary incentives increased anxiety experienced during task responding. As expected, subjective distress also increased as threat imminence increased, showing that participants found the low threat condition the least distressing and the high threat condition the most distress.

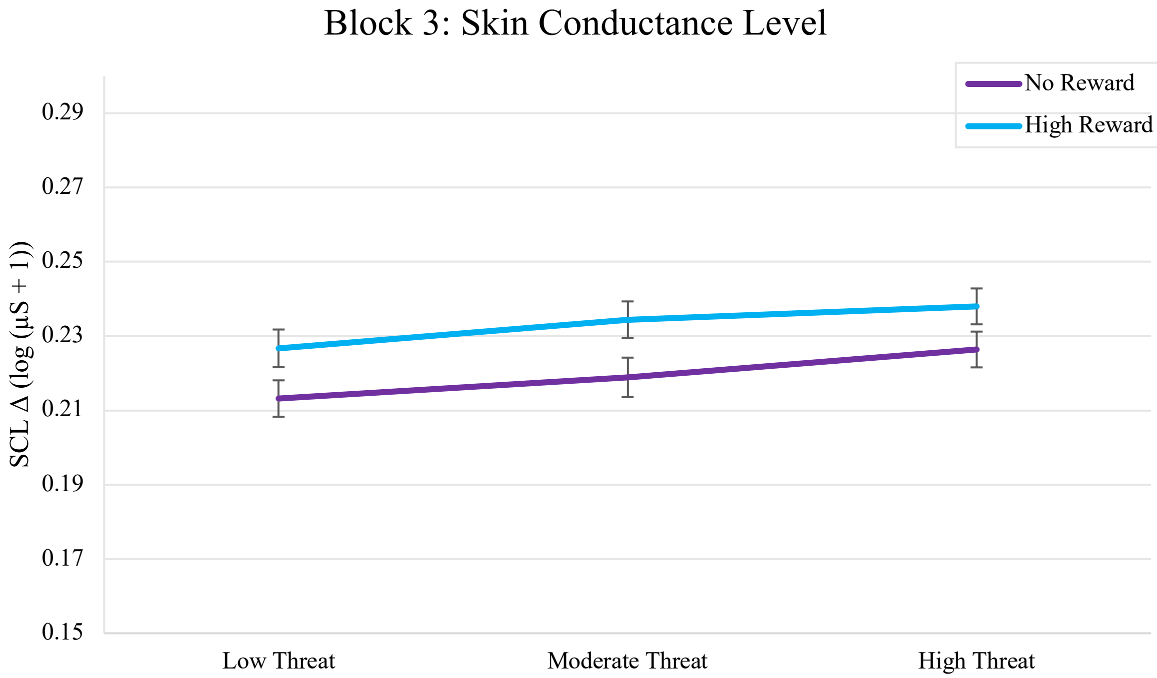
Figure 7. Physiological arousal (SCL) at low threat, moderate, and high threat for the no reward and high reward 7onditions across retrieved in (a) block 1, (b) block 2, and (c) block 3.



a)



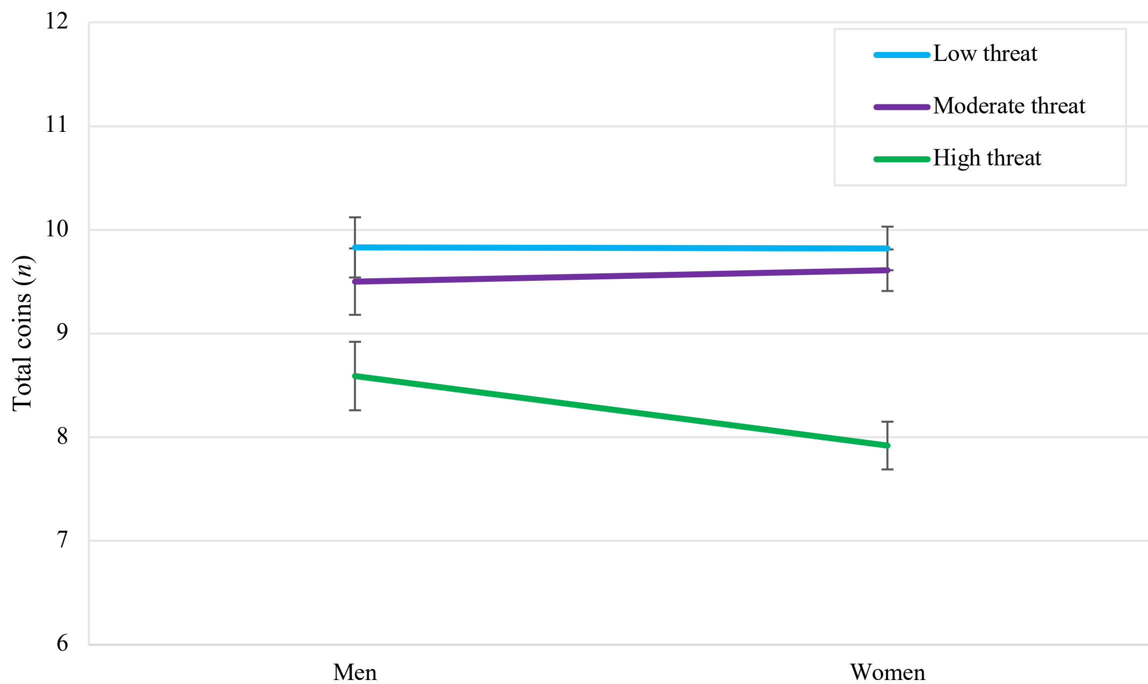
b)



c)

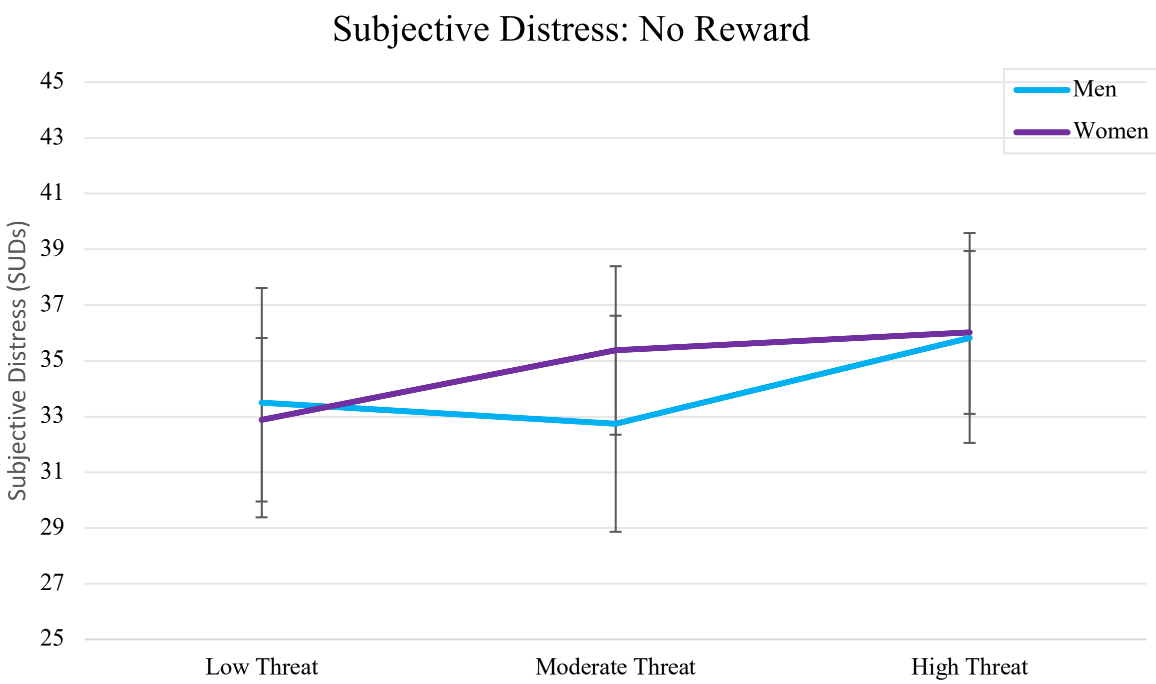
Note. In the Dynamic Avoidance Task (DAT), physiological arousal was measured via skin conductance level (SCL) in each trial. In block 1 (a), when coin retrieval was not incentivized with monetary reward, mean physiological arousal was relatively stable across responding during low, moderate, and high threat. However, when coin retrieval was incentivized with monetary reward, physiological arousal was higher as a function of threat, increasing from low to moderate threat and moderate threat to high threat. Thus, during initial responding to the approach-avoid conflict, increased threat alone did not lead to increased physiological arousal; in contrast, increasing threat in the context of an incentivized approach goal did lead to increased physiological arousal. In block 2 (b) and block 3 (c), physiological arousal increased as a function of threat both when coin retrieval was incentivized by monetary reward and when it was not and, in general, physiological responding was higher when monetary reward was available compared to when it was not.

Figure 8. Interaction between gender and threat on total coins retrieved.

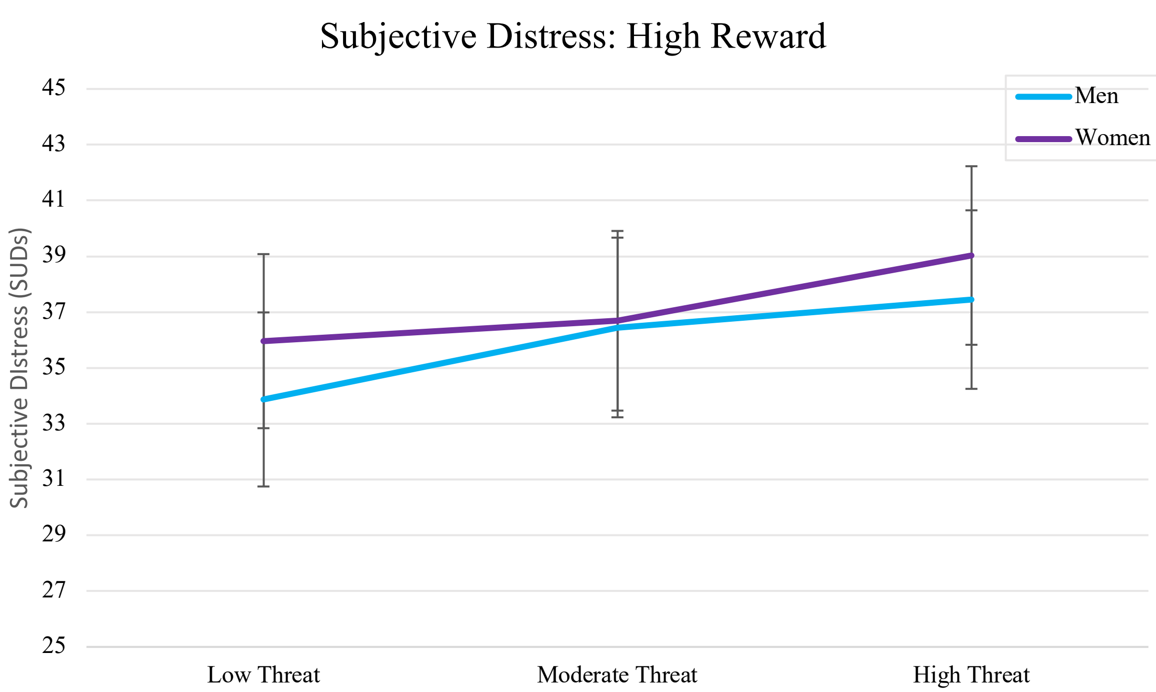


Note. Men and women did not significantly differ in how many coins they retrieved during the DAT at any level of threat. However, when moving from low to high threat, women showed a greater reduction in total coins retrieved (d = 1.57) than men showed (d = 1.41). Thus, women modulated their behavior to a greater degree as a function of increasing threat.

Figure 9. Interaction between gender, reward, and threat when examining subjective distress



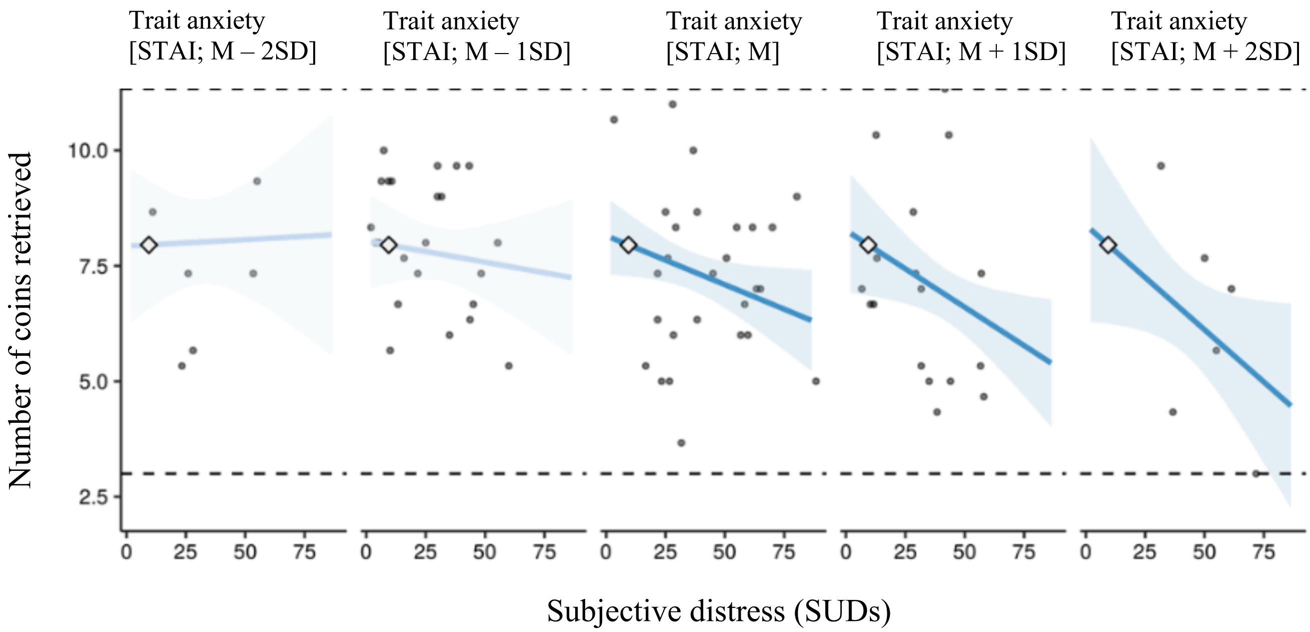
a)



b)

Note. Peak subjective distress during each trial of the Dynamic Avoidance Task (DAT) was assessed immediately after each trial. When coin retrieval was not incentivized by monetary reward (a), men did not show a difference in subjective distress experienced across levels of threat, while women showed increases in subjective distress from low to moderate threat and low to high threat; when reward was available (b), both women and men showed significant increases in subjective distress as a function of threat level, with men showing greater distress when comparing low to moderate threat and low to high threat and women showing greater distress when comparing low to high threat and moderate to high threat.

Figure 10. Relationship between subjective distress and total coins retrieved across lower and high levels of trait anxiety in the no reward, high threat condition.



Note. At two standard deviations below the mean (b = 0.00, 95% CI = [-0.04, 0.05]) and one standard deviation below the mean (b = -0.01, 95% CI = [-0.04, 0.02]) on trait anxiety, subjective distress did not predict total coins obtained on no reward, high threat trials. However, for individuals with average trait anxiety (b = -0.02, 95% CI = [-0.04, 0]), individuals with trait anxiety one standard deviations above the mean (b = -0.03, 95% CI = [-0.06, 0]), and individuals with trait anxiety two standard deviations above the mean ((b = -0.05, 95% CI = [-0.09, 0])), higher subjective distress significantly predicted fewer total coins retrieved.