Journal of Behavior Therapy and Experimental Psychiatry 66 (2020) 101524

Contents lists available at ScienceDirect

Journal of Behavior Therapy and Experimental Psychiatry

journal homepage: www.elsevier.com/locate/jbtep

Costly avoidance in anxious individuals: Elevated threat avoidance in anxious individuals under high, but not low competing rewards

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ARTICLE INFO

Keywords:
Anxiety
Approach-avoidance behavior
Avoidance
Discounting

ABSTRACT

Background and objectives: When avoiding threat conflicts with approaching rewards, balanced responses to threat and reward information is required to guide functional behavior. Elevated threat avoidance characterizes anxious psychopathology. However, little is known about the mutual impact of threat and reward information on approach-avoidance behavior and its link to anxiety.
Methods: High trait-anxious and low-anxious individuals (N = 74) repeatedly choose between two options. A threat/high-reward option was linked to two outcomes: a varying chance to receive an aversive stimulus and a varying high reward. A safe/low-reward option was linked to absence of the aversive stimulus and a low reward.
Results: Avoidance of the threat/high-reward option increased with increasing threat. Despite threat, low-anxious individuals increasingly approached the threat/high-reward option when rewards increased. High- compared to low-anxious individuals showed elevated avoidance, but only in the presence of high competing rewards.
Limitations: Future research should examine boundary conditions by manipulating type and motivational value of appetitive and aversive outcomes (e.g., food as primary reinforcer).
Conclusions: These findings suggest that a weaker impact of rewards competing with threat contributes to elevated threat avoidance in anxious psychopathology. Costly avoidance may thus be a factor involved in anxious psychopathology.

1. Introduction

When encountering threat, avoidance is an adaptive response to prevent harm. However, adaptive functioning requires approaching positive outcomes and rewards even in presence of low-level threat. In complex environments, threat and rewards are oftentimes competing outcomes of the same behavioral option. These competing outcomes establish a conflict between approaching rewards under threat versus avoiding threat at the costs of rewards (Corr, 2013; Pittig, Schulz, Craske, & Alpers, 2014). In such approach-avoidance conflicts, a balanced response to threat and reward information is necessary for functional behavior. Insights into how such competing information mutually influence behavior is important for our understanding of functional and dysfunctional human goal-directed actions.

In healthy individuals, research gained first insights into responses to competing threat and reward information. For example, individuals avoid behavioral options linked to threat of aversive outcomes when competing rewards for approach are small or uncertain. However, approach increases in line with increasing rewards (e.g., Aupperle, Sullivan, Melrose, Paulus, & Stein, 2011; Talmi, Dayan, Kiebel, Frith, & Dolan, 2009). Likewise, verbal threat information induces avoidance of threat-instructed option, but avoidance quickly declines when this option is linked to high competing rewards (Bublatzky, Alpers, & Pittig, 2017). These findings demonstrate a modulation of behavioral responses to threat by changing contingencies of rewards competing with threat. Conversely, fixed rewards are approached in the absence of threat, but approach decreases along with increasing threat (Schlund et al., 2016; Sierra-Mercado et al., 2015; van Meurs, Wiggert, Wicker, & Lissek, 2014). In healthy individuals, these findings indicate that approach is motivated when subjective reward values outweigh subjective threat values, but behavior shifts to avoidance when threat values outweigh reward values (see Schlund et al., 2016; Talmi & Pine, 2012).

Elevated avoidance is commonly associated with anxious psychopathology (for a review see Pittig, Treanor, LeBeau, & Craske, 2018).

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https://doi.org/10.1016/j.jbtep.2019.101524
Received 2 December 2018; Received in revised form 15 October 2019; Accepted 27 October 2019
Available online 31 October 2019

Excessive and persistent avoidance, which is out of proportion to actual threat, is a key feature of anxiety disorders (Craske et al., 2017). Such pathological avoidance is linked to severe impairments and the loss of positive outcomes (Craske et al., 2017). For example, socially anxious individuals avoid social events due to a perceived threat of embarrassment and thereby lose the opportunity to make friends. In line with this clinical perspective, anxious compared to healthy individuals show elevated avoidance of threatening or feared stimuli despite losing rewards (e.g., Aupperle et al., 2011; Pittig, Brand, Pawlikowski, & Alpers, 2014; Pittig, Pawlikowski, Craske, & Alpers, 2014; Pittig, Schulz, et al., 2014; van Meurs et al., 2014). Such costly avoidance mimics the impairments of pathological avoidance in anxiety disorders (see Pittig, Alpers, Niles, & Craske, 2015; Pittig, Brand, et al., 2014). However, none of these studies simultaneously varied threat and reward information to test their mutual impact. It thus remains unclear whether elevated avoidance in anxious individuals is linked to less impact of competing reward information under different levels of threat.

The present study examined the impact of varying threat and reward information on approach-avoidance behavior in high-anxious and low-anxious individuals. In a decision paradigm, a threat/high-reward option was linked to higher rewards, but simultaneously to a varying probability of an aversive unconditioned stimulus (US). A safe/low-reward option was linked to a small reward, but to certain absence of the aversive event. We tested whether the modulation of approach-avoidance by reward and threat information differed between high- and low-anxious individuals. In addition, we also recorded and analyzed mouse movement trajectories during approach-avoidance decisions to examine the temporal dynamics of the underlying decision process (see supplemental material).

2. Material and methods

2.1. Participants

Power analyses were conducted for the different ANOVA and follow-up tests (power = .80, α = .05, $d = 0.6/f = 0.3$; conducted with G-Power; Faul, Erdfelder, Lang, & Buchner, 2007). Analyses for follow-up independent t tests yielded the largest required sample size of 36 participants per group. Seventy-four participants were recruited. Trait anxiety was assessed using the anxiety subscale of neuroticism of the NEO-PI-R (Costa & McCrae, 1992) and the trait version of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, & Vagg, 1983). The trait version of the STAI is a 20-item questionnaire assessing how anxious an individual is in general (range: 20 to 80). Before participation, individuals were screened for high and low levels of trait anxiety using the STAI trait version. Participants with a sum score below 38 were included as low-anxious individuals. Participants with a sum score above 45 were included as high trait anxious.[1] All participants provided written informed consent to procedures approved by the local ethics committee (EK267062016). Exclusion criteria were diagnosed bipolar disorder, psychosis, substance abuse and dependence, depression, current use of psychotropic medication, any serious medical conditions, and pregnancy.

Table 1 shows demographic and questionnaire data. High-anxious participants scored significantly higher on trait and state anxiety and reported lower risk taking. No significant group differences were found for impulsiveness, age, and sex. Groups did also not differ in average consumption of caffeine, nicotine, and alcohol, $ts < 1.27$, $ps > .21$ ds < 0.29.

2.2. Materials and procedure

After providing written informed consent, participants completed a questionnaire battery. In addition to trait anxiety, questionnaires assessed state anxiety (STAI state version; Spielberger et al., 1983), general risk taking (short-scale risk-taking-1; Beierlein et al., 2014), impulsiveness (Barrett impulsiveness scale; Patton et al., 1995), and sociodemographic data. Afterwards, a bar-electrode to deliver the aversive US was attached to the participants' non-dominant forearm. The US was an electrical stimulus of 125 consecutive 2-ms stimulations. Individual US intensity was calibrated by stepwise increasing intensity, asking participants to rate unpleasantness, and instructing them to "choose a level that is unpleasant, but not painful". Next, participants completed the threat discounting paradigm.

2.2.1. Threat discounting paradigm

The paradigm was adapted from a well-established temporal discounting task (see Dshemuchadse, Scherbaum, & Goschke, 2012; Scherbaum, Dshemuchadse, & Goschke, 2012). In a total of 324 trials, participants had to decide between two options. In all trials, the safe/low-reward option was linked to a fixed small reward (25 cent) and the certain absence of the US. The threat/high-reward option was linked to a high reward, which varied in proportion to the small reward of the safe/low-reward option (i.e., 28, 31, 36, 42, 50, 63, 83, 125, or 250 cent). At the same time, the threat/high-reward option was linked to a varying probability to receive an aversive US (i.e., 0%, 10%, 25%, 45%, 70%, 100%). Each combination of the nine reward magnitudes and six US probabilities (54 combinations) was presented six times in a randomized order. Participants were instructed that rewards were hypothetical, but that they should decide as if rewards were real. Previous own studies verified that such hypothetical rewards are experienced as high and low and effectively modulate behavioral responses to feared stimuli and aversive USs (Pittig, 2019; Pittig & Dehler, 2019; Pittig, Hengen, Bublatzky, & Alpers, 2018). The number of selections of the threat/high-reward option served as one main outcome variable. Threat avoidance was operationalized as avoidance of the threat/high-reward option.

Each trial followed a standardized sequence. First, participants had to click into a small box in the bottom middle. After clicking, reward magnitude and US probability of the safe/low-reward option ("25 cent" above "0%") were presented (left or right counterbalanced). In addition, two response squares were displayed in the upper left and right corners. After an upward movement of the mouse, reward magnitude and US probability of the threat/high-reward option appeared beneath the remaining response square. Participants had to decide by moving the mouse into the response square of their preferred option. If participants chose the threat/high-reward option, the US was delivered with a chance of the indicated probability (e.g., 80% chance for 80% US probability). Following an inter-trial-interval of 500 ms, the next trial started. Trial sequence and timing was adapted for mouse movement analyses (see supplemental material). Before starting, participants were instructed that outcomes of the safe/low-reward option would remain fixed, but will vary for the threat/high-reward option. Participants completed 40 practice trials without USs delivered.

2.3. Statistical analyses

Data were analyzed using Matlab 2016a (The Mathworks Inc.) and JASP (JASP Team, 2018; Version 0.8.6). Greenhouse-Geisser correction was applied where appropriate. The proportion of threat/high-reward choices was calculated for each combination of the six US probabilities and nine reward magnitudes for each participant. Higher threat

[1] Cut-off scores were considered meaningful to recruit high and low anxious individuals based on tertiles of a previous study including > 200 participants (see Pittig & Dehler, 2019). Comparison to published norms in the STAI-T manual indicated that a score of 45 for the highly anxious group roughly corresponds to the 84%ile (1 SD above mean) in the STAI manual. Further, the mean of 49.95 for the highly anxious group is comparable to a mean of 49.02 for clinically anxious individuals in the STAI manual (see Spielberger et al., 1983). Due to in-between scores, 39 moderate anxious participants were excluded from participation.

Table 1
Demographic and Questionnaire Data.

	High-anxious (n = 37)		*Low-anxious* (n = 37)		t or χ^2	p	d or r	CI_{95}
Age	22.16	(5.15)	21.35	(3.35)	0.80a	.425	0.19	−0.27–0.64
Sex = Female (%)	33	(89.2%)	27	(73.0%)	3.17[b]	.136	0.21	−0.02–0.42
Trait anxiety:								
STAI-Trait	49.95	(5.29)	34.51	(3.39)	14.94[a]	< .001	3.48	2.75–4.20
NEO-PI-R-N1	21.65	(3.78)	14.06	(4.13)	5.48[a]	< .001	1.27	0.77–1.77
State anxiety (STAI-State)	42.32	(7.89)	37.05	(6.98)	3.04[a]	.003	0.71	0.24–1.18
Risk taking (R-1)	3.11	(1.02)	3.97	(1.12)	3.47[a]	.001	0.81	0.33–1.28
Impulsiveness (BIS)	31.16	(4.68)	30.22	(5.50)	0.80[a]	.428	0.19	−0.27–0.64

Note. Means (and standard deviations) for the demographic and questionnaire data. STAI-S/-T = State-Trait Anxiety Inventory (Spielberger et al., 1983); NEO-PI-R-N1 = anxiety subscale of the NEO-PI- R (Costa & McCrae, 1992); R-1 = Short-scale risk-taking (Beierlein, Kovaleva, Kemper, & Rammstedt, 2014); BIS = Barrett impulsiveness scale (Patton, Stanford, & Barratt, 1995). [a] $t(72)$ with Cohen's d; [b] $\chi^2(1, 74)$ with r.

avoidance is indicated by a lower proportion and higher approach of competing rewards by a higher proportion. Proportion data were entered into a mixed-model analysis of variance (ANOVA) with US Probability and Reward Magnitude as within subject's factor and Anxiety (high vs. low) as between subjects' factor.

3. Results

Groups did not differ in objective intensity of the US (High-anxious: $M = 0.57$ mA, $SD = 0.40$; Low-anxious: $M = 0.53$ mA, $SD = 0.38$), $t(72) = 0.41$, $p = .681$, $d = 0.10$, $CI_{95} = -0.36 – 0.55$, or self-reported unpleasantness of the last delivered US (High-anxious: $M = 70.68$, $SD = 18.90$; Low-anxious: $M = 72.97$, $SD = 14.46$), $t(72) = 0.59$, $p = .559$, $d = 0.14$, $CI_{95} = -0.59 – 0.32$.

3.1. Approach-avoidance decisions

Overall, participants chose the threat/high-reward option in 35.45% ($SD = 18.66$) of the trials. Both groups showed increasing avoidance of the threat/high-reward option in line with increasing US probability (see Fig. 1), which was, however, less step for high competing rewards. This effect was indicated by a significant main effect of US probability, $F(2.67,192.02) = 243.94$, $p < .001$, $\eta^2 = 0.771$, a significant main effect of Reward Magnitude, $F(2.81, 202.04) = 4.74$, $p < .001$, $\eta^2 = .225$, and, importantly, a significant interaction of US probability and Reward Magnitude, $F(16.34, 1176.58) = 3.24$, $p < .001$, $\eta^2 = .042$. Thus, rewards were increasingly discounted under increasing threat, however, the rate of discounting was smaller for high rewards (see Fig. 2).

Most importantly, low- and high anxious responded differently to the varying reward magnitudes as indicated by a significant interaction of Reward Magnitude and Anxiety, $F(2.81,202.04) = 4.74$, $p = .004$, $\eta^2 = 0.048$. Follow-up independent t tests yielded no differences between groups for the four smallest reward magnitudes of the threat/high-reward option (28, 31, 36, 42 cent), $ts < 1.72$, $ps > .09$, $ds < 0.40$. As indicated in Fig. 3, low-anxious compared to high-anxious participants, however, more often chose the threat/high-reward option when this option was associated with higher rewards (50, 63, 83, 125 cent), $ts > 2.09$, $ps < .04$, $ds > 0.48$. A similar trend was found for the highest rewards magnitude (250 cent), which, however, missed significance, $t(72) = 1.89$, $p = .06$, $d = 0.44$, $CI_{95} = -0.02 – 0.90$. There were no other significant interaction effects, $Fs < 1.17$, $ps > .22$, $\eta^2 < 0.016$. Due to elevated approach, low-anxious individuals ($M = 22.68$, $SD = 26.56$) received more USs compared to high-anxious individuals ($M = 11.66$, $SD = 13.61$), $t(72) = 2.23$, $p = .029$, $d = 0.52$, $CI_{95} = 0.05–0.98$. In sum, all participants increasingly avoided the threat/high-reward option in line with increasing US probability, which was attenuated under high competing rewards. High-anxious and low-anxious did not differ when rewards for approaching the threat/high-reward option were only slightly higher compared to the safe/low-reward option. However, high-anxious individuals showed elevated avoidance in the presence of high rewards for approach.

3.2. Exploratory analyses of temporal dynamics

Mouse movement trajectories were recorded and analyzed to examine the temporal dynamics of approach-avoidance decisions. Summarized, time-continuous multiple regression analyses (TCMR, see Dshemuchadse et al., 2012; Scherbaum, 2017; Scherbaum & Dshemuchadse, 2019; Scherbaum et al., 2012) demonstrated that threat compared to reward information showed a stronger and faster impact during decision-making in both groups (see Fig. S3 in supplement). Whereas high-anxious and low-anxious individuals showed no differences in the impact of threat information, the impact of reward information was reduced in high-anxious individuals. However, the latter analyses can only be seen as tentative and preliminary due to unexpectedly low statistical power in a post-hoc test and thus require replication. A full description is provided in the supplemental material.

4. Discussion

This study investigated the impact of threat and reward information on approach-avoidance in high-anxious and low-anxious individuals. As expected, avoidance increased with increasing threat and approach increased with reward magnitude. Most importantly, high- compared to low-anxious individuals showed reduced approach of high rewards under threat, i.e., elevated threat avoidance despite high competing positive outcomes. Thus, anxious psychopathology was linked to elevated costly avoidance. However, there were no differences between high- and low-anxious individuals in low-cost avoidance.

As expected, avoidance increased with increasing threat, which supports previous findings (e.g., Schlund et al., 2016; van Meurs et al., 2014). By manipulating threat along a probability continuum, the present results can be linked to discounting phenomena in traditional decision research (e.g., Green & Myerson, 2004; Rachlin, 2000). For example, probabilistic or temporal discounting refers to reduced subjective values of rewards due to its probabilistic uncertainty or temporal delay (e.g., receiving €2 now may have a higher subjective value than €3 in one year). The decreasing value is inferred from progressively decreasing selection of the corresponding option. In the present study, the progressive reduction of threat/high-reward choices closely resembles typical discounting gradients (Frederick, Loewenstein, & O'Donoghue, 2002). The behavioral effects may thus be described as threat discounting: Increasing threat information progressively devalued the high reward of the threat/high-reward option so that the subjective value of the safe/low-reward option exceeded the value of the threat/high-reward option.

The progressive increase of avoidance was not a linear function of threat probability. The strongest increase of avoidance was evident in the transition from low to medium threat probability (0–45%), with

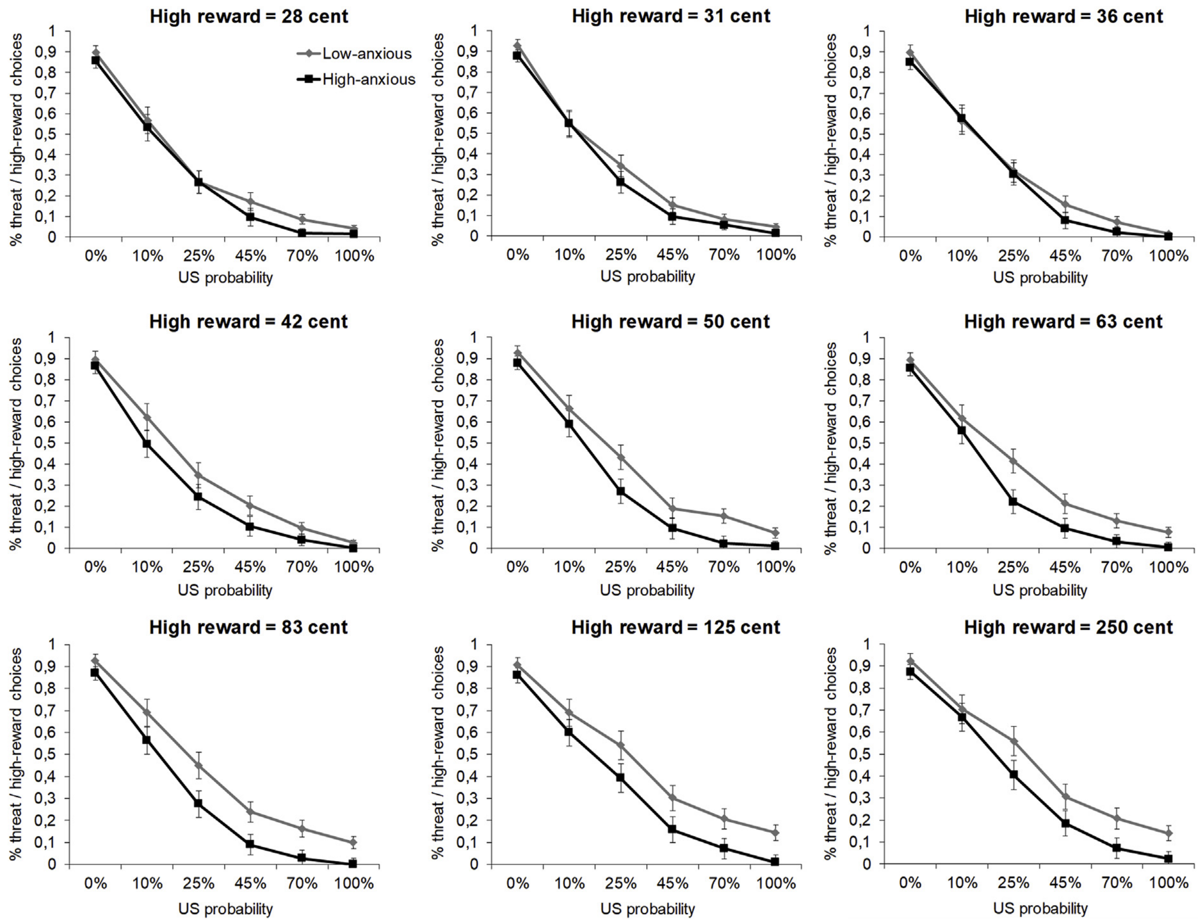

Fig. 1. Mean percentage of choices of the threat/high-reward option (with standard error of the mean) in relation to threat probability for high- and low-anxious individuals. Graphs represent mean percentage separated by reward magnitudes (i.e., Reward: 28–250 cent).

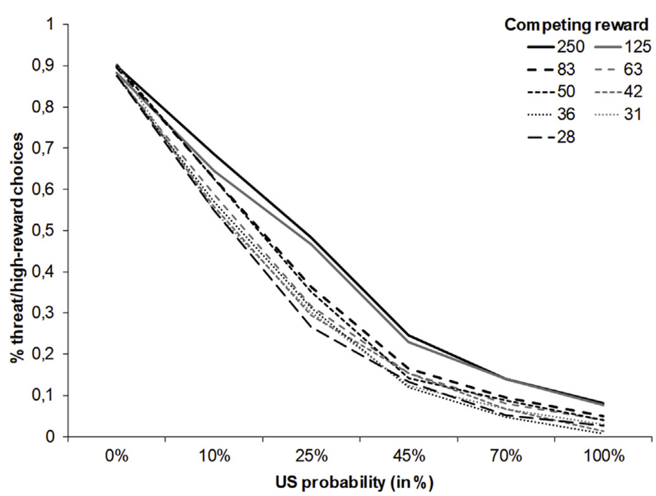

Fig. 2. Mean percentage of choices of the threat/high-reward option in relation to threat probability for each level of competing reward (across groups). Data points and error bars are not displayed to increase visual clarity.

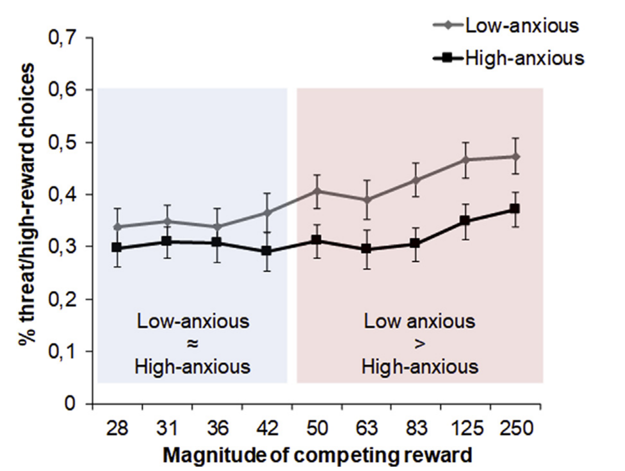

Fig. 3. Mean percentage of choices of the threat/high-reward option (with standard error of the mean) in relation to reward magnitude for high- and low-anxious individuals.

little differentiation for high US probabilities (70% and 100%). This supports the idea of a hyperbolic threat discounting gradient (see Talmi & Pine, 2012). The significant impact of reward magnitude yielded a smaller effect size compared to threat information. This smaller impact of reward information may be due to a higher negative value of the aversive US compared to the positive value of the rewards. Although both outcomes had a systematic effect, they seemed to have no equivalent motivational value. As a limitation, this study did not equate or manipulate the motivational value of both outcomes (e.g., by using real and hypothetical reward). Future research may thus examine the differences in approach-avoidance for different magnitude and types of threat and rewards.

Importantly, threat avoidance was elevated in highly trait anxious individuals, supporting recent studies in individuals with high trait anxiety (Pittig, Schulz, et al., 2014), neuroticism (Lommen, Engelhard,

& van den Hout, 2010), or clinical fear or anxiety (Dymond, Schlund, Roche, & Whelan, 2014; Pittig, Brand, et al., 2014; Pittig, Pawlikowski, et al., 2014). These previous studies, however, did not manipulate reward magnitude. In the present study, no differences were found when approach was linked to only slightly higher rewards compared to avoidance. For higher competing rewards, low-anxious individuals increasingly approached and tolerated aversive outcomes (i.e., more frequent USs). Importantly, approach under high competing rewards was significantly attenuated in high-anxious individuals. Increasing threat thus lead high-anxious participants to devalue high rewards at a higher rate. Combined, these findings provide first evidence that costly avoidance, but not low-cost avoidance, may characterize anxious psychopathology. The ability to modulate behavioral responses to gain rewards despite low-level threat is important for adaptive functioning. Healthy individuals oftentimes approach low-threat situations to gain competing positive outcomes despite fear. Such fear-opponent action can even result in fear reduction when expected threat does not occur (Pittig, 2019). Further research to pinpoint altered responses to rewards competing with threat in anxious individuals is thus required.

Some design considerations and limitations need to be considered. Most importantly, the sensitivity of the reported effects to specific design features should be further examined. For example, the present study used hypothetical rewards. Hypothetical rewards effectively decrease avoidance of feared or aversive stimuli (Pittig, 2019; Pittig & Dehler, 2019; Pittig, Hengen et al., 2018), can be generalized to everyday life (Locey, Jones, & Rachlin, 2011), and elicit similar decisions as real rewards (Bowman & Turnbull, 2003; Jenkinson, Baker, Edelstyn, & Ellis, 2008). Importantly, the present results showed systematic effects of both threat and reward information, which supports the responsiveness to the magnitude of the appetitive value of the rewards. Thus, responses to hypothetical rewards indicate a reduced impact of appetitive outcomes competing with threat in high-anxious individuals. However, the motivational value of the US seems to have been larger than the positive value of high rewards. Using real rewards or linking no reward to the safe option (instead of a small reward), for example, may entail a higher appetitive value and thereby result in different effects (e.g., more frequent approach). Future research may thus examine different outcomes by manipulating type and motivational value of outcomes (e.g., food as primary reinforcer, real money). Moreover, the reduced impact of positive outcomes in anxious individuals demonstrates a difference between high- and low-anxious individuals in response to objectively comparable positive outcomes. These results are informative, as outcomes in real life are oftentimes also not subjectively equated. Using subjectively equivalent outcomes may, however, help to examine differences in the decision process itself. In sum, manipulating design features of the present paradigm is a fruitful approach to provide further insights into the pathways and boundary conditions of elevated costly avoidance in high-anxious individuals.

In addition, the present sample consisted of highly anxious individuals. Average levels of trait anxiety were slightly higher compared to normative data from a sample with clinical anxiety (see Spielberger et al., 1983). However, the present study did not formally assess diagnostic status of the participants. Thus, replication studies may examine the impact of high trait anxiety versus formally diagnosed anxiety disorder to verify first evidence that costly avoidance, but not low-cost avoidance may be a factor involved in anxious psychopathology.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgement

This work was funded by the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) grant PI1269/2-1 - 389569971 to AP and grant SFB 940/2 2016, project A8 to SS. The authors would like to thank Christine Rathemacher and Christina Wolf for their help with data collection. The authors have no conflicts of interest regarding this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2019.101524.

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