PROBABILISTIC LEARNING BY REINFORCEMENT AND APPROACH OF REWARD VERSUS AVOIDANCE OF PUNISHMENT IN GENERALIZED ANXIETY DISORDER

A Thesis in
Psychology
by
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Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science

August 2016
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ABSTRACT

Worry research suggests that those with GAD may bear differential learning tendencies compared to controls, such as greater learning by 1) negative reinforcement over positive reinforcement and 2) avoidance of punishment over approach of rewards. The current study used computerized implicit cognitive tasks with probabilistic reinforcement to determine if such differences exist. 157 participants, 59 GAD and 98 non-GAD, took a modified version of the Probabilistic Learning Task (PLT) to study negative vs. positive reinforcement learning and the standard Probabilistic Selection Task (PST) to study approach vs. reward learning. In our specially designed PLT, participants chose between stimuli with specific probabilities of reinforcement, learning over time which of each pair had the highest probability. Correct choices in the negative condition removed an angry face, whereas those in the positive condition made a happy face appear. The unaltered, classic PST design was used. Results showed that compared to non-GADs, those with GAD learned at a significantly slower rate over time and to a lesser degree on both probabilistic tasks both implicitly and explicitly, regardless of condition. Marginally significant explicit learning effects suggested that those with GAD had poorer learning via positive reinforcement than did non-GADs, especially when reward probability was high. No significant findings arose regarding avoidance vs. approach learning. Reaction time differences were minimal to absent. Those with GAD may have deficits in probabilistic learning, facilitating the use of unlikely fearful expectations to buffer against negative emotional shifts. They may also learn worse by positive reinforcement than those without GAD.

*Keywords:* generalized anxiety disorder, GAD, cognitive bias, learning, operant conditioning, reinforcement, punishment, reward, probabilistic learning, implicit, explicit, Probabilistic Selection Task.
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Introduction

Reinforcement and Avoidance Learning in Generalized Anxiety Disorder

Among mental health conditions, generalized anxiety disorder (GAD) is especially widespread. Research has estimated lifetime GAD prevalence to be 14.2% with a past-year prevalence of 4.2% (Moffitt et al., 2010). Despite its high prevalence and a rich history of both basic and treatment research, much of the nature of GAD remains unknown. In fact, historically GAD has been considered to be the least successfully treated of all anxiety disorders (Borkovec & Ruscio, 2001). Theoretically, its particularly high resistance to treatment may be due to the disorder’s resilient maintenance factors. As with any phenomena, the more tenaciously symptoms are maintained, the more difficult it is to halt their progression long-term and to prevent relapse. Yet despite difficulty, such maintenance factors are potentially prime targets for intervention and thus a vital area for study. It is possible that conditioned learning processes unique to GAD are one such maintenance factor. Although previously unstudied in GAD, learning processes can drive important behaviors, cognitions, and choices in a person’s life, potentially maintaining and exacerbating disorder-congruent thoughts and acts. It is therefore crucial that both the basic and applied study of this disorder address how patterns of cognition and behavior are set in motion, become ingrained, and terminate in anxious persons. Two theoretical domains may be fruitful frameworks for conceptualizing and testing the learning processes of those with GAD: Reinforcement learning and learning by avoidance of punishment versus approach of reward.

Negative reinforcement and avoidance of negative shifts in emotion have been implicated as core features of GAD’s primary criterion, excessive and uncontrollable worry (APA, 1994). Within the study of GAD, theories on the function, etiology, and maintenance of worry have
taken prominence in the literature. Among these functional theories of worry, Newman and Llera (2011) have proposed a novel model for worry that accounts for both the reinforcement and avoidance processes found in GAD. Newman and Llera’s Contrast Avoidance Model of Worry suggests that individuals with GAD employ worry to create and sustain anxious feeling in order to avoid unwanted negative shifts in emotional state. Stated differently, those with GAD prefer to remain continually distressed—a state maintained by worry—so that if something undesirable occurs they will be less likely to experience a sharp spike in negative emotion (i.e., an experience of “negative contrast”). Such buffering of negative emotional shifts via worry has been experimentally demonstrated in those with GAD (Llera & Newman, 2010). Moreover, those with GAD have reported a preference for using distress-inducing worry to cope with later shifts in distress induced by upsetting films, in contrast to non-anxious participants who preferred relaxation (Llera & Newman, 2014). The Contrast Avoidance Model of Worry suggests that 1) worry actually creates subjective and physiological anxiety that can be relieved when feared outcomes do not occur, reinforcing the worry process and maintaining the disorder; and 2) those with GAD use worry to induce distress as a strategy to evade the uncontrollable and punishing experience of negative emotional contrasts.

Following from these features of worry suggested by the Contrast Avoidance Model, the tendency to learn from negative (vs. positive) reinforcement and, similarly, avoidance of punishment vs. approach of reward in those with GAD may be significantly different compared to the general population, functioning to maintain the disorder. Accordingly, the remainder of this introduction will address each process separately, making a case for studying the differential effectiveness of these learning mechanisms within GAD.

**Negative vs. Positive Reinforcement Learning**
When a person is anxious, the perceived prevention or avoidance of a punishing experience (e.g., a catastrophic outcome) provides consequential relief, maintaining anxiety, avoidance, and the behaviors and cognitions that fostered them (i.e., worry). This common anxious process is known more broadly as negative reinforcement, a construct within the behavioral learning domain of operant conditioning. Operant conditioning is learning via the association of a behavior with an enjoyable or aversive consequence. Within operant conditioning, reinforcement occurs when a consequence increases the likelihood of future behavior, whereas punishment occurs when a consequence decreases the likelihood of a behavior’s repetition. Negative reinforcement—the promotion of behavior by the removal of an aversive stimuli or feeling—and positive reinforcement—the promotion of behavior by the reception of rewards—may be possible mechanisms in implicit learning in anxiety, but they have yet to be empirically explored.

Under a cognitive-behavioral framework, it has been suggested that worry itself is perpetuated by continual negative reinforcement: 1) Those with GAD frequently engage in future-oriented fearful thoughts imagining aversive outcomes for upcoming events (worry), however improbable, 2) causing and/or maintaining affective and somatic distress. 3) When their unlikely worried outcomes do not occur, their somatic relief provides negative reinforcement and their worry is continuously utilized as a harmful coping mechanism (Borkovec, Hazlett-Stevens, & Diaz, 1999). Research has supported each of these theorized reinforcement stages for worry. I now aim to make an argument for each step of the process.

As mentioned previously, the primary criteria for GAD is the presence of excessive and uncontrollable worry—perseverative apprehensive expectation for negative future outcomes (APA, 1994). Contrary to several conspicuous perspectives in the field, studies have
demonstrated that worrying actually catalyzes and maintains anxious distress (see Newman, Llera, Erickson, Przeworski, & Castonguay, 2013, for a comprehensive review). To begin broadly, the literature suggests that it is possible that those with GAD exhibit an underlying trait vulnerability toward relatively high negative emotionality. Both the heritable personality trait of negative emotionality (known as neuroticism) and genetic risk for increased metabolic activity in the amygdala (the fear response region of the brain) are associated with GAD (Hettema et al., 2012; Hettema, Neale, Myers, Prescott, & Kendler, 2006). More specifically, trait worry is associated with heightened cardiovascular activity and other markers of sympathetic nervous system activation (SNS), as well as lower heart rate variability and other markers of parasympathetic nervous system (PNS) activation (Brosschot, Van Dijk, & Thayer, 2007; Pieper, Brosschot, van der Leeden, & Thayer, 2010). In addition, laboratory experiments have found that induced worry causes increased SNS activation and decreased PNS activation relative to baseline, relaxation periods, and even a cognitive challenge task (Hammel et al., 2011; Llera & Newman, 2014, 2010). In fact, those with GAD recognize and report these increases in anxiety and distress in themselves during worry. Subjective ratings by those with GAD demonstrate that experimental worry inductions lead to elevated negative emotions, such as unpleasantness, anxiety, and fear (Borkovec & Inz, 1990; Borkovec, Lyonfields, Wiser, & Deihl, 1993; Llera & Newman, 2010; Stapinski, Abbott, & Rapee, 2010). On many levels, GAD worry manifests upsetting emotionality.

Distress produced by worries about future misfortune creates a sense of preparedness for negative outcomes. If expected deleterious events do not occur, or feared shifts in emotion never arise, worry-generated negative affect abates and worry is negatively reinforced by that relief. It appears that the vast majority of feared outcomes of those with GAD never come to fruition. In a
daily diary study on a clinical population of those with GAD, Borkovec et al. (1999) found that 85% of clients’ worried outcomes did not turn out badly; of those events that did, participants reported coping better than expected in 79% of the situations. To summarize, worry in GAD is excessive; worry creates aversive feelings contingent on future events; and worrisome outcomes rarely happen. Therefore, maintenance of worry is likely a negative reinforcement process.

Yet other avenues of study suggest that the maintenance of GAD may not only be due to frequent habitual response to negative reinforcement, but also to a relative lack of sensitivity to positive reinforcement. Research under other theoretical domains has supported low positive reinforcement response in those with high anxiety, as is certainly the case with GAD. Gray’s (1970) well-known Reinforcement Sensitivity Theory (RST) posits that there are trait differences in individuals’ response sensitivity to reinforcers and punishers. Psychopathology has been studied under the purview of this theoretical lens, including anxiety disorders (Bijttebier, Beck, Claes, & Vandereycken, 2009; Corr, 2004; Corr, Pickering, & Jeffrey, 1995; Gray, 1991).

Generally, anxiety symptoms have had very weak relationships with behavioral approach sensitivity to rewarding stimuli and positive relationships with behavioral inhibition sensitivity (Campbell-Sills, Liverant, & Brown, 2004; Johnson, Turner, & Iwata, 2003; Kimbrel, Nelson-Gray, & Mitchell, 2007; Muris, Meesters, de Kanter, & Timmerman, 2005). Note that a childhood temperament of behavioral inhibition has been shown to be a risk factor for GAD—behavioral inhibition being characterized by restraint, low threshold to novelty, and avoidance when exposed to novel stimuli (Kagan & Snidman, 1999; Rothbart, 2007). Furthermore, Zinbarg and Revelle (1989) employed a series of inter-locking “go/no go” tasks to test reinforcement effects on anxiety and impulsivity within an RST framework. Interestingly, high anxiety individuals (who were also low on impulsivity) rapidly learned to avoid punishment by
inhibiting their responses, but did not learn relatively well to make responses to achieve rewards. In contrast, individuals low on anxiety (and high in impulsivity) did learn rapidly to make reward-achieving responses, but had significant trouble making punishment-avoiding responses.

These findings suggest that anxious individuals may have a relatively low tendency to learn by positive reinforcement (and a high response to avoidance learning), whereas nonanxious individuals (especially those with high impulsivity) have a high sensitivity to reward learning. Similarly, Ruscio, Seitchik, Gentes, Jones, and Hallion (2011) found that perseverative thought (worry and rumination) in those with GAD predicted an attenuated positive affective response to success and a heightened negative affective response to failure. Although this study did not address learning, it may suggest that stronger and weaker punishment and reinforcement effectiveness result from amplified and diminished affective responses to those stimuli in persons with GAD. Yet findings are mixed and conclusions uncertain. Somewhat countering Ruscio et al.’s conclusions, in two studies Llera & Newman (2010; 2014) found no differences in reactivity to a positive emotion inducing film clip when comparing those with and without GAD. Yet these positive emotional reactions were not contingent on participant behavior, such as success or failure, as would be the case during learning. Although those with GAD may experience positive emotion to the same degree as controls, the relative emotional reward value of their behavior is still uncertain. However, the Contrast Avoidance Theory does suggest that those with GAD are less likely to allow themselves to feel good for very long, as this increases the likelihood that if something bad happens, they will experience a negative emotional contrast (Newman & Llera, 2011). Consequently, those with GAD may attend to, savor, and maintain positive emotions less, possibly diminishing the reinforcement value of positive experiences.

Considered together, the aforementioned findings suggest that anxious individuals are
likely to have a relatively lower tendency to learn by positive reinforcement, in addition to their hypothesized elevated response to negative reinforcement from habitual relief responding. Yet it is important to recognize that 1) most of these studies do not address learning processes directly, and 2) although these findings hold true for those who score highly on anxiety measures, most of them do not come from studies researching strictly GAD populations. Further research is necessary to determine if those with GAD differentially show greater response to punishment and a lesser response to reward.

Yet indirect evidence suggests that differential reinforcement effects in GAD populations may be similar to broader populations marked by high trait anxiety alone. An elevated vigilance and reactivity toward threatening stimuli may cause those with GAD to attend more to negative, anxiety-causing information, taking up attentional resources that could be used to attend to positively reinforcing information (i.e., rewards). Research has shown that individuals with GAD exhibit a heightened alertness to perceived external threats and threatening faces (Mogg, Millar, & Bradley, 2000; Waters, Mogg, Bradley, & Pine, 2008). Moreover, those with GAD react with strong negativity to even neutral or ambiguous stimuli, as if perceiving them to be negative (Olatunji, Ciesielski, Armstrong, Zhao, & Zald, 2011). In addition, Olatunji et al. demonstrated poorer attentional control in those with GAD compared to controls. It may be the case that those with GAD not only focus on perceived punishing information, but also have greater difficulty commanding their attention away from such negative information and/or toward reward. In short, those with GAD are likely to be too drawn to and distracted by negative stimuli to sufficiently dwell on positive stimuli, at least relative to nonanxious individuals. More direct evidence is necessary to test this hypothesis. In fact, broadly, research on the impact of operant conditioning in GAD is greatly lacking.
Although classical conditioning in GAD has received research attention in the differential fear learning domain (see Arnaudova et al., 2013), and anxious biases in attention, memory, and interpretation have been discovered (e.g., Bishop, Duncan, Brett, & Lawrence, 2004; see Mathews & MacLeod, 2005), neither operant conditioning forces nor differential behavioral learning tendencies have been studied in this disorder. Considering that operant conditioning processes are central to the behaviorist view of GAD symptoms and their maintenance, this void in the literature is surprising—a state of affairs the current study seeks to remedy. Both positive and negative reinforcement learning in GAD can be studied rather easily with a probabilistic learning task (PLT). In the PLT, the correct choice between two stimuli of differing reward probabilities either provides a reward (positive reinforcement) or removes an aversive stimulus (negative reinforcement). Despite the elegance of the negative reinforcement model for worry promotion in GAD, studies addressing operant conditioning in GAD individuals are essentially nonexistent. In the effort of understanding and targeting GAD’s robust maintenance factors, a great deal more research is needed in the area of behavioral learning tendencies in this disorder. Negative reinforcement sensitivity may be a crucial first target.

**Avoidance (of Punishment) vs. Approach (of Reward) Learning**

The vehicle for negative reinforcement in anxiety is prevention and avoidance of punishing stimuli and events. As negative stimuli or perceived risks are prevented or avoided, anxious feelings are diminished and future preventative and evasive techniques are promoted. Yet avoidance is unique in the presentation of GAD specifically: It is likely avoidance of sharp increases in distress rather than distressing stimuli themselves. It has been recognized that all of the major theoretical models of clinical worry place a strong emphasis on avoidance of some form, including the avoidance of negative emotional shifts in the Contrast Avoidance Model.
GAD is the only DSM anxiety disorder without a behavioral symptom criterion. Despite this, a few studies have claimed that individuals with GAD may exhibit forms of behavioral avoidance: The overt evasion of actual stimuli and events that may cause or increase harm and/or distress. Yet this evidence is tangential, often poorly operationalizing avoidance constructs. Uncontrolled, anecdotal clinician reports have noted that GAD clients often engage in subtle behaviors which attempt to diminish or preclude discomfort, such as avoiding worrisome situations (e.g. medical appointments), information (e.g. opening mail, reading news columns), or decision-making (e.g. choosing a college major) (Hazlett-Stevens, 2008; Wells, 2005). Yet the notion that those with GAD avoid such distressing stimuli is quite contested. Primarily, behavioral avoidance may be present in some of those with GAD, but no research suggests that it is characteristic of the disorder. The types of avoidance that may be characteristic of GAD are those confounded with worry; they are preparatory actions fending off an unsavory future occurrence. Rather than framing anxious behaviors in GAD as behavioral avoidance, they are perhaps best regarded as “preventative”—aiming to preclude some negative outcome. There is no data to suggest that such preventative behaviors are disabling in the way that they might be in, for example, obsessive compulsive disorder. True avoidance inherent to GAD may be avoidance of unpredictable fluctuations in one’s internal experiences, which is a cognitive process via worry rather than a behavioral one. When outcomes are unforeseen, they are often unpreventable. Consequently, their impact must be buffered by increasing and maintaining distress via cognition.
In fact, behavioral avoidance may not even be feasible for the particular concerns of those with GAD. The events those with GAD wish to avoid are by definition probabilistic: One cannot be certain worried future events will occur, but rather must project some subjective assessment of likelihood (i.e., risk) that the negative events created in worry will come to fruition over time. Several GAD researchers have suggested that these future-oriented, intangible, highly probabilistic fears of those with GAD—associated with uncontrollable, multiple, vague, and personally-generated anxiety cues—often make behavioral avoidance or active prevention difficult or impossible (Borkovec et al., 1999; Dugas & Koerner, 2005). Consequently, the vast majority of avoidance in GAD may be via worry itself.

As previously mentioned, Newman and Llera’s Contrast Avoidance Model proposes just such a function for worry: That it maintains a state of distress to avoid dramatic changes in negative emotion when aversive events occur. In a GAD sample, Newman and Llera demonstrated experimentally that worrying prior to viewing a fearful film clip leads to significantly less change in physiological and subjective anxious responding than relaxation, and less subjective responding than a neutral induction (Llera & Newman, 2010). Therefore, although those with GAD engage frequently in worry—which is itself an emotionally aversive experience—they do so to avoid sudden shifting in aversive emotion. Stated differently, the induction of distress via worry is active prevention of plummets in emotional valence with an affective buffer. Theoretically, to experience such a negative emotional contrast, some punishing causal event or thought must occur. It then follows that those with GAD may at times avoid experiences (or experience-arising cognitions) that would cause dramatic swings toward negative emotion. Therefore, the Contrast Avoidance Model of worry accounts for behavioral avoidance (if any), active prevention, and the punishment avoidance function of worry in GAD. Following
from the ubiquitous influence of prevention and contrast avoidance in those with GAD, worry-prone individuals may learn implicitly to lead lives of preclusion of punishment to an unnecessary degree, rather than pursuing positive outcomes in a healthy manner.

In research arenas outside the study of anxiety disorders, individuals have been shown to be differentiable along a continuum of whether they learn more successfully by approach of rewards or avoidance of punishment (Frank, D'Lauro, & Curran, 2007). According to this theory, people can be categorized as either “positive” or “negative” learners. *Positive learners* exhibit better implicit learning in response to reward feedback for choosing stimuli with a high probability of positive return. In contrast, *negative learners* show more accuracy in avoiding stimuli that have a high probability of punishment (i.e., negative feedback). Several studies have employed a probabilistic selection task (PST) to capture this trait difference (e.g. Baker, Stockwell, & Holroyd, 2013; Frank et al., 2007). In this laboratory task, participants choose between paired stimuli, each of which has either have a high, neutral, or low likelihood of punishment/reward. This design allows researchers to determine whether the participant is more successful at choosing (approaching) the highest rewarding stimuli or not choosing (avoiding) the highest punishing stimuli. Although avoidance of punishment learning has been studied in other anxiety disorders and depression, it has yet to be applied to those with GAD (Cavanagh, Bismark, Frank, & Allen, 2011; Chase et al., 2010; Endrass, Kloft, Kaufmann, & Kathmann, 2011; Whitmer, Frank, & Gotlib, 2012).

The application of this second task to the study of those with GAD is perhaps obvious. With prevention of negative outcomes and avoidance of spikes in negative emotion being a central function of worry, it is likely that individuals with GAD will show superior avoidant learning—be strongly negative learners—on the PST. Individuals with GAD show a higher
perception of negative outcomes (Maner & Schmidt, 2006) and exaggerated processing of probabilistic negative events that may occur in the future (Dugas, Gagnon, Ladouceur, & Freeston, 1998; Wells, 1999), suggesting that they may be more sensitive to, learn more quickly from, and be more accurate with recognizing and avoiding stimuli that result in punishing feedback compared to reward feedback.

The aim of the current study was to determine what, if any, learning tendencies regarding reinforcement or avoidance vs. approach exist in individuals with GAD, both relative to non-anxious controls and within GAD groups. Following from the presented series of rationales, I hypothesized that individuals with GAD would learn better via negative reinforcement, would show poorer learning via positive reinforcement, and would exhibit proportionally less positive learning (i.e., will be worse positive learners) than individuals without GAD for both implicit and explicit learning. Lastly, within those with GAD, I proposed that negative reinforcement would lead to faster, more accurate implicit learning than positive reinforcement and would be considered a more preferable mode of learning. I predicted that the tendency for those with GAD to overestimate probabilities of negative outcome (see Borkovec et al., 1999) would make them less likely to be accurate negative learners compared to controls. More specifically, the following hypotheses were primary to the study at hand:

**Reinforcement Learning Hypotheses.**

1. Those with GAD will implicitly learn more quickly and more accurately by negative reinforcement on the PLT than those without GAD.

2. Those without GAD will implicitly learn more quickly and more accurately by positive reinforcement on the PLT than those with GAD.

3. At the end of the task, negative reinforcement on the PLT will have produced more
accurate implicit probabilistic learning than positive reinforcement in those with GAD.

4. At the end of the task, positive reinforcement on the PLT will produce more accurate implicit probabilistic learning than negative reinforcement in those without GAD.

5. Reaction times will decrease faster and be lower at task’s end in the negative reinforcement condition for those with GAD but in the positive reinforcement condition for those without GAD.

6. Where explicit learning is concerned, compared to non-GADs those with GAD will have more accurate probability of reinforcement estimations for all levels of probabilistic reinforcement after having learned via negative reinforcement, but worse accuracy after having learned via positive reinforcement.

7. Those with GAD will report less undesirability and greater motivation toward learning from negative reinforcement compared to positive reinforcement when engaging in the PLT, whereas the opposite will be true for those without GAD.

8. Those with GAD who experience positive reinforcement will report a greater degree of belief that they would prefer negative reinforcement than vice versa, whereas the opposite will be true for those without GAD.

**Avoidance vs. Approach Learning Hypotheses.**

9. Within those with GAD, those with GAD will show more accurate learning via avoidance of punishment than by approach of reward on the PST. That is to say, significantly more people with GAD will be negative learners than people without.

10. Between groups, those with GAD will be worse negative learners compared to those without GAD.
11. Between groups, those without GAD will be better negative learners compared to those with GAD.

12. Reactions will be faster on avoidance of punishment trials for those with GAD but will be faster on approach of reward trials for those without GAD.

These propositions find their importance in the hope that better understanding the deep, implicit processing tendencies of GAD pathology will lay a foundation for extension studies seeking a better comprehension of, and subsequent improved treatments of, the maintenance factors of the disorder.
Method

Both reinforcement and avoidance learning tendencies were studied via a computer-based experimental within- and between-subjects design. This study was approved by an Institutional Review Board.

Participants

Power analysis suggested a need for 216 participants to achieve adequate power (0.80) for repeated measures analysis. RMASS calculation software was used to run a power analysis for a two level linear mixed effects model accounting for longitudinal repeated measures. Results indicated a need for 54 participants per group. Four groups are necessary to make all anticipated comparisons in this study (negative reinforcement and positive reinforcement in both GADs and non-anxious controls); therefore, 216 participants were needed to achieve adequate power—108 GAD and 108 non-GAD.

Participants were identified through the Pennsylvania State University subject pool—a database of students who are first prescreened with a variety of measures and then asked to participate in research studies as a course requirement. The post-pool screening GAD sample was comprised of individuals who met DSM-IV criteria for Generalized Anxiety Disorder on the GAD-Q-IV, a widely used measure of GAD pathology (Newman et al., 2002), based off their subject pool screening responses. Studies have shown that undergraduates in early adulthood are particularly prone to experiencing anxiety-provoking circumstances, as they face a host of difficult developmental tasks within a short period of time (e.g., independence from family, choosing a career path, long-term relational commitments, formation of social groups); thus, undergraduates are an appropriate and relevant sample for research on anxiety pathology (Towbes & Cohen, 1996). Non-GAD controls were students who do not sufficiently meet any of
the GAD criteria and scored half of a standard deviation below the mean of the entire sample on the GAD-Q-IV. Contact information was collected via the subject pool. Eligible GAD and non-GAD students were emailed an invitation to participate in the study. All participants were 18 years of age or older. Data was collected from 191 participants, 87 GAD and 104 non-GAD, over the course of the 2015-2016 school year. Each participant completed the GAD-Q-IV again during the session to confirm that they did in fact meet criteria for GAD. Many individuals did not meet all strict criteria for GAD after this second, in-person assessment. After diagnostic criterion scoring of the second GAD-Q-IV administration, the final sample included 157 participants, 59 GAD and 98 non-GAD. One hundred and twenty-three were female and 34 were male. Regarding ethnicity, the sample was 81.5% White, 7.6% Asian, 5.1% Black, 4.5% Hispanic, 0.6% Middle Eastern, and 0.6% Pacific Islander. Based on the aforementioned power analysis, the current study was underpowered for multilevel analysis. Yet for factorial ANOVAs a series of post-hoc power analyses using GPower software indicated that this sample generally has adequate power to detect a moderate effect (power values near .85), but not a small effect (power values of 0.50).

**Materials**

**Generalized Anxiety Disorder Questionnaire for DSM-IV.**

The Generalized Anxiety Disorder Questionnaire for the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.) (APA, 1994; Newman et al., 2002) is a 9 item self-report measure intended to assess DSM-IV diagnostic criteria for Generalized Anxiety Disorder. As noted by Rodebaugh, Holaway, and Heimberg (2008), the GAD-Q-IV is the only measure that assesses the entire clinical syndrome of GAD, as most GAD measures focus exclusively on worry. The GAD-Q-IV consists of five yes/no questions evaluating the presence of
uncontrollable and excessive worry (e.g., “Is your worry excessive in intensity, frequency, or the amount of distress it causes?”), entry spaces for a list of the participant’s most common worry topics, a checklist of the six somatic symptoms related to GAD (e.g., irritability, tension), and two questions assessing the degree of distress and life interference that can be ascribed to the worry and anxiety symptoms, scored on a 0 (None) to 8 (Very Severe) scale. The measure is most commonly used as it is employed in the current study: For initial screening of clinically-significant GAD symptomatology (Newman et al., 2002). Although the GAD-Q-IV can be scored according to a dimensional scoring system, the criterion-based scoring system will be used in this study to determine if subject pool participants meet minimum criteria for GAD. Dimensional severity is of less concern in the context of the current project. Moreover, the validity of the dimensional cutoff has been in dispute in recent years, whereas the criterion-based system has not.

Studies on the validity and reliability of the GAD-Q-IV have demonstrated properties adequate to determine participant GAD diagnoses with consistency. Newman et al. (2002) found that the GAD-Q-IV had good rates of kappa agreement ($\kappa = .67$) with the Anxiety Disorders Interview Schedule (ADIS). It has also demonstrated strong convergent validity with measures of worry such as the Penn State Worry Questionnaire, as well as discriminant validity with measures of social anxiety and panic disorder (Newman et al., 2002). Internal consistency (Cronbach’s alpha = .94) is also robust, and over a two-week period the GAD-Q-IV evidenced sufficient test-retest reliability in classifying participants as either being likely to have GAD or not ($\kappa = .64$; 92% of the sample). Consequently, the GAD-Q-IV appears to be a sufficient measure for screening participants for GAD psychopathology.

**Beck Depression Inventory II.**
In order to be able to assess for comorbidity, participants were administered the Beck Depression Inventory II (Beck, Steer, & Brown, 1996). The BDI-II is a widely used, 21-item self-report survey designed to measure the presence and severity of depressive symptoms (affective, cognitive, motivational, vegetative, and psychomotor) in both clinically-diagnosed and non-depressed adolescents and adults. The BDI-II has demonstrated high internal consistency ranging from $\alpha = 0.91$ (Duzois, Dobson, & Ahnberg, 1998) in a sample of 1,022 undergraduate students to $\alpha = 0.93$ (Beck et al., 1996) in Beck’s original sample of 120. Criterion-related validity has been established for the BDI-II as well: Persons diagnosed with major depressive disorder have been shown to score significantly higher on the BDI–II than non-depressed populations (Arnau, Meagher, Norris, & Bramson, 2001). Lastly, convergent and discriminant validity have been demonstrated for the instrument: The BDI-II has stronger correlations with other measures of depression than with measures of anxiety (Beck et al., 1996).

The Social Phobia Diagnostic Questionnaire.

Comorbidity rates of GAD and Social Anxiety Disorder in the sample was also assessed. To this end, participants were asked to complete the Social Phobia Diagnostic Questionnaire (SPDQ). The SPDQ is a 25 item self-report survey that utilizes a combination of yes/no and symptom rating scale questions to assess the presence and degree of excessive fearfulness in social, observational, and evaluative situations. Specifically, the inventory includes questions asking whether the participant experiences a fear of embarrassment, being viewed critically, and/or attempts to avoid interaction (yes/no), among others, as well as a list of 16 social situations for which the assessee rates fear and avoidance on a 4-point Likert scale ranging from “none” to “very severe and/or consistent.” In a study inquiring into whether the SPDQ is an acceptable measure for selecting for social anxiety disorder among undergraduate research
participants, the inventory showed acceptable sensitivity, specificity, and discriminative ability (Newman, Kachin, Zuellig, Constantino, & Cashman-McGrath, 2003). In this same study, the SPDQ was also shown to be highly internally consistent with a Cronbach’s alpha of 0.92 and a Guttman split-half reliability of 0.89; it also demonstrated good test-retest reliability, as well as acceptable convergent and discriminant validity.

**Post-Questionnaire.**

Participants completed a self-report questionnaire developed specifically for this study following completion of the probabilistic learning task (see Appendix A). This short series of questions depended on the participant’s condition and included manipulation check measures and questions about participants’ reinforcement experience and explicit learning. These items were intended to assess two points of interest: 1) Do those with GAD report a preference for learning by negative reinforcement over positive reinforcement? and 2-5) do individuals, with or without GAD, learn the accuracy of reinforcement cues explicitly as well as implicitly? That is, do reported probabilities of reward/punishment-removal match the actual probabilities?

**Computers.**

All computerized tasks were run with E-Prime 2.0 on Dell Optiplex 7010 desktop computers with Intel CORE i7 processors running Windows 7. These computers were restarted before every run and researchers strictly adhered to the rule that no software other than E-prime be open or running during task administration. Such procedures lend greater confidence to the validity of uninterrupted reaction time monitoring.

**Procedure**

After arriving at the laboratory, participants recruited from the subject pool first completed informed consent. Once consent was given, participants completed the GAD-Q-IV
once again to verify that they did (or did not) in fact meet criteria for GAD as suggested by the prescreening. In-session GAD status was not diagnosed until data analysis, so no participants were excluded from completing their run at this time. They then completed the BDI-II and the SPDQ to assess for comorbidity. Afterwards, participants engaged in two of three computer-based learning tasks, all randomly counterbalanced across participants. These three tasks (as explained in detail throughout the subsequent sections) were the Negative Reinforcement Probabilistic Learning Task, the Positive Reinforcement Probabilistic Learning Task, and the Probabilistic Selection Task. Each learning task was completed separately without intermixing of positive reinforcement and negative reinforcement trials. Every participant in the study engaged in the Probabilistic Selection Task and one of the two other condition tasks, randomly assigned. Prior to each trial, participants were given on-screen instructions regarding how to complete each respective task. The PLT designed specifically for this study did not include practice trials for the tasks due to their simplicity, brevity, and the possibility that practice may influence learning outcomes of later trials. The PST did include ten practice trials according to its usual replicated protocol. Tasks were presented (and data was collected) via the E-Prime 2.0 software application suite for computerized experiments. After the PLT was finished (regardless of presentation order with PST), participants completed manipulation check measures to determine if they in fact found the rewards rewarding (positive) and the aversive states aversive (negative) (see section “Manipulation Checks”). Lastly, they completed the post-questionnaire developed for this study, depending on condition (see Appendix A). Following study participation, participants received an educational debriefing handout as required by the subject pool.

**Probabilistic Learning Task I: Negative Reinforcement.**

The probabilistic learning by negative reinforcement task employed the removal of an
aversive face upon certain stimulus choices to reinforce future choices of a stimulus with a high probability of face-removal. The task design utilized in the current study is based on that by Lin, Adolphs, and Rangel (2012), but was reprogrammed with significant modification. Their task was been modified to include elements of a disappearing face task procedure similar to that of Stevens, Peters, Abraham, and Hermann (2014).

In the task participants were seated in front of a computer screen with the middle finger of each hand placed on the “H” and “L” keys of the keyboard. Participants first read a series of instructions while listening to a research assistant recite them out loud. Before advancing they were given the opportunity to ask clarification questions, but researcher answers were highly restricted to repeating or clarifying the content of the on screen instructions. The instructions read, “In the following task you will be presented with many pairs of slot machine images, as well as the angry face of someone who strongly disapproves of you. Each slot machine will have a specific color and design. There is no deep meaning to the specific color or specific design of the slot machines. These features are only meant to help you distinguish one slot machine from another. If one color/design appears more often than others, that does not necessarily mean it is special. You can choose the slot machine on the left by pressing the "H" key (left hand). You can choose the slot machine on the right by pressing the "L" key (right hand). Please place your left middle finger on the H key and your right middle finger on the L key now. Each particular slot machine color/design has a unique probability of removing the face from the screen. In other words, some slot machines have a higher chance of removing the face than others do. Each slot machine's probability is consistent throughout the task. Your goal is to remove the angry face from the screen by choosing the slot machine that is most likely to lead to the face disappearing. When the face goes away, you will see a blank screen. Otherwise, the face will remain. After
each trial another pair of slot machines will appear and the next trial will begin. You must learn by trial and error which slot machine has the best likelihood of removing the face in each pair. Pay attention to whether you made the face disappear or not. Make the face disappear as soon as possible. Choose as quickly as you can. You have a very short time limit for each choice.”

Afterward, a centered fixation cross appeared for 500ms and then trials began immediately. Task trials displayed paired images of two animated slot machines differing in color (blue, orange, green) and frontal design pattern (circle of dots, checkered squares, X of dots) on the left and right of the screen, as well as (in this condition) a large, persisting color photograph of an unfamiliar angry face in the center. All face stimuli were taken from the NimStim collection (Tottenham et al., 2009); see Appendix C). Each distinct slot machine icon was associated with one of three probabilistic outcome distributions: High probability of reinforcement (80% chance of face image removal), chance probability of reinforcement (50% chance of removal), and low probability of reinforcement (20% chance of removal). That is to say, if a certain stimulus was chosen it had a specific likelihood of giving the reinforcer (e.g. if the high probability stimulus were to be chosen ten times, it would remove the face eight times, etc.). In each trial the chance probability icon was paired with either the high or low probability icon. Thus, trials included either the high probability stimulus paired with the chance probability stimulus or the chance probability stimulus paired with the low probability stimulus. Pairs were presented in random order. Location of each stimulus (left or right) was randomized. In each trial participants were charged with choosing one of the two slot machines in order to remove the angry face (aversive stimulus) from the screen. Participants underwent 100 trials each (50 of each pair in random order; 10 blocks of 10 trials where data analysis is concerned). Participants chose one or the other by pressing the left or right corresponding key. There was a 2.5s time period available for
participants to make their choices in all cases. Once participants made their choices, the slot machines disappeared from the screen. If participants chose a stimulus that was reinforced, the angry face also disappeared from the screen for 2s. If participants chose a stimulus that was not reinforced, the angry face remained on the screen (without the slot machines) until the next trial when the icons reappeared (2s). Pilot testing determined these reinforcement times to be optimal for task learning, brevity, and efficiency. Participants were tasked with learning by trial and error which stimulus was more likely to lead to the removal of the aversive face in each pair. They were not informed of the differing stimulus response probabilities beforehand, but had to learn them via reinforcement across trials.

**Probabilistic Learning Task II: Positive reinforcement.**

In the positive reinforcement PLT, participants attempted to make a happy face appear as a reward for reinforced choices. This task was directly equivalent to the negative reinforcement PLT with a few exceptions. The instructions were modified to inform the participants to expect the appearance of “a happy face of someone who strongly approves of” them instead of an angry face. The trial screen in this task only included a pair of slot machine icons with no face image present. It had a between-icon distance equal to that of the negative PLT and a blank, black area between icons. On choosing a reinforced stimulus, an unfamiliar happy face appeared for 2s. On choosing a stimulus that was not reinforced, the screen remained blank for 2s. Mirroring the negative reinforcement PLT, there were 100 trials with 50 of each stimuli pair. Other than the reinforcement style (happy face reward) all other details were identical between the two tasks.

**Probabilistic Selection Task.**

Similar to the probabilistic learning tasks, the probabilistic selection task (PST) asked participants to choose between two computerized stimuli, each with differing probabilities of
reinforcement. Yet the PST is a more complex task with two stages: One in which the reward/punishment probabilities of six symbols were learned as in the PLTs, and a second in which the previously consistent symbol pairs were separated and intermixed with one another and tested. In the first phase participants learned by positive reinforcement and positive punishment through immediate feedback. In the second phase they were tested on whether they showed differences in choosing higher reward symbols or avoiding higher punishment symbols, as learned in the first stage. This testing phase did not include reinforcement feedback. The PST version employed by the current study was identical to that of (Frank et al., 2007).

In the PST participants first placed their middle fingers on the 0 and 1 keys, each used to choose a stimulus on its respective side of the screen. They then read task instructions: “Two black figures will appear simultaneously on the computer screen. One of the figures will be "correct" and one will be "incorrect", but at first you won't know which is which. Try to guess the "correct" figure as quickly and accurately as possible. There is no ABSOLUTE right answer, but some symbols have a higher chance of being correct than others. Try to pick the symbol that you find to have the highest chance of being correct.” Afterward, they underwent six short practice trials with stimuli that never appear in later trials. In each phase, pairs of unfamiliar visual stimuli (Japanese Hiragana characters; see Figure 1 from Frank et al., 2007, below) were presented to participants in black on a white background. Participants then chose which stimulus they believed to be most likely to be “correct” in both phases as quickly as possible. Following each choice, feedback was provided: “Correct!” in blue font as a reward for a reinforced choice or “Incorrect” in red font as a punishment for a non-reinforced choice. The visual feedback remained on the screen for 1.5s after each choice.

In the first phase participants learned the relative reward probabilities of three different
stimulus pairs (AB, CD, and EF) by trial and error. These pairs were presented in random order and always remained in their original pair throughout the phase (that is, C will always be beside D, etc.). According to this design, stimulus A had an 80% probability of leading to rewarding (correct) feedback on being chosen in AB trials, whereas Stimulus B had an 80% probability of punishing (incorrect) feedback (or, conversely, a 20% chance of reward). CD and EF pairs had intermediate, less reliable probabilities: Stimulus C had a 70% reward probability in CD trials, whereas E had a 60% reward probability in EF trials. It was expected that over the course of training participants would learn to choose stimuli A, C, and E more often than B, D, or F. At minimum participants went through 60 trails (covering each possible pair multiple times) before proceeding to phase two (although most participants did not finish in 60 trials). To ensure that participants were implicitly learning the most commonly rewarded symbols, a performance criterion automatically evaluated after each block of 60 trials was enforced (at least 65% choice of A in AB, 60% of C in CD, and 50% of E in EF, due to their differing reward probabilities). Consequently, one can assume that participants were at relatively the same performance level before they advanced to the testing phase.

Once training phase criteria were met, participants underwent a testing phase. Here participants were presented with new pair combinations of the individual symbols (e.g. AF, BD, AC, etc.) in random order, each of which had either the highest rewarding symbol (A) or the highest punishing symbol (B), as well as the original pairs. Participants were assessed on whether they were more accurate in choosing the highest rewarding symbol (A) in the novel pairs or not choosing (avoiding) the highest punishing symbol (B). This second phase included 180 trials with a feedback (Correct!/Incorrect) duration of 1.5 seconds each. See Figure 1 from Frank et al. (2007) for a clarifying depiction of the task.
Manipulation checks.

In order to verify that the suggested social reinforcers used in these tasks were in fact valid manipulations of positive and negative feeling, manipulation checks were employed for the PLT. After the completion of tasks participants were asked to rate both valence (highly unpleasant to highly pleasant) and arousal (not arousing at all to highly arousing) on a 9-point scale for the angry face, neutral face, and happy face using the Self-Assessment Manikin (Bradley & Lang, 1994). No manipulation checks were necessary for the PST.

Data Management

SPSS 22.0 software was used for all data management and statistical analyses. Both the PLT and the PST automatically progress to the next trial if the participant does not make a response within the time limit. Thus, non-responses needed to be addressed. All non-responses due to inaction were marked as missing data. Implicit accuracy was determined by the number of times a participant chose the higher probability of reinforcement icon over the lower icon, organized in several different ways as explained below. Reaction time for each trial was provided by E-prime. For longitudinal analyses of implicit learning on the PLT, data was organized into blocks as is common practice for rapid trial cognitive tasks. Accuracy and reaction were organized into ten blocks of ten trials each. Blocked data controls for outliers and random mistakes in reaction time due to meaningless errors and allows for streamlined analysis of accuracy. Sum of accurate responses within each set of ten trials was aggregated to block. Reaction time was averaged across each block of ten trials. Based on the range of the data, the threshold for blocks to criterion outcome scores was the number of blocks prior to achieving 70% accuracy or greater on two consecutive blocks.

Explicit learning on the PST was operationalized by the participant’s estimations of each
stimulus’ likelihood of providing the reinforcement response after completing the PLT.

Estimating the exact probability of reinforcement post-task from only 50 trials (for each stimulus pair) is a task of high difficulty. Pilot testing demonstrated that explicit learning could be well-determined by a participant’s ability to correctly rank the order of stimuli probabilities (the 80% icon over the 50% icon and the 50% icon over the 20% icon). Correctly ranking a pair of stimuli was determined by whether a participant gave the pair’s higher true probability stimulus a higher estimated probability than the lower probability stimulus. Thus, for overall explicit accuracy participants who did not correctly rank any pair of stimuli received a 0, those who correctly ranked one pair but not the other received a 1, and those who correctly ranked both pairs of stimuli received a 2. Estimation accuracy for each individual stimuli was computed by subtracting each stimuli’s correct probability from each participant’s estimated likelihood (a difference score) for each person. Lastly, when participants were asked whether they believed they would prefer learning by the other reinforcement type (the one they did not receive), they were given a 0 for their preference of opposite reinforcer if they answered that they would not prefer the other type.

As stated in Method, the primary outcome of the PST is the difference between accuracy on approach of reward trials and on avoidance of punishment trials during the testing phase. Approach of reward trial accuracy was determined by the number of correct responses when the stimulus with the highest probability of reward was paired with any other lower stimulus during the testing phase. Avoidance of punishment trial accuracy was determined by the number of correct responses when the stimulus with the lowest probability of reward (i.e. highest probability of punishment) was paired with any higher stimulus during the testing phase. A difference score was formed by subtracting avoidance of punishment accuracy from approach of
reward accuracy, as is common practice. Participant learner type (Positive, Negative, or Balanced Learners) was a categorical variable determined by whether a participant had a higher approach accuracy than avoidance accuracy (Positive Learner), a higher avoidance accuracy than approach accuracy (Negative Learner), or were equally accurate on both trial types (Balanced Learner). Analyses also employed reaction time for these two types (approach or avoidance) and their difference.

**Planned Analyses**

First, chi-square tests determined if there were differences in the number of missing values between diagnostic groups for both tasks. To establish the effectiveness of the PLT’s manipulation, I then ran a t-test predicting SAM emotional valence scores in response to the face stimuli between reinforcement conditions. Afterwards primary task analyses were conducted.

The high number of within-person repeated measures coupled with the between-subject design of this study makes for significant issues concerning the independence of errors assumption of most common statistical analyses. In order to accommodate for correlated error terms in the many repeated measurements within subject, multilevel modeling was used to analyze all longitudinal implicit learning PLT data by block. For longitudinal analyses of both accuracy and reaction time after implicit probabilistic learning, I used linear mixed models that included GAD status, reinforcement condition, linear trend across ten blocks, quadratic trend across ten blocks, and all possible interactions between these variables as fixed effects, the intercept as a random effect, and a diagonal covariance matrix for repeated measures. Additionally, I ran separate factorial ANOVAs where GAD status, condition, and their interaction predicted number of accurate responses in the last three blocks, average reaction time across the last three blocks, and blocks to criterion accuracy.
Explicit learning on the PLT was first determined by the number of correct rankings of explicitly estimated probabilities of reinforcement for each of the three slot machine stimuli post-task. For this analysis I ran a factorial ANOVA where GAD status, reinforcement type, and their interaction predicted ranking accuracy. I employed the same ANOVA model to predict explicit learning by estimated likelihood for each of the three probabilistic stimuli—high probability of reinforcement (80%), chance probability of reinforcement (50%), and low probability of reinforcement (20%). For perceptions of participant experience on the PLT, the same factorial ANOVA predicted task undesirability, how motivating participants found their reinforcement condition, and degree of preference for the other reinforcement type.

In all PST analyses, only GAD status could be used as a predictor, as there were no experimental conditions (everyone received both positive reinforcement and punishment feedback). For analyses of the PST’s testing phase, I ran a t-test to determine if those with and without GAD differed in their accuracy and reaction time in the difference between approach of reward and avoidance of punishment trials, approach of reward trials only, and avoidance of punishment trials only. I also ran a chi-square test to determine if there were differences in participant learner type (positive, negative, or balanced) between diagnostic groups. Lastly, exploratory analyses investigated overall learning and trajectory of learning during the training phase of the PST. I first explored whether there were differences in the total percentage of correct responses on the training (i.e. learning) phase of the PST with a between GAD/non-GAD group t-test. I used the percent of correct trials out of total trials for each participant because the PST’s criterion-based phase design results in each participant having a different number of training trials. Thus, a linear mixed model including all trials of each participant could not be run. Although a linear mixed model of all trials was not possible, each participant did undergo at
least 60 trials. Consequently, I conducted an exploratory analysis of the trajectory of learning accuracy over time in the first 60 trials of the PST’s training phase. For this analysis I employed a linear mixed model predicting accuracy across the 60 trials with GAD status, linear trend, quadratic trend, and the interaction between GAD and quadratic trend with a random intercept and a diagonal covariance matrix for repeated measures.

Effect sizes corresponded to their respective analysis. Partial eta squared was calculated for factorial ANOVAs with SPSS, formula $\eta^2 = \frac{SS_{between}}{SS_{between} + SS_{error}}$ (Rosenthal & Rosnow, 1991). Chi-square analyses employed Cramér’s $V$ via SPSS, formula $V = \sqrt{\left( \frac{\chi^2}{n} \right) / (\min(k - 1, r - 1))}$ (Cramér, 1946). Cohen’s $d$ was calculated in the traditional manner for t-tests, Cohen’s $d = \frac{(M_2 - M_1)}{SD_{pooled}}$ where $SD_{pooled} = \sqrt{\left( (SD_1^2 + SD_2^2) / 2 \right)}$ (Cohen, 1988). In linear mixed models Cohen’s $d$ was calculated with an alternative formula fit for multilevel models, $d = 2t/df$, as recommended by Rosenthal (1994).
Results

Probabilistic Learning Task (Reinforcement Learning)

**Missingness.** Only 0.56% of values were missing for responses during the PLT. There was no significant difference in number of missing values between those with GAD and those without ($\chi^2(1, N = 156) = 0.040, p = 0.841, V = 0.002$). Therefore, the number of non-responses was low and approximately equivalent for both groups.

**Manipulation check.** A significant difference in the SAM emotional valence scores in response to the face stimuli between the negative reinforcement ($M = 3.56, SD = 1.50$) and positive reinforcement ($M = 6.05, SD = 1.65$) conditions ($t(155) = -9.91, p < 0.001, d = 1.58$) supported the effectiveness of the manipulation.

**Implicit Probabilistic Learning. Accuracy.** When predicting implicit PLT accuracy over time, the overall linear ($t(597) = -2.20, p = 0.028, d = -0.25$) and quadratic ($t(597) = -2.20, p = 0.028, d = -0.25$) trends were significant (both groups showed such change in accuracy). Notably, there was also a significant interaction between GAD status and linear trend ($t(597.41) = -2.20, p = 0.028, d = -0.18$) and a marginally significant interaction between GAD status and quadratic trend ($t(689) = 1.70, p = 0.090, d = 0.13$). Thus, those with GAD learned less and at a slower rate than those without GAD. No other significant findings arose from the model (i.e., there were no effects of condition; see Table 1). Analyses of the number of accurate responses in the last three blocks also revealed a main effect of GAD status alone ($F(1, 155) = 11.41, p = 0.001, \eta^2 = 0.07$) with non-GADs having more accurate responses ($M = 21.20, SD = 4.89$) than those with GAD ($M = 18.34, SD = 5.25$). Yet again no differences in accuracy were found between conditions ($F(1, 155) = 1.098, p = 0.296, \eta^2 = 0.007$) and no interaction effect was present ($F(1, 155) = 0.294, p = 0.588, \eta^2 = 0.002$). Thus, similar to multilevel results, those with
GAD exhibited worse implicit probabilistic learning than non-GADs near the end of the task. Where blocks to criterion analyses were concerned, there was a marginally significant main effect of GAD status only as well \((F(1, 155) = 3.46, p = 0.061, \eta^2 = 0.023; \text{GADs, } M = 6.32, SD = 3.79; \text{non-GAD, } M = 5.19, SD = 3.50)\), revealing that once again those with GAD learned less than non-GADs across conditions. Overall, results generally showed that those with GAD were less accurate, increased in accuracy less over time, and learned at a slower rate of change over time than those without GAD regardless of reinforcement type (see Table 1). These results contradict the prediction that implicit learning in those with GAD would be faster and more accurate via negative reinforcement and worse via positive reinforcement compared to controls. They also failed to support the hypotheses that positive reinforcement would be more effective than negative reinforcement for implicit learning within GADs alone and that the opposite would be true within non-GADs.

*Reaction time.* For longitudinal analyses of reaction time, there was only a significant linear decrease \((t(705) = -6.23, p < 0.001, d = -0.47)\) and quadratic leveling out \((t(597) = -2.20, p = 0.028, d = -0.25)\) in reaction times across all participants; both groups got equally faster in reaction time up to a point, regardless of condition. These results counter the hypothesized effects that reaction times would decrease faster in the negative reinforcement condition for GADs and faster in the positive reinforcement condition for non-GADs (see Table 1). Similarly, for analyses of the average reaction time across the last three blocks, there were again no significant findings. Notably, there was no significant difference in average reaction time between those with GAD \((M = 748, SD = 247)\) and those without GAD \((M = 789, SD = 254; F(1, 155) = 0.82, p = 0.355, \eta^2 = 0.005)\). There was neither a difference in reaction time between conditions \((F(1, 155) = 2.05, p = 0.154, \eta^2 = 0.013)\) nor an interaction \((F(1, 155) = \text{ }}\)

These findings show that response latency was not significantly different for groups and conditions at the task’s end.

**Explicit Probabilistic Learning.** Explicit learning was first determined by the number of correct rankings of explicitly estimated probabilities of reinforcement for each of the three slot machine stimuli post-task. When ranking accuracy served as the outcome, there was a significant main effect of GAD status ($F(1, 156) = 4.17, p = 0.043, \eta^2 = 0.027$) and a marginally significant interaction between GAD status and condition ($F(1, 156) = 3.44, p = 0.066, \eta^2 = 0.022$; see Figure 2), but no main effect of condition (see Table 2). Regarding the main effect of GAD status, those with GAD were generally less accurate ($M = 1.27, SD = 0.64$) than non-GADs ($M = 1.48, SD = 0.60$). Regarding the interaction between GAD status and condition, for those in the negative reinforcement condition there was no difference in ranking accuracy ($F(1, 156) = 0.017, p = 0.895, \eta^2 < .001$). Yet for those in the positive reinforcement condition, those with GAD had significantly worse explicit ranking accuracy ($M = 1.16, SD = 0.64$) than non-GADs ($M = 1.55, SD = 0.58; F(1, 156) = 7.72, p = 0.006, \eta^2 = 0.048$). These findings support the hypothesis that the explicit learning of those with GAD via positive reinforcement would be worse than that of non-GADs. For within GAD simple effects, means were in the expected direction with higher scores for negative reinforcement ($M = 1.39, SD = 0.63$) than positive reinforcement ($M = 1.16, SD = 0.64$), but statistically significant differences did not arise ($F(1,153) = 2.12, p = 0.147, \eta^2 = .014$). For within non-GAD simple effects, means were also in the expected direction with higher scores for positive ($M =1.55, SD = 0.58$) than negative reinforcement ($M = 1.41, SD = 0.61$), but again these differences were not statistically significant ($F(1,153) = 1.32, p = 0.253, \eta^2 = .009$). Thus, results did not support the hypotheses that negative reinforcement would be more powerful than positive for the explicit learning of GAD participants and that positive
reinforcement would be more powerful than negative for non-GADs. Overall, those with GAD had worse explicit learning than those without GAD when learning by positive reinforcement, but there were no between group differences in learning by negative reinforcement and no within-group learning differences by reinforcement type.

Explicit learning of stimuli reinforcement probabilities was then examined separately for each of the three probabilistic stimuli—high probability of reinforcement (80%), chance probability of reinforcement (50%), and low probability of reinforcement (20%). For the high (80%) probability icon, there was a significant main effect of GAD status ($F(1, 156) = 5.71, p = 0.018, \eta^2 = 0.036$) and a marginally significant interaction between GAD status and condition ($F(1, 156) = 2.93, p = 0.089, \eta^2 = 0.019$; see Figure 3), but no main effect of condition (Table 2). Regarding the main effect of GAD status, those with GAD inaccurately underestimated the likelihood of the high probability icon ($M = -25.15, SD = 26.33$) to a greater degree than those without GAD ($M = -15.66, SD = 22.05$). Regarding the interaction between GAD status and condition, for those in the negative reinforcement condition there was no difference in likelihood estimations between diagnostic groups ($F(1, 156) = 0.225, p = 0.636, \eta^2 = .001$). Yet once again, for those in the positive reinforcement condition, those with GAD underestimated the likelihood of the high probability icon ($M = -29.57, SD = 4.25$) to a greater degree than non-GADs ($M = -13.55, SD = 3.45; F(1, 156) = 8.56, p = 0.004, \eta^2 = 0.053$). When positively reinforced, those without GAD had better explicit learning for high reward probability stimuli than those with the disorder, but not when negatively reinforced. For within GAD simple effects, means were in the expected direction with higher scores for negative reinforcement ($M = -20.25, SD = 27.41$) than positive reinforcement ($M = -29.57, SD = 24.92$), but again these differences were not statistically significance ($F(1,153) = 2.28, p = 0.133, \eta^2 = .015$). For within non-GAD
simple effects, means were also in the expected direction with higher scores for positive reinforcement ($M = -13.55$, $SD = 20.81$) than negative reinforcement ($M = -17.61$, $SD = 23.17$), but again these differences were not statistically significant ($F(1,153) = 0.718$, $p = 0.398$, $\eta^2_p = .005$). This set of findings once again support the hypothesis that when there is a high likelihood of reward, those with GAD have worse explicit learning by positive reinforcement than those without GAD. Yet findings failed to support the prediction that within GAD explicit learning would be better by negative reinforcement than positive and that the opposite would be true for non-GADs in high probability of reward scenarios.

For the chance (50%), or medium, probability icon, results revealed no significant differences in likelihood estimation between GAD status groups or conditions and no interaction (see Table 2); degree of explicit learning in difficult chance trials did not depend on GAD status or reinforcement type as hypothesized. Yet for the low (20%) probability icon, there was a significant main effect for GAD status ($F(1, 156) = 0.225$, $p = 0.636$, $\eta^2_p = .001$) where those with GAD provided worse over-estimations of the low probability icon ($M = 10.58$, $SD = 19.51$) than those without GAD ($M = 3.63$, $SD = 14.11$). There was no main effect of reinforcement type or interaction effect for this icon (see Table 2). The GAD group had worse explicit probabilistic learning than the non-GAD group under low reward probability conditions, regardless of reinforcement type. Neither of these sets of findings align with the hypotheses that for the 50% and 20% probability icons, those with GAD would learn better by negative reinforcement compared to those without GAD, but worse by positive reinforcement.

**Perceptions of Task Experience.** Contrary to expectations, analyses of task undesirability found only a main effect of GAD status ($F(1, 156) = 4.60$, $p = 0.034$, $\eta^2_p = 0.029$), but no condition ($F(1, 156) = 0.83$, $p = 0.364$, $\eta^2_p = 0.005$) or interaction effect ($F(1, 156) = $
0.04, $p = 0.838, \eta^2 < 0.001$). Such results showed that those with GAD found the PLT more undesirable ($M = 4.64, SD = 2.68$) than those without GAD ($M = 3.80, SD = 2.12$), regardless of reinforcement type. For how motivating each participant found their respective reinforcement condition, there was only a marginally significant main effect of condition ($F(1, 156) = 3.74, p = 0.055, \eta^2 = 0.024$) with positive reinforcement perceived as more motivating ($M = 6.13, SD = 2.05$) than negative reinforcement ($M = 5.47, SD = 2.40$) for everyone. No effects were found for GAD status ($F(1, 156) = 1.923, p = 0.168, \eta^2 = 0.012$) or the interaction ($F(1, 156) = 0.643, p = 0.424, \eta^2 = 0.004$). When participants were asked if they believed they would prefer the condition they did not undergo (removal of angry face for those in positive condition, appearance of happy face for those in the negative condition) and to what degree, responses again showed only a main effect of condition ($F(1, 155) = 36.34, p < 0.001, \eta^2 = 0.192$). Regardless of GAD status, on average participants in the negative reinforcement condition believed they would prefer the positive reinforcement condition ($M = 4.53, SD = 3.18$) more so than those in the positive condition believed they would prefer the negative ($M = 1.74, SD = 2.67$). Again, no effects arose for GAD status ($F(1, 156) = 1.72, p = 0.192, \eta^2 = 0.011$) or the interaction ($F(1, 156) = 0.76, p = 0.384, \eta^2 = 0.005$). Thus, on average both those with and without GAD believed they would prefer positive reinforcement over negative reinforcement. These results failed to support the hypothesis that those with GAD would prefer negative reinforcement, whereas those without GAD would prefer positive reinforcement.

**Probabilistic Selection Task (Avoidance vs. Approach Learning)**

**Missingness.** Only 1.13% of values were missing for responses during the PST. A chi-square analysis revealed that there was no significant difference in number of missing values between those with GAD and those without ($\chi^2(1, N = 156) = 0.436, p = 0.509, V = 0.004$). Once
again, the number of non-responses was low and approximately equivalent for both groups.

**Testing Phase Results. Accuracy.** Analyses examining differences between diagnostic groups on the primary outcome of the PST (difference between accuracy on approach of reward and avoidance of punishment trials) showed no significant findings ($t(154) = -0.897, p = 0.371, d = 0.15$). This result demonstrates that there was no difference in approach versus avoidance learning between those with GAD and those without. Thus, the hypothesis that GADs would learn better by avoidance than non-GADs was not supported. Alternative outcome measures for the PST include whether the participant was a positive, balanced, or negative learner, accuracy solely on approach of reward trials, and accuracy solely on avoidance of punishment trials. Similar to the above findings, there were no differences in participant learner type between GADs and non-GADs ($\chi^2(2, N = 156) = 0.140, p = 0.933, V = 0.030$). This result counters the prediction that GADs would be more likely to be negative learners than non-GADs. There were also no differences between diagnostic groups in approach of reward accuracy ($t(154) = -0.621, p = 0.536, d = 0.10$) nor in avoidance of punishment accuracy ($t(154) = 0.628, p = 0.531, d = 0.10$), mirroring the above PST results and conclusions.

**Reaction time.** There was a marginally significant difference between GADs and non-GADs in reaction time for approach of reward trials ($t(154) = 1.19, p = 0.066, d = 0.31$) with GAD participants responding slightly faster ($M = 950.64, SD = 323.40$) than non-GADs ($M = 1063.67, SD = 395.05$). Yet there were no significant differences between GAD groups on reaction time during avoidance of punishment trials ($t(154) = 1.31, p = 0.191, d = 0.217$) nor the reaction time difference score between the two trial types ($t(154) = 0.928, p = 0.355, d = 0.157$). None of the findings for reaction time in the PST aligned with the hypothesized results that those with GAD would respond faster to avoidance of punishment trials whereas those without GAD
would have faster responses to approach of reward trials.

**Training Phase Learning Results.** Due to the consistent finding that GADs learned more slowly and to a lesser degree than non-GADs on the other probabilistic learning task, I explored whether there were differences in the total percentage of correct responses on the training (i.e. learning) phase of the PST. Those with GAD did have a significantly lower percentage of accurate trials \( (M = 0.565, SD = 0.061) \) compared to non-GADs \( (M = 0.588, SD = 0.072; t(138) = 1.988, p = 0.049, d = 0.330) \), again showing worse probabilistic learning for GADs than non-GADs. I also conducted an exploratory analysis of the trajectory of learning accuracy over time in the first 60 trials of the PST’s training (i.e. learning) phase. In this analysis there was a significant difference in quadratic trajectory of learning between GADs and non-GADs \( (t(4271.44) = 2.23, p = 0.022, d = 0.068) \) where those with GAD learned more slowly and to a lesser degree than non-GADs once again. There was also a significant difference between GADs and non-GADs in their average trial accuracy collapsed across the 60 trials \( (t(417.64) = -3.00, p = 0.003, d = -0.294) \), a significant main effect of linear time trend \( (t(3755.21) = 3.35, p = 0.001, d = 0.109) \), and a significant main effect of quadratic time trend \( (t(4367.35) = -3.40, p = 0.001, d = -0.103) \). These results show that although both groups increased in probabilistic learning to a point across the training phase of the PLT, those with GAD learned less and more slowly.
Discussion

Worry process theories suggest that those with GAD may have differential learning tendencies compared to those without GAD. Worry’s cycle of creating distress only to receive relief from benign outcomes suggests worry is maintained by negative reinforcement. Thus, those with GAD may learn better by negative reinforcement over positive reinforcement. The use of worry to avoid negative emotional shifts (contrast avoidance) suggests better learning by avoidance of punishment in GAD than approach of rewards. The current study used two implicit probabilistic cognitive tasks to assess trajectories and outcomes of reinforcement and avoidance/approach learning between those with and without GAD. Overall, both implicit and explicit learning results showed that those with GAD generally learned at a slower rate and to a lesser degree on both probabilistic tasks when compared to non-GADs. Although this deficit was present for explicit learning overall, marginally significant effects also suggested that those with GAD may have poorer learning via positive reinforcement than do non-GADs, especially when there is a high likelihood of reward. No between-group differences arose for negative reinforcement learning. Although mean directions aligned with the hypothesis that learning may be better facilitated by negative over positive reinforcement within GADs, the effects were not significant. Reinforcement type means were opposite for those without the disorder (positive overcame negative reinforcement), but again significance was absent. Thus, neither of the within-group reinforcement hypotheses (better learning by negative reinforcement for those with GAD, but by positive reinforcement for non-GADs) were supported. Also contradicting predictions, there were no significant differences between avoidance of punishment and approach of reward learning between GADs and non-GADs. Lastly, there were almost no significant differences in reaction times between diagnostic groups for the many longitudinal and
non-repeated measures analyses tested. There was only one slight exception, as the GAD group had minimally faster responses during approach of reward trials on the PST. These findings weave a complex pattern of conclusions both contradicting and supporting different predictions offered by study hypotheses, all of which deserve explanation.

To begin, why did those with GAD do worse than non-GADs on nearly all of these tasks and outcomes, regardless of learning paradigm? This question is perhaps the greatest and most unexpected curiosity posed by these findings. Poorer learning by the GAD group was certainly the most prominent, pervasive result. Linear mixed models, blocks to criterion analyses, and analyses of end-of-task accuracy revealed that the implicit learning of those with GAD increased in accuracy less over time, had a slower rate of change, and reached a lower level of accuracy than non-GADs regardless of reinforcement type. Explicit post-task learning results also showed that GAD persons had significantly worse difference scores on post-learning reinforcement probability estimations than non-GADs in ranking probability levels, high reinforcement probability trials (greater under-estimation), and low reinforcement probability trials (greater over-estimation). Yet this was not true for the more ambiguous 50/50 chance probability trials, understandably. These findings inspired further exploratory analyses on the learning phase of the PST, seeking to find if this accuracy deficit held across different probabilistic tasks. This suspicion was confirmed. Analyses of percentage of accurate trials out of all learning trials showed lower accuracy in the GAD group overall. A linear mixed model of punishment/reward learning across the first 60 trials of the PST showed slower learning in GADs as well. Why might those with GAD be falling short across these domains? Although several explanations are possible, it is plausible that the answer may lie in the probabilistic nature of these tasks.

Those with GAD may have cognitive deficits in learning the likelihood of outcomes over
time—both implicitly and explicitly. Several lines of research have demonstrated that those with GAD have problems with estimating the probability of future events based on past operant consequences. Excessive worrying is linked to higher subjective likelihoods for the occurrence of negative events (Berenbaum, Thompson, & Bredemeier, 2007; MacLeod, Williams, & Bekerian, 1991) and such probabilities are higher when both GAD analogues and those who meet full criteria are compared to controls (Berenbaum, Thompson, & Pomerantz, 2007; Butler & Mathews, 1983). More crucially, these estimated probabilities of event occurrence are often highly inaccurate. After GAD therapy clients had tracked the actual outcomes of their worrisome predictions in a daily diary, Borkovec et al. (1999) found that 85% of the events did not turn out as predicted. That is to say, only 15% of their estimated probabilities were correct, and of these outcomes participants coped better than expected in 79% of instances. In another study, ecological momentary assessment with the Worry Outcome Journal revealed that 91% of GAD participants’ predictions about feared future events were wrong (LaFreniere & Newman, manuscript in preparation). Furthermore, therapists recognize faulty probability forecasting in their GAD clients. Fifty-eight percent of clinicians report that when clients’ believe in these likelihoods, it is an impediment to treatment (Szkodny, Newman, & Goldfried, 2014). Although previous studies have only demonstrated this problem at a macro-level, the current study shows deficits in probabilistic learning at a finer grain—rapid, implicit operant feedback learning on the scale of a cognitive task. But does this tendency align with theory?

There is reason to believe that GAD persons should bear probabilistic learning deficits as a function of their disorder. If those with GAD worry about future events to protect against unsavory affect change (Newman & Llera, 2011) and also view their worry as positive, useful, and self-defining (i.e. positive worry beliefs; Hebert, Dugas, Tulloch, & Holowka, 2014), then
they are not motivated to learn—nor reinforced for learning—the true probabilities of future events. They are intrinsically rewarded for making poor predictions about probabilistic outcomes because of worry’s utility for contrast avoidance. If they learned the true likelihood of their catastrophes, worry would make little sense. Any probabilities they form are then not based on previous learning—which generally shows that their fears seldom come true—but rather only serve to increase distress for impeding emotional contrast. Therefore, long-term they do not learn to estimate realistic likelihoods from operant data in their experience (i.e. situational consequences). Consistent with the current findings, these issues with likelihood may reside even at an implicit cognitive level. Such deficits may exist either before clinical levels of worry arise—allowing for uncontested use of contrast avoidance across development—or emerge after this process through habit. The latter is to say, disregarding evidence and failing to incorporate it into probability learning for the sake of worry may lead to later cognitive shortcomings. In brief, probabilistic learning deficits facilitate contrast avoidance by keeping clients from retaining the actual likelihoods of innocuous probabilistic outcomes. These faulty wagers permit them to stave off affective whiplash through continual worry.

Yet in regard to this study’s particular operationalization, probabilistic learning deficits are not the only possible explanation for the current results. In such quick tasks it is possible that those with GAD-level anxiety either “jump the gun,” responding too quickly to be accurate, or anxiously hesitate to make a choice, second-guessing themselves. However, there were no significant differences in reaction times between GAD and non-GAD persons in almost any analysis in this study. In the sole exception, those with GAD responded only one-tenth of a second faster than those without GAD on average for approach of reward trials in the PST. Even so, one could still argue that perhaps they waited for so long that trials ended, leading to more
missing answers and less choice feedback. Yet analyses showed missingness of only 1% or less overall across both tasks, as well as no significant differences in missingness between diagnostic groups. Perhaps another explanation could be attentional distraction in GADs toward the social reinforcers in the PLT. Many studies have shown that those with GAD have an attentional bias towards both threatening and happy faces (Bradley, Mogg, White, Groom, & de Bono, 1999). Such biases could have lessened processing of the probabilistic stimuli themselves. However, the GAD group also showed lower accuracy across the PST—a task which did not include face images.

It is also possible that worrying could have interfered with GAD participants’ focus and learning during both of these tasks. Normally, intruding worry does not seem to have factored into GAD persons’ performance on other cognitive tasks. Cognitive studies in GAD are notorious for not finding learning or memory performance differences between GAD groups and controls (Mathews & MacLeod, 2005), with one meta-analysis showing no differences on tasks such as explicit memory recall and recognition and implicit memory word-stem completion and lexical decision/stimulus identification (Mitte, 2008). Thus, worry interference in such tasks is an improbable issue. Still, it is possible that probabilistic tasks may induce interfering worry in those with GAD. The presence of rapid uncertain outcomes may have invited GAD participants to be uncomfortable with ambiguous material and worry. To avoid emotional contrast, they may become concerned about doing well and what their performance may indicate about the self, for example. Such worrying in probabilistic matters may factor into deficits in probabilistic learning in the real world, as worry may hinder correct likelihood formation. Perhaps some other type of mental drift in GADs may have been the culprit of lower accuracy. Having not been stimulated by this simple, repetitive task, thoughts for those with GAD may have more easily shifted to
other concerns, especially given their tendency toward perseverative thought. Lastly, it is possible that once those with GAD found the correct stimuli choice within a pair, they did not maintain confidence in their choice and switched to a wrong strategy. When suddenly not reinforced by a previously rewarded choice, they may work to prevent the negative experience (i.e. contrast) happening again by changing their answering approach, ultimately leading to errors. In the PLT, both GAD and non-GAD participants often achieved greater than 70% accuracy in an early block only to drop in accuracy on a later block. In fact, this was the reason a criterion level of two consecutive 70% blocks had to be applied.

Although significant findings showed unexpected global deficits, some explicit, conscious learning results did align with hypotheses. Marginally significant effects revealed that the post-task probability rankings of those with GAD were less accurate than controls when learning by positive reinforcement. Additionally, GAD participants also showed lower explicit learning than non-GADs via positive reinforcement when the stimulus had a high probability of being reinforced (a “sure bet” on a good outcome), giving greater under-estimations of reward likelihood. The groups’ explicit learning did not differ in the negative reinforcement condition for both of these outcomes. Those with GAD may not be registering rewarding experience very well, leading to worse learning from positive consequences. When choices lead to outcomes that induce positive emotion, they may not dwell on the reward long enough to be adequately reinforced. In accordance with Contrast Avoidance Theory, those with GAD are likely to dismiss positive feelings quickly because such feelings leave them vulnerable to greater negative emotional shifts. Without acknowledging and learning from positive outcomes, it is then no surprise that they often have “apprehensive expectations” for the future. Study results suggest this reward learning problem is even true when good outcomes are quite likely, allowing those
with GAD to expect the worst even when it is highly improbable. Previous prediction research and the motivation to avoid contrast through worry would both propose as much. Again, a problem with probabilities surfaces in directions that serve contrast avoidance. Furthermore, the current study found that those with GAD actually made higher estimations of reinforcement for the low (20%) probability stimulus than non-GADs. A deficit in probabilistic learning may again be at play here, creating greater off-base conscious estimation than healthy controls—even for a situation where those with GAD can feel assured that a good outcome is unlikely. Perhaps the explicit learning of some individuals in the GAD group was so poor that they guessed at chance levels (50%), raising the average estimation for GAD persons for this low probability stimuli beyond that of controls. Although both findings were only marginally significant, recall that this study was underpowered to find small effects, which are likely the nature of these subtle biases.

Turning to GAD participants’ phenomenological experience of these tasks, those with GAD found the PLT more undesirable in general than those without GAD, as hypothesized. However, there were no undesirability effects for reinforcement type or the interaction. This result may mean that those with GAD not only do not perform well with probabilistic reinforcement, but are also more likely to find it aversive. Such distaste for probabilistic choices may be related to intolerance of uncertainty, a well-supported theory that those with GAD find ambiguous situations unpleasant (Dugas, Buhr, & Ladouceur, 2004; Dugas et al., 1998). By nature, uncertain outcomes are probabilistic outcomes. One is unsure of an ensuing consequence and must make a probabilistic judgment about various possible outcomes. If those with GAD are worse at doing so and the stakes are high, such choices may be very bothersome. Such upset can then further increase distress for avoiding contrast. This undesirability may lead those with GAD to not engage in uncertain events as much as they can, seeking or creating non-probabilistic,
certain endeavors. When they do not engage in probabilistic experiences—or work preventatively to reduce such situations’ probabilistic nature (achieve certainty)—they then receive less opportunity to “learn to learn” from probabilistic events. Hence, they bear worse probabilistic learning.

Contrary to hypotheses, those with GAD preferred to learn by positive reinforcement over negative reinforcement and a marginally significant effect suggested they may believe it to be more motivating. In fact, all participants preferred positive reinforcement. Why might this be? For GADs, such preferences may simply be a schema-driven belief and not their true phenomenological experience given a perfect study. The current study was merely between-subjects. Therefore, those with GAD were not directly monitoring and comparing real experience, but rather forecasting beliefs. Without reflecting on experience, who would ever say they would prefer watching an enraged scowl over a beaming smile? Alternatively, perhaps those with GAD do find positive reinforcement to be more enjoyable and motivating immediately after experiencing it, but ultimately learn worse by it due to not dwelling on and savoring that reward.

Unlike study expectations, there were no differences in approach of reward or avoidance of punishment learning between those with and without GAD. GAD participants were neither more likely to be positive learners nor negative learners on average. Admittedly, the theoretical evidence proposing such a difference here is much thinner than that for positive versus negative reinforcement. Although contrast avoidance can be thought of as true avoidance of punishment (a negative shift), it may actually be experienced more like ongoing punishment that prevents worse punishment—all while breeding expectations for further suffering in the future. There is also very little evidence supporting behavioral avoidance in GAD, suggesting that such avoidance of punishment may be more central to disorders such as panic, agoraphobia, and social
phobia. Furthermore, one line of thought would suggest that approach of reward learning may actually be rather effective for those with GAD, since continual worry leads to positive contrasts when they do happen (larger shifts from negative to positive than controls), which may be more reinforcing.

One may wonder why those with GAD did worse on explicit learning by positive reinforcement in the PLT, but did not differ from controls on approach of reward learning in the PST. Theoretically, approach of reward learning and working toward positive reinforcement feedback may appear very similar, if not identical. Yet their operationalization in these tasks was quite different in reality. First, approach of reward in the PST was operationalized by choosing the most rewarding icon over any less rewarding icon when in a pair, not by type of feedback. In contrast, positive reinforcement learning in the PLT was determined solely through feedback type for all reinforced choices for any pair of stimuli. Most importantly, the PST did not include purely positive reinforcement (“Correct!”), but also punished participants when making a poor choice (“Incorrect”). In contrast, the PLT was purely positive reinforcement (in the relevant condition). Punishment learning may have compensated for any deficits in approach of reward learning in those with GAD. Since they hold an attentional bias towards threatening information (such as critical feedback; Bishop et al., 2004) and punishment creates aversion, those with GAD may attend to and register punishment feedback better than reward. Such encoding may occur because distress-inducing punishment supports contrast avoidance processes in a way that registering pure reward does not. Clearly these tasks were not equivalent in regard to reward-based learning, and thus offered different findings among the many here.

This intricate constellation of results leaves many questions to be answered. The current study was not without limitations. For both tasks the current sample size was not large enough
for multilevel modeling. Although powerful enough to find moderate effect sizes for non-repeated measures analyses, this sample still undershoots power for finding small effects. Unfortunately, short implicit cognitive tasks such as the PLT and PST do tend to show smaller effect sizes. Furthermore, as with any implicit cognitive task, generalizability must be interpreted with some caution. Though it allows for strict experimental control, the real world relevance of making rapid, electronic choices based on abstract images with artificial reinforcers is questionable. Another limitation was the sheer amount of time participants had to undergo these low stimulation, repetitive, simplistic tasks. Having participants undertake these tasks back to back for 45 minutes may have led to fatigue and boredom over time, which could have affected focus, accuracy, and reaction time. Using more engaging tasks (such as those based on game play) and running the tasks separately may result in clearer findings. For the PLT, the primary limitation was perhaps the low number of trials (100). This number was based on Lin et al.’s (2012) findings that most people learned correct PLT pair choices completely after only 40 trials. In the current sample that was not the case, and some of the participants—particularly those with GAD—never learned the symbols well at all. In fact, most participants did not learn to always choose the higher probability icon by the final block. Designing a longer task may lead to more precise analysis of learning, inquiring into how long it takes until perfect choices are consistently made. In addition, although the manipulation check showed facial reinforcers did work to create aversion and pleasure, greater distress or pleasantness could have been induced, leading to stronger learning. Physiological measures may test the manipulation more convincingly as well. Race of the social reinforcer may also have differential effects for different people, but this study only included one race for each gender. Where the PST is concerned, the biggest limitation was the task’s uneven between-participant training phase durations. Although this is the standard
design of the PST and outcomes usually only concern the testing phase, it did not fit our exploratory ends. This differing number of training trials per participant limited analysis to only the first 60 trials in longitudinal tests. Though using a common, well-validated task is certainly a strength, designing a task where all participants have a full, even number of learning trials would allow for better longitudinal analysis for approach vs. avoidance learning.

With regard to future studies, replication is a must for these unexpected exploratory findings. Probabilistic learning deficits in GAD need to be studied to a much greater degree with varying designs. The current task was quite simple; replication with more complex tasks is recommended. Testing different operant consequence comparisons (e.g., punishment vs. reward or positive vs. negative punishment) and different types of learning (e.g., classical or modeling) in a probabilistic framework is warranted as well. Probabilistic learning may also be tested with an experiential, behavioral task rather than a computerized one. To optimally test for probabilistic learning deficits, GAD and non-GAD persons’ performance on a probabilistic task will ultimately need to be tested against an identical but non-probabilistic task of comparable difficulty. Another question for ensuing research is whether actively worrying affects accuracy on probabilistic learning, perhaps tested by comparing a pre-task worry induction to a relaxation period. Lastly, future studies would do well to see if the implicit and explicit probabilistic learning of those with GAD can be manipulated through intervention.

In fact, GAD treatments for improving estimated outcome probabilities—such as worry outcome monitoring—already exist and are supported by science (LaFreniere & Newman, 2016). Perhaps such therapies can alter something more implicit in GAD than conscious forecasting. The clinical implications of probabilistic learning deficits and worse conscious learning from positive reinforcement are significant. These deficits may be a maintenance factor for GAD,
facilitating ongoing contrast avoidance by leaving faulty catastrophic predictions undisputed by a poorly trained mind. Therapy may benefit from guiding those with GAD to savor rewards and attend to favorable outcomes. Such targets may not only help clients learn better and form healthier, more accurate predictions, but also provide them greater exposure to contrast vulnerability by extending post-outcome positive feeling. Such exposure may increase their tolerance for being open to unexpected emotional downturns, ultimately reducing the need to gird themselves with worry. Whatever outcome, auspicious or otherwise, these possible newfound deficits in probabilistic learning demand further exploration.
References


Footnotes

1 Note that the PST is a different task than the PLT, testing different cognitive phenomena, although they share similar methods of execution.

2 It is important to understand that avoidance vs. approach learning in the PST is avoidance of punishment versus approach of reward. Under the Contrast Avoidance Model, engagement in worry can be conceptualized as an approach of distress process for the sake of buffering emotional shift, but the PST is not a means to address such forms of “approach.”
Appendix A

Post-Study Questionnaire

For all conditions:

1. One a scale of 1 (not appealing at all) to 10 (highly appealing), how appealing did you find the slot machine task in general? [Probabilistic Learning Task]

2. On a scale of 1 (not undesirable at all) to 10 (highly undesirable), how undesirable did you find the slot machine task in general?

For the positive reinforcement condition:

3. In the slot machine task, what would you estimate the probability, out of 100, that choosing the blue slot machine resulted in the appearance of a happy face?

4. In the slot machine task, what would you estimate the probability, out of 100, that choosing the orange slot machine resulted in the appearance of a happy face?

5. In the slot machine task, what would you estimate the probability, out of 100, that choosing the green slot machine resulted in the appearance of a happy face?

6. On a scale of 1 (not motivating at all) to 10 (highly motivating), how motivating was the appearance of the happy face for learning which slot machine to choose?

7. For the slot machine task, do you think you would have preferred learning the correct choice of slot machine by working to remove an angry face from the screen rather than getting a happy face on each correct choice? (Yes or No)

8. If yes, on a scale of 1 (very slightly preferable) to 10 (very highly preferable), how preferable would you have found learning by removing an angry face to learning by getting happy face responses?

For the negative reinforcement condition:

9. In the slot machine task, what would you estimate the probability, out of 100, that choosing the blue slot machine resulted in the disappearance of the angry face?

10. In the slot machine task, what would you estimate the probability, out of 100, that choosing the orange slot machine resulted in the disappearance of the angry face?

11. In the slot machine task, what would you estimate the probability, out of 100, that choosing the green slot machine resulted in the disappearance of the angry face?
12. On a scale of 1 (not motivating at all) to 10 (highly motivating), how motivating was removing the angry face for learning which slot machine to choose?

13. For the slot machine task, do you think you would have preferred learning the correct choice of slot machine by getting the image of a happy face on correct choices rather than working to remove an angry face? (Yes or No)

14. If yes, on a scale of 1 (very slightly preferable) to 10 (very highly preferable), how preferable would you have found learning by getting happy face responses to learning by working to remove an angry face?
Appendix B

Manipulation Checks

After the completion of tasks participants will be asked to rate both valence (highly unpleasant to highly pleasant) and arousal (not arousing at all to highly arousing) on a 9-point scale for the angry face and happy face using the Self-Assessment Manikin (Source: Bradley & Lang, 1994; see image below). No manipulation checks will be necessary for the probabilistic selection task, as it is assessing avoidance versus approach learning rather than the relative potency of reinforcers on learning. Participants need only know whether their choices are correct or incorrect; they do not need to be guided by reinforcers of any significant strength (e.g. the pleasure of success).
Appendix C

Probabilistic Learning Task Stimuli

Source: Tottenham et al., 2009

Female – Angry

Female – Happy
Male - Angry

Happy – Male
Table 1

*Linear mixed model effects for accuracy and reaction time across ten blocks of the probabilistic learning task (operant conditioning).*

<table>
<thead>
<tr>
<th></th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Intercept</td>
<td>29.778</td>
<td>&lt;.001**</td>
<td>3.28</td>
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<td>GAD Status</td>
<td>-.724</td>
<td>.469</td>
<td>-0.080</td>
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<tr>
<td>Condition</td>
<td>.535</td>
<td>.593</td>
<td>0.059</td>
</tr>
<tr>
<td>Linear Time</td>
<td>5.405</td>
<td>&lt;.001**</td>
<td>0.442</td>
</tr>
<tr>
<td>Quadratic</td>
<td>-3.265</td>
<td>.001**</td>
<td>-0.249</td>
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<tr>
<td>GAD*Linear</td>
<td>-2.196</td>
<td>.028*</td>
<td>-0.180</td>
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<tr>
<td>GAD*Quadratic</td>
<td>1.700</td>
<td>.090†</td>
<td>0.129</td>
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<tr>
<td>Cond.*Linear</td>
<td>-.553</td>
<td>.580</td>
<td>-0.045</td>
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<td>Cond.*Quadratic</td>
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<td>0.018</td>
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<td>GAD*Cond.</td>
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<td>GAD*Cond.*Quadratic</td>
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<td><strong>Reaction Time</strong></td>
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<tr>
<td>Intercept</td>
<td>32.604</td>
<td>&lt;0.001**</td>
<td>3.677</td>
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<tr>
<td>GAD Status</td>
<td>-2.165</td>
<td>.031*</td>
<td>-0.244</td>
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<tr>
<td>Condition</td>
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<td>.195</td>
<td>-0.147</td>
</tr>
<tr>
<td>Linear Time</td>
<td>-6.234</td>
<td>&lt;0.001**</td>
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<tr>
<td>Quadratic</td>
<td>3.901</td>
<td>&lt;0.001**</td>
<td>0.274</td>
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<tr>
<td>GAD*Linear</td>
<td>.628</td>
<td>.530</td>
<td>0.047</td>
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<td>GAD*Quadratic</td>
<td>0.069</td>
<td>.945</td>
<td>0.005</td>
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<td>Cond.*Linear</td>
<td>-1.47</td>
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<td>0.114</td>
<td>.909</td>
<td>0.008</td>
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</table>

*Note.* †marginally significant at $\alpha = .10$. *significant at $\alpha = .05$. **significant at $\alpha = .01$. 

Table 2

Factorial ANOVA results for explicit learning of probabilistic stimulus reinforcement likelihoods in the probabilistic selection task.

<table>
<thead>
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<th>Explicit Learning Target</th>
<th>Predictor</th>
<th>$F$</th>
<th>$p$</th>
<th>$\eta^2$</th>
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<td>Stimulus Ranking Accuracy</td>
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<td>.027</td>
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<tr>
<td></td>
<td>Condition</td>
<td>.201</td>
<td>.655</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>GAD*Cond.</td>
<td>3.440</td>
<td>.066†</td>
<td>.022</td>
</tr>
<tr>
<td>High (80%) Probability Stimulus Accuracy</td>
<td>GAD Status</td>
<td>5.711</td>
<td>.018*</td>
<td>.036</td>
</tr>
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<td></td>
<td>Condition</td>
<td>.455</td>
<td>.501</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>GAD*Cond.</td>
<td>2.934</td>
<td>.089†</td>
<td>.019</td>
</tr>
<tr>
<td>Chance (50%) Probability Stimulus Accuracy</td>
<td>GAD Status</td>
<td>.050</td>
<td>.823</td>
<td>.000</td>
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<td></td>
<td>Condition</td>
<td>.038</td>
<td>.847</td>
<td>.000</td>
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<td>GAD*Cond.</td>
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<td>.525</td>
<td>.003</td>
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<td>Low (20%) Probability Stimulus Accuracy</td>
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<td>.010*</td>
<td>.042</td>
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<td></td>
<td>Condition</td>
<td>.382</td>
<td>.538</td>
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<td>GAD*Cond.</td>
<td>.970</td>
<td>.326</td>
<td>.006</td>
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Note. †marginally significant at $\alpha = .10$. * significant at $\alpha = .05$. **significant at $\alpha = .01$. 


Figure 1. Visual representation of the training and testing phases of the Probabilistic Selection Task and theorized performance by learner type. Source: Frank, D’Lauro, and Curran (2007).
Figure 2. GAD status by condition interaction plot of estimated marginal means for explicit reinforcement probability ranking of stimuli.
Figure 3. GAD status by condition interaction plot of estimated marginal means for explicit likelihood estimation of high probability of reinforcement icon.