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# Same fear responses, less avoidance: Rewards competing with aversive outcomes do not buffer fear acquisition, but attenuate avoidance to accelerate subsequent fear extinction

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ABSTRACT

Rewards for approaching a feared stimulus may compete with fear reduction inherent to avoidance and thereby alter fear and avoidance learning. However, the impact of such competing rewards on fear and avoidance acquisition has rarely been investigated. During acquisition, participants chose between one option (CS+ option) associated with a neutral stimulus followed by an aversive unconditioned stimulus (US) and another option (CS− option) associated with another neutral stimulus followed by no US (N = 223 randomized into three groups). In a subsequent test, no more USs occurred. In one group, competing rewards were established by linking the CS+ option to high rewards and the CS− option to low rewards during acquisition and test (Reward Group). In a second group, rewards were present during acquisition, but discontinued during test (Initial-Reward Group). In a third group, rewards were completely absent (No-Reward Group). Without competing rewards, significant avoidance was acquired and persisted in the absence of the US. Competing rewards attenuated avoidance acquisition already after the first experience of the aversive US. Avoidance remained attenuated even when rewards were discontinued during test. Rewards did, however, not change the level of fear responses to the CS+ (US expectancy, skin conductance). Finally, rewards did not change the level of fear reduction during test, which was, however, experienced earlier. Summarized, rewards for approaching aversive events do not buffer fear acquisition, but can prevent avoidance. This damping of avoidance may initiate fear extinction.

Maladaptive and persistent avoidance behavior is a cardinal symptom of anxiety, post-traumatic stress, and obsessive-compulsive disorder (APA, 2013). Persistent avoidance has been linked to the maintenance of fear and anxiety (Lovibond, Davis, & O'Flaherty, 2000) and pathways into aggravating psychopathology such as secondary depression or substance abuse (Beesdo et al., 2007; Craske et al., 2017; Wittchen, Beesdo, Bittner, & Goodwin, 2003). Importantly, maladaptive avoidance is linked to severe impairments as competing goals and rewards are not approached (e.g., not making new friends or missed career opportunities due to social anxiety). In this regard, maladaptive avoidance comes at the costs of competing rewards and positive outcomes. Insights into how fear and avoidance are acquired and maintained in the presence of such competing rewards are thus crucial for the understanding of functional versus dysfunctional fear regulation and the development and maintenance of anxiety and related disorders (see Arch & Craske, 2009).

Research on avoidance learning only recently (re)emerged (see Arnaudova, Kindt, Fanselow, & Beckers, 2017; Krypotos, Effting, Kindt, & Beckers, 2015; Pittig, Treanor, LeBeau, & Craske, 2018b; Pittig, van den Berg, & Vervliet, 2016; Servatius, 2016; Treanor & Barry, 2017). To this end, basic and translational research used laboratory learning models for real-life avoidance (e.g., Dymond & Roche, 2009; Pittig, Treanor, et al., 2018b). In corresponding studies, healthy and anxious individuals quickly acquire avoidance responses to prevent the (re-) occurrence of an aversive unconditioned stimulus (US; e.g., Delgado, Jou, Ledoux, & Phelps, 2009; Lovibond, Saunders, Weidemann, & Mitchell, 2008; Ly & Roelofs, 2009). Specifically, individuals first learn that a conditioned fear stimulus (CS+) is followed by an aversive stimulus (i.e., the aversive US). As a consequence, individuals acquire conditioned fear towards the CS+, which is, for example, seen in elevated skin conductance responses (SCRs) and increasing expectancy of the aversive stimulus (see e.g., Lipp, 2006; Lonsdorf et al., 2017). Next, individuals learn to perform simple avoidance responses to cancel the upcoming aversive stimulus, for example, by pressing a button

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whenever the CS+ is presented. Successful avoidance responses are typically accompanied by a reduction of conditioned fear (e.g., Lovibond, Chen, Mitchell, & Weidemann, 2013; Lovibond, Mitchell, Minard, Brady, & Menzies, 2009; Ly & Roelofs, 2009; Vervliet & Indekeu, 2015). When these avoidance responses persist in the absence of the aversive stimulus, avoidance prevents the extinction of fear (Lovibond et al., 2009; Treanor & Barry, 2017). Thus, the acquisition of fear and avoidance is oftentimes seen as an imperative process: Fear acquisition triggers avoidance and avoidance in turn down-regulates fear responses as long as avoidance is available. This relationship has already been stated in the classical two-factors theory (Miller & Matzel, 1989; Mowrer, 1960).

However, fear and avoidance learning do not always proceed in strict congruence. Theoretically, a divergence between fear and avoidance can be linked to the differentiation between fear learning and fear expression on different response levels (for a brief summary see Lonsdorf et al., 2017). Fear learning refers to the result of associative learning processes forming a fear memory (i.e., a CS−US association). Fear expression is the manifestation of this fear memory on different response levels, i.e., the physiological (e.g., SCRs), cognitive (e.g., expectancy ratings), or behavioral level (e.g., avoidance) (see Bradley & Lang, 2000). However, fear expression is also influenced by other factors than fear memory alone. In addition, the different levels of fear expression oftentimes do not converge and may map on distinct processes of fear learning (e.g., Hamm & Vaitl, 1996; Sevenster, Beckers, & Kindt, 2012). Most important for the present study, behavioral responses are oftentimes influenced by a variety of factors so that avoidance is not an inevitable consequence of fear or threat. As a clinical example, avoidance in panic disorders is not solely driven by the severity of panic, but substantially influenced by other factors such as social demands, history of mastery, or alternative gains (see Craske & Barlow, 1988). Moreover, socially anxious individuals sometimes approach social situations despite high levels of distress due to a competing motivation such as the wish to make new friends (Kashdan, Elhai, & Breen, 2008). In this regard, fear may be expressed on physiological or cognitive levels, but not end in avoidance behavior. These findings highlight the divergence between fear and avoidance and the importance of alternative factors motivating behavioral responses in complex approach-avoidance situations.

In an approach-avoidance conflict, one behavioral option is simultaneously linked to positive and negative outcomes (e.g., Corr, 2013; Talmi & Pine, 2012). While positive outcomes motivate approach, negative outcomes motivate avoidance. Understanding how competing rewards may modulate fear and avoidance learning in such conflict-laden situations may offer important insights into the divergence of fear and avoidance. As most real-life decisions are characterized by a variety of competing outcomes, paradigms including both positive and negative outcomes provide more ecologically validity compared to paradigms with a single outcome. Recent studies provided insights for the mutual influence of negative and positive outcomes on the behavioral level. For example, healthy individuals chose to avoid aversive stimuli in the absence of rewards, but approached the same stimuli when approach was highly rewarded (Aupperle, Sullivan, Melrose, Paulus, & Stein, 2011; Sierra-Mercado et al., 2015; Talmi, Dayan, Kiebel, Frith, & Dolan, 2009). These findings suggests that avoidance may be counteracted by competing rewards for approach (see also Schlund et al., 2016). However, studies so far mostly showed a reduction of avoidance as long as competing rewards are present. It remains unclear whether or not avoidance returns after all positive and negative outcomes are discontinued. Such return of avoidance could indicate a “better safe than sorry” strategy when there is nothing more to gain.

Preliminary findings also addressed the impact of fear on approach-avoidance behavior. For example, after healthy individuals acquired conditioned fear to a formerly neutral stimulus (i.e., the CS+), they avoided high reward options that were linked to task-irrelevant presentations of the CS+ (Pittig, Schulz, Craske, & Alpers, 2014c). This impact of prior fear acquisition was modulated by the individual level of physiological fear responses during decision making: Elevated skin conductance responses to the CS+ during initial decisions were linked to stronger avoidance (Pittig, Schulz, et al., 2014c). Similar costly avoidance after fear acquisition was also found for instructed fear learning (Bublatzky, Alpers, & Pittig, 2017), fear generalization (Hunt, Cooper, Hartnell, & Lissek, 2017; van Meurs, Wiggert, Wicker, & Lissek, 2014), and in response to fear stimuli such as spiders or angry faces (Pittig, Alpers, Niles, & Craske, 2015; Pittig, Brand, Pawlikowski, & Alpers, 2014a; Pittig, Pawlikowski, Craske, & Alpers, 2014b). These studies therefore provided evidence that prior fear acquisition may trigger avoidance despite the loss of competing rewards.

Less is known about the impact of the presence versus absence of competing rewards on fear and avoidance learning. One recent study provided evidence that higher avoidance costs reduce avoidance, which in turn resulted in a reduction of conditioned fear when no more aversive stimulus occurred (measured as US expectancy ratings; Rattel, Miedl, Blechert, & Wilhelm, 2017). In addition, avoidance of an instructed threat stimulus quickly subsided when in conflict with losing high rewards (Bublatzky et al., 2017). In this study, approach of the threat stimulus was accompanied by a reduction of physiological fear responses (SCRs). Finally, introducing incentives for approaching an individually feared stimulus (spiders pictures), counteracted avoidance in highly fearful individuals and reduced the self-reported aversiveness of the feared stimulus (Pittig, Hengen, Bublatzky, & Alpers, 2018a). These studies provide initial evidence that rewards for approaching a feared stimulus may help to reduce avoidance and thereby initiate fear extinction learning. However, these findings only addressed fear responses in the absence of an aversive stimulus. It remains unclear whether competing rewards may alter the initial acquisition of fear responses while the aversive stimulus is still present. It seems likely that participants will equally learn to predict the aversive event and show similar physiological fear responses, irrespective of the competing rewards. These differential effects would indicate a divergence between physiological and cognitive fear and behavioral responses.

The present study, therefore, investigated the interaction of fear and avoidance learning in an approach-avoidance decision paradigm. Main goals were to test i) whether acquisition of avoidance of an aversive stimulus is attenuated in the presence of competing rewards for approach, ii) whether the attenuation of avoidance persists when outcomes are discontinued, and iii) whether competing rewards will not attenuate physiological and cognitive fear responses. Addressing these research questions provides insights into the differentiation between fear learning and a potential divergence in its expression on different response levels. In exposure-based treatments, patients oftentimes need to overcome avoidance behavior in the context of high physiological and cognitive fear. Thus, understanding the divergence between behavioral versus cognitive and physiological fear responses and their underlying learning mechanisms offers important insights into the development and maintenance of anxiety disorders and may help to optimize prevention and treatment efforts (see Boddez, Baeyens, Hermans, & Beckers, 2014; Pittig, Treanor, et al., 2018b; Richter, Pittig, Hollandt, & Lueken, 2017; Vervliet, Craske, & Hermans, 2013).

In three randomized groups, participants could choose between two options during approach-avoidance acquisition training. One option was associated with a CS+ followed by an aversive stimulus. The other option was associated with a CS− not followed by an aversive stimulus. During a subsequent test, no more aversive stimuli were presented in all groups. In the *Reward Group*, selections of CS+ option were continuously linked to high rewards and the CS− option to low rewards. In the *Initial-Reward Group*, the same rewards were present during acquisition, but discontinued during test. In the *No-Reward Group*, rewards were completely absent. SCRs and US expectancy ratings to the CSs were assessed as physiological and cognitive indicators of fear learning. To assess fear responses for each participant, participants who

consistently avoided during test were forced to select the CS+ option at the end of the test phase.

## 1. Method

### 1.1. Participants

Overall, 223 participants from the student body at TU Dresden and the general community were recruited and randomized to three groups.[1] All participants provided written informed consent to procedures approved by the local ethics committee (EK304072015). Exclusion criteria were current or past bipolar disorder, psychosis, traumatic brain injury or mental retardation, substance abuse and dependence, diagnosed depression or emotional disturbances, current use of psychotropic medication, cardiovascular, respiratory or neurological diseases, serious medical conditions, and pregnancy. Individuals were between 18 and 55 years due to a potential bias of higher age on decision making (see Cauffman et al., 2010; Denburg, Tranel, & Bechara, 2005). No significant differences between groups were found for age, sex, state and trait anxiety, depression, general risk-taking, or acceptance of negative states (see Table 1). Groups did also not differ in self-reported consumption of caffeine, nicotine, and alcohol as well as the average amount of physical activity per week, $Fs < 2.25$, $ps > .10$; $BF_{01} > 2.80$.

### 1.2. Materials and procedure

After participants provided written informed consent, electrodes for physiological recording were attached and participants completed a questionnaire battery to account for individual differences that may affect fear and avoidance learning or decision making. Questionnaires assessed state and trait anxiety (State-Trait Anxiety Inventory; Spielberger, Gorsuch, Lushene, & Vagg, 1983; anxiety facet of neuroticism of the International Personality Item Pool- NEO-PI-R, IPIP-N1; Goldberg et al., 2006), symptoms of depression (general depression scale; Hautzinger, Bailer, Hofmeister, & Keller, 2012), general risk taking (short-scale risk-taking-1; Beierlein, Kovaleva, Kemper, & Rammstedt, 2014), acceptance of unpleasant or unwanted distress (Acceptance scale; Wolgast, 2014), and various sociodemographic data. Afterwards, the individual US intensity was determined. The US was an electrical stimulus consisting of 125 consecutive 2-ms stimulations delivery through a bar-electrode to the participants' non-dominant forearm (Digitimer DS7A Stimulator). Individual US intensity was calibrated by asking participants to rate US unpleasantness and discomfort (0 = *no unpleasantness/discomfort* and 5 = *strong discomfort*) and instructing them to "choose a level that is unpleasant, but not painful". Importantly, groups did not differ in self-reported unpleasantness of the US (see Table 1) or actual intensity of the US, $F(2, 220) = 1.84$, $p = .161$; $BF_{01} = 4.17$. After US calibration, participants completed an approach-avoidance paradigm, which differed between groups.

### 1.3. Approach-avoidance paradigm

The computerized paradigm consisted of two phases: 40 acquisition trials and 20 test trials (see Table 2). Participants were never instructed about the contingencies or the duration of the task, thus had to learn from experience. Participants were instructed that they can freely choose between two options and that each option will be followed by a geometrical stimulus. Participants in the *Reward* and *Initial-Reward Group* were also instructed that they will receive feedback whether or not a reward was obtained. Trial sequence is depicted in Fig. 1. During approach-avoidance acquisition, participants in the *Reward Group* repeatedly chose between two options presented as distinct fractals (pictures counterbalanced across participants). Choices were completed by clicking on the corresponding option via computer mouse using the dominant hand. After choosing the CS+ option, participants rated their expectancy of receiving a US after the subsequent presentation of the $CS_1$ (blue square; see US expectancy ratings). Next, the $CS_1$ was presented for 7s, which terminated with the administration of the aversive US in 70% of the presentations. Afterwards, a fixation cross was displayed (3s), which was followed by a high reward (50 cents coin presented for 3s) in 60% of the trials or no reward (crossed out coin; 3s). Reward probability was independent of US probability. Following another fixation cross (5s), the next choice trial began. Trial sequence for choosing the CS− option was similar, however, another $CS_2$ (yellow circle) was presented, which was never paired with the US. In addition, choosing the CS− option was linked to either a low reward (20 cents coin; 3s) in 40% of the trials or no reward (crossed out coin; 3s). CS pictures were counterbalanced across participants. Summarized, participants in the *Reward Group* could avoid the CS+ option and the US by choosing the CS− option, which resulted in the loss of high rewards. Alternatively, they could approach the high reward, but then had to tolerate presentations of the designated CS+ and US. Participants in the *Reward Group* were instructed that the rewards were hypothetical in nature. Previous studies verified that such hypothetical rewards are experienced as high and low and can effectively modulate behavioral decisions (Bublatzky et al., 2017; Pittig, Hengen, et al., 2018a; Pittig, Schulz, et al., 2014c). In the *Initial-Reward Group,* acquisition trials were identical. For the *No-Reward Group*, acquisition trials were similar, except that no rewards were presented at all. Thus, participants in this group chose between an option linked to the designated CS+ followed by the US (70%) and an option linked to the designated CS− never followed by the US.

During the test phase, no more USs occurred in all groups. Whereas rewards were continued in the *Reward Group*, rewards were discontinued in the *Initial-Reward Group*. For the *No-Reward Group*, rewards remained absent during test. Onset of the test phase was not signaled or instructed, so that participants again had to learn from experience. To assess fear responses after acquisition for each participant, at least one presentation of the CS+ during the test phase was necessary. To this end, the number of possible avoidance choices was limited so that participants who consistently avoided during test were forced to select the CS+ option. Specifically, participants could freely choose between both options at the beginning of the test phase, however, each option could only be selected ten times during the 20 test trials. After being selected the tenth time, a given option was no longer available: participants were then forced to select the other option. This design was used to investigate avoidance in the absence of the US during the first ten unrestricted trials and fear responses to the first experience of each CSs. This manipulation introduced an additional factor Freedom of Choice (free vs. forced CS+ choice), which was accounted for in the statistical analyses.

Immediately after the task, all participants indicated their motivation to avoid the US (0–100) and participants in the *Reward* and *Initial-Reward Group* also indicated their motivation to maximize their overall gain as an indicator of approach motivation. Finally, unpleasantness of the last administered US was assessed to assure sustained unpleasantness of the US (Table 1).

### 1.4. US expectancy ratings and skin conductance responses (SCRs)

For each CS presentation, participants rated their subjective expectancy of a US occurring after the CS. Specifically, a small-scale

[1] An a-priori power analysis (power = .80, α error = 0.05, using G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) indicated 36 participants per group to detect medium effect sizes (Cohen's $d = 0.6$ for (in-) dependent t tests or $f = 0.3$ for the repeated measures ANOVA based on Pittig, Schulz, et al., 2014c). Given separate analyses for participants who freely chose versus who were forced to choose the CS+, at least twice as many participants were recruited.

**Table 1**
Demographic and questionnaire data.

| Group | | *Reward* (*n* = 72) | | *Initial-Reward* (*n* = 79) | | *No-Reward* (*n* = 72) | | *F* or $\chi^2$ | *p* | Bayes factor |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | | 21.93 | (3.63) | 22.77 | (2.79) | 21.46 | (4.47) | 2.50[a] | .084 | $BF_{01}$ = 2.32 |
| Sex = Female (%) | | 50 | (69.4%) | 55 | (69.6%) | 57 | (79.2%) | 2.28[b] | .320 | $BF_{01}$ = 7.82 |
| Trait anxiety: | IPIP-N1 | 16.56 | (4.84) | 16.04 | (6.12) | 16.20 | (5.80) | 0.17[a] | .847 | $BF_{01}$ = 18.26 |
| | STAI-T | 37.99 | (8.50) | 37.67 | (8.43) | 36.59 | (9.61) | 0.20[a] | .817 | $BF_{01}$ = 17.68 |
| State anxiety (STAI-S) | | 36.75 | (6.50) | 36.37 | (6.73) | 36.80 | (6.96) | 0.09[a] | .912 | $BF_{01}$ = 19.49 |
| Depression (ADS-L) | | 14.49 | (8.68) | 11.67 | (7.73) | 14.11 | (8.65) | 2.56[a] | .080 | $BF_{01}$ = 2.20 |
| Risk taking | | 3.93 | (1.07) | 3.85 | (1.18) | 3.90 | (1.06) | 0.11[a] | .896 | $BF_{01}$ = 19.34 |
| Acceptance of unpleasantness (AS) | | 26.50 | (5.64) | 26.36 | (3.71) | 26.74 | (4.92) | 0.12[a] | .889 | $BF_{01}$ = 19.14 |
| Unpleasantness of last US | | 67.78 | (21.65) | 72.17 | (20.45) | 67.88 | (22.62) | 1.02[a] | .364 | $BF_{01}$ = 8.43 |
| Avoidance motivation | | 59.64 | (30.57) | 63.65 | (31.80) | 80.33 | (24.75) | **10.18**[a] | **< .001** | **$BF_{10}$ = 328.38** |
| Approach motivation | | 57.00 | (30.21) | 54.91 | (28.38) | – | – | 0.44[c] | .662 | $BF_{01}$ = 7.19 |

*Note.* Means (and standard deviations) for the three groups. IPIP = International Personality Item Pool-NEO-PI-R, range = 0–32 (Goldberg et al., 2006); STAI-S/-T = -Trait Anxiety Inventory, range = 20–80 (Spielberger et al., 1983); ADS-L = General depression scale, range 0–60 (Hautzinger et al., 2012); Risk taking = Short-scale risk-taking-1, range = 1–7 (Beierlein et al., 2014); AS = Acceptance scale, range = 7–49 (Wolgast, 2014). Bayes factors refer to the effect of group compared to null model. [a] $F(2, 220)$. [b] $\chi^2(2, 223)$. [c] $t(149)$.

**Table 2**
Experimental design.

| Group | Option | Outcomes | |
|---|---|---|---|
| | | Acquisition phase (40 free choices) | Test phase (20 semi-free choices) |
| *Reward* | CS+ option | $CS_1$ ⇨ US (70%) + High reward | $CS_1$ + High reward |
| | CS− option | $CS_2$ + Low reward | $CS_2$ + Low reward |
| *Initial-Reward* | CS+ option | $CS_1$ ⇨ US (70%)+ High reward | $CS_1$ |
| | CS− option | $CS_2$+ Low reward | $CS_2$ |
| *No-Reward* | CS+ option | $CS_1$ ⇨ US (70%) | $CS_1$ |
| | CS− option | $CS_2$ | $CS_2$ |

*Note.* High reward = 60% chance of winning 0.50€ (vs. 40% chance of 0.00€), low reward = 40% chance of winning 0.20€ (vs. 60% chance of 0.00€); $CS_1$ and $CS_2$ = blue square or yellow circle.

Products, Germany). Raw data were filtered with a notch filter (50 Hz), a 1 Hz FIR lowpass filter to remove high frequency noise, and a 0.05 Hz FIR high-pass filter to obtain phasic SCRs. Movement and similar artifacts were recorded by a research assistant who observed the assessment via video from an adjacent room. Intervals containing artifacts were excluded from data analyses. SCRs to the CSs served as physiological indicator of fear learning. SCRs were calculated with trough-to-peak scoring by calculating the maximum increase in skin conductance in the interval of 1–7s after onset of the full-scale CS in comparison to the corresponding trough of the SCR (see Boucsein et al., 2012). The square root was taken to obtain normal distribution (Dawson, Schell, & Filion, 2007). One participant of the *No-Reward Group* was excluded from SCR analyses due to technical failure.

### 1.5. Statistical analysis

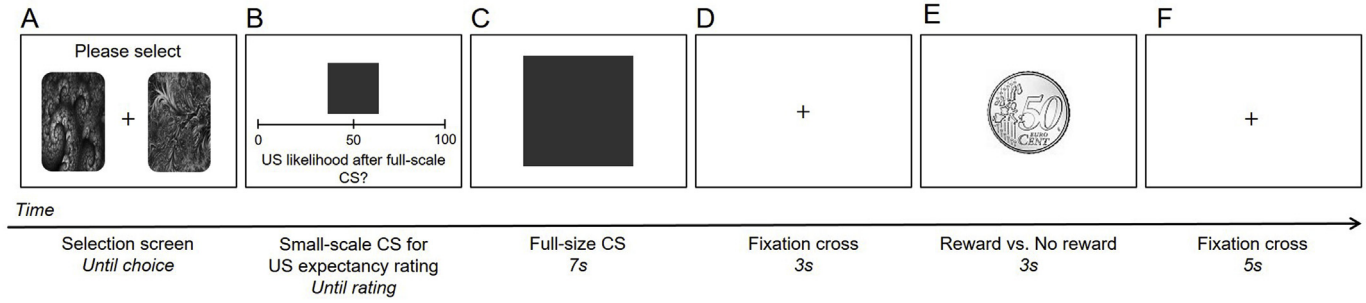


**Fig. 1.** Schematic representation of the trial sequence.

picture of the upcoming CS was presented after a deck was chosen and participants were asked to rate the subjective likelihood of a US following the subsequent full-scale presentation of the CS (see Fig. 1). This stepwise approach was used to not confound US expectancy ratings with SCR analyses. Ratings were completed via computer mouse on a visual analog scale (0%–100%) presented beneath the small-scale CS. Like option selection, ratings were completed with the dominant hand to not interfere with skin conductance recording on the non-dominant hand. Participants were instructed that their ratings will not affect the probability of an aversive US or a reward.

Electrodermal activity (EDA) was continuously recorded with two reusable Ag/AgCl electrodes with electrodermal conducting gel attached to the hypothenar eminence of the non-dominant hand and a constant voltage of 0.5 V using a V-Amp system (Brain Products, Germany; sampling rate = 1000 Hz). Online data monitoring, acquisition, and analyses were conducted with BrainVision software (Brain

For all ANOVAs, Greenhouse-Geisser correction was applied whenever necessary. Main analyses focused on the number of CS− option selections during acquisition and test. Avoidance was operationalized as the relative number of CS− option selections, with a larger number indicating stronger avoidance (i.e., avoidance referred to avoidance of the CS+ option). During acquisition, the 40 trials were divided into four blocks of ten trials and the relative number of CS− option selections was calculated for each block (i.e., 0.5 indicates equal selections of both options). Two statistical analyses were conducted to test whether acquisition of avoidance is attenuated in the presence of competing rewards for approach (first research question). First, the number of CS− option selections was analyzed across the whole acquisition phase using a 4 × 3 repeated measure ANOVA with Block (Block 1–4) as within subject factor and Group (*Reward* vs. *Initial-Reward* vs. *No-Reward*) as between subject factor. Second, the immediate effect of competing rewards on avoidance acquisition was

analyzed. To this end, the individual number of immediate avoidance choices was quantified by counting the number of CS− option selections following the first US presentation for each participant. Again, a higher number indicated stronger avoidance. The mean number of immediate avoidance trials was compared between groups using a one-way ANOVA. For both analyses, a lower number of CS− option selection in the two reward groups compared to the *No-Reward group,* but no difference between the reward groups, was expected groups (i.e., *No-Reward* < *Reward* = *Initial-Reward*). This result would indicate attenuated avoidance of the aversive US. In addition, the mean number of USs administered during the acquisition phase was compared between groups using a one-way ANOVA.

For approach-avoidance during test, the relative number of CS− option selection for the first ten unrestricted trials (i.e., trials 41–50, in which all participants could freely choose) was calculated and compared to the last block of acquisition (trials 31–40) using a planned 3 × 2 repeated measures ANOVA with Group as between subject factor and Block as within subject factor. This analysis was conducted to address whether an attenuation of avoidance persists when outcomes are discontinued (second research question). In addition, self-reported avoidance motivation was compared between groups using a one-way ANOVA as a subjective-verbal indicator of attenuated avoidance in the reward groups.

For fear acquisition, US expectancy ratings and SCRs to the first CS + during test were analyzed. As described above, the number of avoidance choices was limited so that participants who consistently avoided during test were forced to select the CS+ option. This manipulation ensured CS+ presentations for each participant and an equal number of CS+ and CS− presentations during test. However, it introduced a confounding factor of free versus forced CS+ choice. To eliminate this confounding factor, all following analyses were conducted separately for participants who freely chose versus who were forced to choose the CS+. Two sets of analyses were conducted. First, SCRs and US expectancy ratings were compared between the first CS+ and CS− presentation during test. These analyses served as a manipulation check to verify that CS+ and CS− functions were formed after acquisition training. Accordingly, higher SCRs and US expectancies to the CS+ compared to CS− were expected (and one-tailed test used). Because almost all participants freely choose the first CS− (expect nine participants; 4.0%), dependent *t*-test compared CS+ to free CS− choices. Second, SCRs and US expectancy ratings for the first CS+ presentation were compared between groups using one-way ANOVAs to test whether or not fear responses after the acquisition phase are modulated by competing rewards (third research question).

Finally, the reduction of fear in the absence of the US was explored by analyzing SCRs and US expectancy ratings during the ten CS+ presentations at test. The present study was not designed to analyze a reduction of fear; thus these analyses were exploratory. These responses may be biased if participants initially freely chose the CS+, but were forced during later trials. Therefore, analyses were limited to participants who either freely chose or were forced to choose all CS+ presentations at test. US expectancy ratings and SCRs were entered into separate 3 × 10 repeated measures ANOVA with Trial (CS+ test trial 1–10) as within subject and Group as between subject factors. Analysis did not include CS− presentations across the test phase as these responses may be confounded by a switch from free-to forced-choices.

We also performed statistical analyses within a Bayesian framework. Specifically, we computed separate Bayesian Factor (BF) for each statistical test. BFs have the advantage of providing relative evidence for data coming from the null (H0) compared to alternative hypothesis (H1) or vice versa. We report $BF_{10}$ for comparing the probability of the data coming from the H1 compared to the H0 and $BF_{01}$ for the reversed comparison. For example, $BF_{10} = 5$ would indicate that it is five times more likely that the data come from the alternative hypothesis (e.g., mean difference between groups is not zero) than from the null hypothesis (e.g., mean difference between groups is zero). Conversely, $BF_{01} = 5$ would indicate it is five times more likely that the data come from the null hypothesis than from the alternative hypothesis, thus providing relative evidence for the null hypothesis. Bayesian and frequentist analyses were performed using corresponding tests in JASP (Version 0.8.6; JASP Team, 2018). For Bayesian *t* tests, the same priors were used (location = 0; cauchy scale = 1; see also Rouder, Speckman, Sun, Morey, & Iverson, 2009). To test whether the direction of the Bayesian results change based on the choice of the prior distribution for the H1, we performed robustness checks, as those provided within JASP. These tests indicated that the direction of the BFs remained the same, independent of the chosen prior distribution. For Bayesian (repeated) ANOVAs, default prior settings were used (r scale fixed effects = 0.5, random effects = 1, covariates = 0.354). In case of multiple factors, BFs refer to analyses of effects (across matched models), in which models containing the effect are compared to equivalent models without inclusion of the effect. Bayesian ANOVAs were conducted with the H0 of zero difference between groups and the H1 of the difference between groups not being zero. For more information on Bayesian analyses in fear and avoidance research see Krypotos, Blanken, Arnaudova, Matzke, and Beckers (2017).

## 2. Results

### 2.1. Avoidance learning during acquisition

The relative number of CS− option selections during acquisition is shown in Fig. 2A (Trials 1–40). The 3 × 4 repeated measures ANOVA with Group and Block yielded a significant interaction, $F(5.26, 578.06) = 3.07$, $p = .008$, $\eta^2 = 0.026$. Follow-up tests indicated a significant increase of CS− option selections in the *No-Reward Group*, *F*

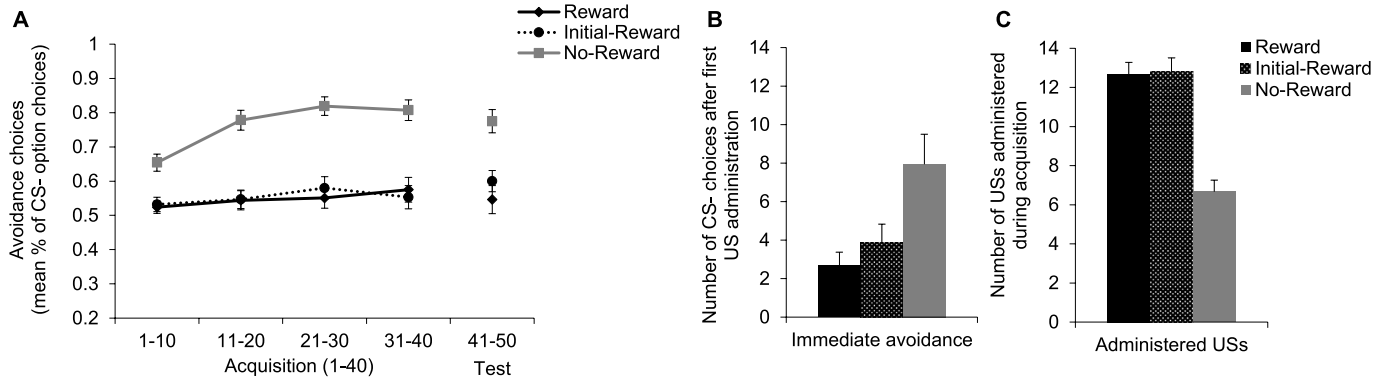


**Fig. 2.** A: Relative number of CS− option selections during acquisition and the first ten unrestricted trials at test (with SEM) averaged across blocks of ten trials. B: Immediate avoidance as quantified by the average number of CS− option selections after administration of the first US (with SEM). C: Average number of USs administered during the acquisition phase (with SEM).

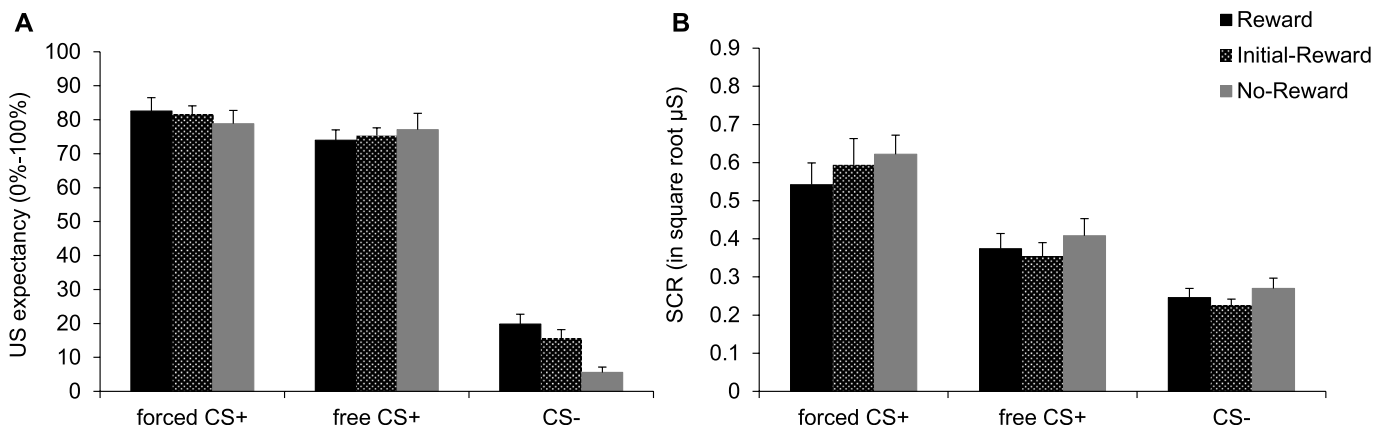


**Fig. 3.** US expectancy ratings (A) and skin conductance responses (B) to the first CS+ and CS− during the test phase (with SEM). Forced CS+ = participants who were forced to choose the CS+; free CS+ = participants freely chose the CS+.

(2.54, 180.35) = 15.36, $p < .001$, $\eta^2 = 0.178$; $BF_{10} > 1000$, but not in the two reward groups, $Fs < 1.17$, $p > .32$, $\eta^2 < 0.016$; $BFs_{01} > 15.83$. In addition, the *No-Reward Group* showed more frequent CS− option selections compared to both reward groups in all blocks of the acquisition phase, $ts > 3.80$, $ps < .001$, $ds > 0.61$; $BFs_{10} > 109.75$. As expected, no differences were found between the two reward groups, $ts < 0.64$, $ps > .53$, $ds < 0.11$; $BFs_{01} > 1000$.

Within groups, the *No-Reward Group* consistently showed more frequent CS− option selections compared to an equally balanced selection in all acquisition blocks, $ts(71) > 6.22$, $ps < .001$, $d > 0.73$; $BFs_{10} > 1000$ (two-tailed one-sample *t*-test against 0.5). In contrast, both reward groups showed an equally balanced selection in most acquisition blocks, $ts < 1.76$, $ps > .08$, $ds < 0.20$; $BFs_{01} > 2.52$. A slight preference for the CS− option was found in Block 3 for the *Initial-Reward Group*, $t(78) = 2.41$, $p = .018$, $d = 0.27$; $BF_{10} = 1.43$, and Block 4 for the *Reward Group*, $t(71) = 2.08$, $p = .041$, $d = 0.25$; $BF_{10} = 0.74$. In sum, the *No-Reward Group* showed an increasing number of CS− option selections indicating progressive avoidance during acquisition. For both reward groups, avoidance was markedly attenuated in the presence of competing rewards. In other words, avoidance costs strongly reduced the acquisition of avoidance.

Moreover, analysis of immediate avoidance yielded a main effect of Group, $F(2, 217) = 6.00$, $p = .003$, $\eta^2 = 0.052$; $BF_{10} = 9.04$. Post-hoc tests showed that participants of the *Reward Group*, $t(139) = 3.13$, $p = .002$, $d = 0.53$; $BF_{10} = 12.25$, as well as the *Initial-Reward Group*, $t(146) = 2.29$, $p = .024$, $d = 0.38$; $BF_{10} = 1.91$, selected the CS+ option significantly earlier after experiencing the first US compared to the *No-Reward Group* (see Fig. 2B). No differences were found between the reward groups, $t(149) = 1.01$, $p = .313$, $d = 0.17$; $BF_{01} = 4.83$. Thus, findings indicated an reduction of immediate avoidance due to competing rewards.

As expected from the differences in CS− option selections, the mean number of USs administered during acquisition differed between group, $F(2, 220) = 29.90$, $p < .001$, $\eta^2 = 0.214$; $BF_{10} > 1000$ (see Fig. 2C). Post-hoc test showed that participants of both reward groups experienced more USs during acquisition compared to the *No-Reward Group*, $ts > 6.64$, $ps < .001$, $ds > 1.08$; $BFs_{10} > 1000$. No differences were found between the reward groups, $t(149) = 0.14$, $p = .889$, $d = 0.02$; $BF_{01} = 7.81$.

### 2.2. Avoidance responses in the absence of the US (at test)

The relative number of CS− option selections during the first ten unrestricted test trials is shown in Fig. 2A (Trials 41–50). A significant main effect of Group, $F(2, 220) = 16.40$, $p < .001$, $\eta^2 = 0.130$; $BF_{10} > 1000$, indicated consistently more CS− option selections in the *No-Reward Group* compared to both reward groups, $ts > 4.84$, $ps < .001$, $ds > 0.32$; $BFs_{10} > 1000$. Importantly, there was no difference between the two reward groups, $t(149) = 0.37$, $p = .715$, $d = 0.02$; $BF_{01} = 7.14$. No significant main effect of Block, $F(1, 220) = 0.09$, $p = .771$, $\eta^2 < 0.001$; $BF_{10} = 9.35$, or interaction of Block and Group, $F(2, 220) = 2.56$, $p = .078$, $\eta^2 = 0.023$; $BF_{01} = 2.17$, was found.

Due to elevated avoidance, the CS+ presentations were experienced significantly later in the *No-Reward Group* compared to both reward groups, $F(2, 220) = 10.44$, $p < .001$, $\eta^2 = 0.087$; $BF_{10} = 407.43$. On average, each CS+ presentation was experienced 2.45 trials ($SE = 0.76$) earlier in the *Reward Group*, $t(142) = 4.28$, $p < .001$, $d = 0.71$; $BF_{10} = 526.85$, and 1.60 trials ($SE = 0.76$) earlier in the *Initial-Reward Group*, $t(149) = 3.29$, $p = .001$, $d = 0.54$; $BF_{10} = 19.04$.

Finally, self-reported avoidance motivation after the test phase differed between groups (see Table 1). Pairwise comparisons yielded lower avoidance motivation in both reward groups compared to the *No-Reward Group*, $ts > 3.57$, $ps > .001$, $d > 0.58$; $BFs_{10} > 46.23$. No difference in avoidance motivation were found between the two reward groups, $t(149) = 0.79$, $p = .432$, $d = 0.13$; $BF_{01} = 5.86$. In addition, the reward groups did not differ on approach motivation (see Table 1) and there was no difference between approach and avoidance motivation within the two reward groups, *Reward Group:* $t(71) = 0.41$, $p = .685$, $d = 0.05$; $BF_{01} = 9.93$, *Initial-Reward Group:* $t(78) = 1.47$, $p = .144$, $d = 0.17$; $BF_{01} = 3.91$.

In sum, behavioral avoidance and self-reported avoidance motivation persisted in the *No-Reward Group* even in the absence of the US. No avoidance during test was found in the reward groups. There were no differences between the reward groups in avoidance at test. Thus, avoidance acquisition was attenuated by the presence of competing rewards during acquisition, which persisted during test even when rewards were discontinued.

### 2.3. Fear responses after acquisition

For US expectancy ratings within groups, participants in all groups showed higher US expectancies to the first CS+ compared to the first CS− during test, regardless of whether CS+ option selections were free or forced, $ts > 9.78$, $ps < .001$, $ds > 1.33$; $BFs_{10} > 1000$ (see Fig. 3A). US expectancies for participants who freely chose the CS+ did not differ between groups ($n_{Reward} = 54$; $n_{Initial\text{-}Reward} = 59$; $n_{No\text{-}Reward} = 34$), $F(2, 145) = 0.21$, $p = .808$, $\eta^2 = 0.003$; $BF_{01} = 12.21$. US expectancies for participants who were forced to choose the CS+ did also not differ between groups ($n_{Reward} = 18$; $n_{Initial\text{-}Reward} = 20$; $n_{No\text{-}Reward} = 37$), $F(2, 72) = 0.61$, $p = .548$, $\eta^2 = 0.017$; $BF_{01} = 5.14$. Summarized, US expectancies were higher for the CS+ than the CS− demonstrating successful fear acquisition. However, groups showed comparable levels of US expectancies indicating comparable cognitive

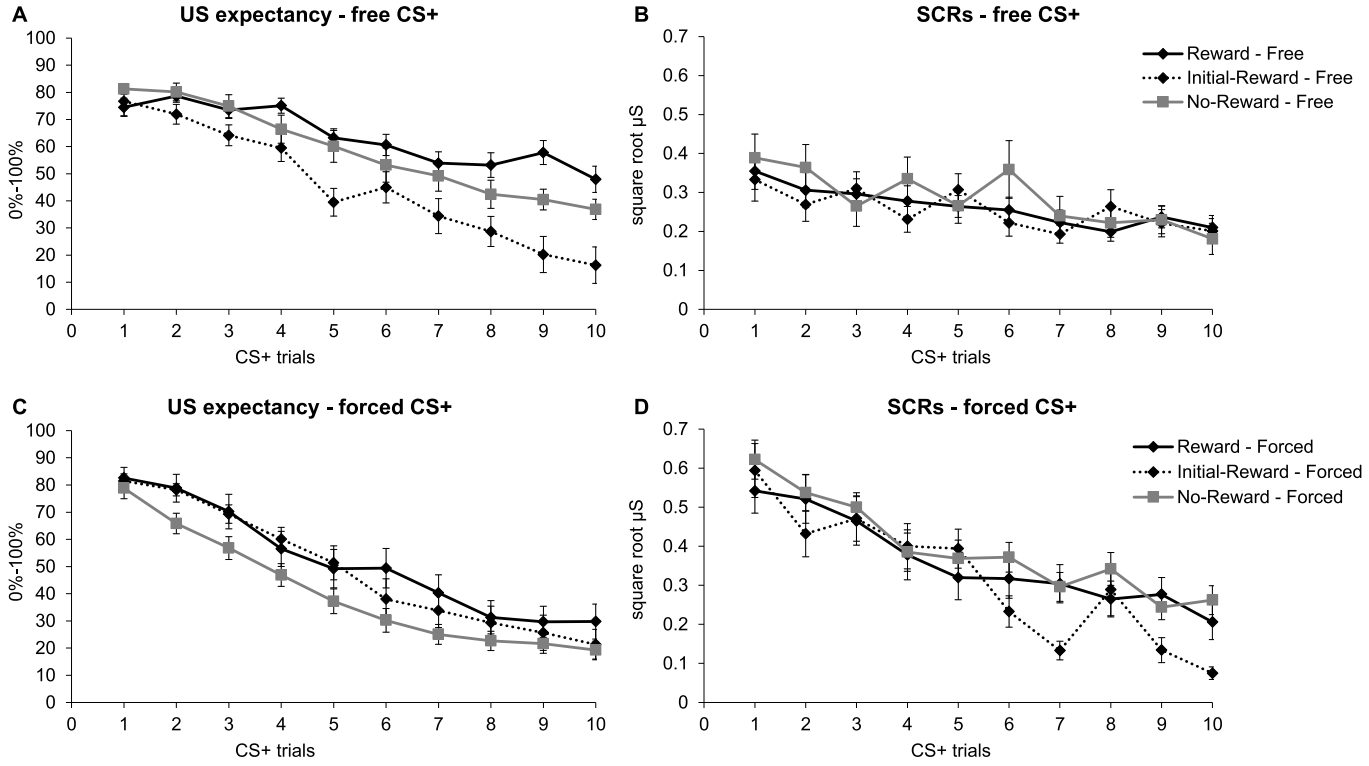


**Fig. 4.** A: US expectancy ratings (A, C) and skin conductance responses (B, D) to the ten CS+ presentation during the test phase (with SEM). Forced CS+ = participants were forced to choose all CSs+; free CS+ = participants freely chose all CSs+.

fear learning indicators.

For SCRs within groups, participants in all groups showed higher SCRs to the first CS+ compared to the first CS− during test, regardless of whether CS+ option selections were free or forced, *ts* > 3.00, *ps* < .002, *ds* > 0.40; $BFs_{10}$ > 12.70 (see Fig. 3B). SCRs for participants who freely chose the CS+ did not differ between groups, $F(2, 144) = 0.42$, $p = .658$, $\eta^2 = 0.006$; $BF_{01} = 10.20$. SCRs for participants who were forced to choose the CS+ did also not differ between groups, $F(2, 72) = 0.46$, $p = .635$, $\eta^2 = 0.013$; $BF_{01} = 5.84$. In sum, SCRs were higher to the CS+ than the CS−, again demonstrating successful fear acquisition. However, groups showed the same levels of SCRs indicating comparable acquisition of physiological fear responses.

### 2.4. Exploratory analyses: fear extinction during forced and free CS + presentations

For participants who freely chose all CSs+, US expectancy ratings significantly decreased across trials, $F(5.39, 495.96) = 56.18$, $p < .001$, $\eta_p^2 = 0.36$; $BF_{10} > 1000$, which was modulated by a significant Group × Trial interaction, $F(1.77, 495.44) = 3.19$, $p < .001$, $\eta_p^2 = 0.04$; $BF_{10} > 1000$ (see Fig. 4A). Follow-up analyses indicated that the reduction of US expectancy was more pronounced in the *Initial-Reward Group* compared to the *Reward Group*, Group × Trial interaction: $F(5.41, 389.13) = 5.53$, $p < .001$, $\eta_p^2 = 0.05$; $BF_{10} > 1000$. In addition, US expectancies were lower in the *Initial-Reward Group* compared to the *No-Reward Group*, $F(1, 51) = 6.34$, $p = .015$, $\eta_p^2 = 0.11$; $BF_{10} = 3.29$, without a significant interaction of Group and Trial, $F(4.85, 247.18) = 0.96$, $p = .440$, $\eta_p^2 = 0.01$; $BF_{01} = 28.57$. No differences were found between the *Reward* and *No-Reward Group*, main effect Group: $F(1, 61) = 1.35$, $p = .249$, $\eta_p^2 = 0.02$; $BF_{01} = 2.23$; Group × Trial interaction: $F(4.82, 294.18) = 2.10$, $p = .068$, $\eta_p^2 = 0.02$; $BF_{01} = 2.39$.

For SCRs in participants who freely chose all CSs+ (Fig. 4B), a significant reduction across trials was found, $F(7.09, 645.39) = 7.47$, $p < .001$, $\eta_p^2 = 0.074$; $BF_{10} > 1000$. This reduction did not differ between groups, $F(2, 91) = 0.21$, $p = .808$, $\eta_p^2 = 0.005$; $BF_{01} = 8.55$, and there was no significant Group × Trial interaction, $F(14.14, 645.39) = 1.20$, $p = .270$, $\eta_p^2 = 0.024$; $BF_{01} = 100$.

For participants who were forced to choose all CSs+, US expectancy ratings decreased across trials, $F(2.81, 202.40) = 125.50$, $p < .001$, $\eta_p^2 = 0.63$; $BF_{10} > 1000$ (see Fig. 4C). No significant group, $F(2, 72) = 2.45$, $p = .094$, $\eta_p^2 = 0.06$; $BF_{01} = 0.97$, or interaction effect was found, $F(5.62, 202.40) = 0.99$, $p = .428$, $\eta_p^2 = 0.01$; $BF_{01} = 90.91$.

For SCRs (see Fig. 4D), a significant reduction across trials was found, $F(9, 648) = 34.46$, $p < .001$, $\eta_p^2 = 0.315$; $BF_{10} > 1000$. This reduction again did not differ between groups, $F(2, 72) = 1.40$, $p = .253$, $\eta_p^2 = 0.037$; $BF_{01} = 3.17$, and there was no significant Group × Trial interaction, $F(18, 648) = 1.53$, $p = .115$, $\eta_p^2 = 0.028$; $BF_{01} = 10.42$.

In sum, US expectancy and SCRs decreased across test trials for all participants. Groups showed comparable reduction of SCRs. Reduction of US expectancies did not differ between groups for participants who were forced to choose all CSs+. For participants who freely chose all CSs+, reduction of US expectancies was more pronounced in the *Initial-Reward Group*.

## 3. Discussion

The present study investigated the impact of competing rewards for approach on the acquisition of fear and avoidance. Main findings demonstrate significant avoidance of an aversive stimulus when competing rewards were absent, which persisted in the absence of the aversive stimulus. Competing rewards markedly attenuated avoidance acquisition, despite more frequent experiences of the aversive stimulus. This attenuation of avoidance was immediately evident after the first aversive stimulus and did not depend on reward continuation during test. In contrast to these behavioral effects, competing rewards did not modulate fear responses after acquisition. These results point to a divergence between fear and avoidance acquisition in the presence of competing rewards. Exploratory results indicated that competing

rewards did not change the level of fear reduction in the absence of the aversive event. When competing rewards were present, the CS+ was, however, approached earlier. As a consequence, fear reduction was experienced earlier. Combined, these findings suggest that rewards for approaching a feared stimulus facilitate a divergence of fear and avoidance acquisition and may thereby help to initiate fear extinction.

Competing rewards significantly reduced the acquisition of avoidance of an aversive event. Framed differently, high rewards triggered approach of an aversive event. Participants in both reward groups chose each of the two options about equally often. In contrast, participants significantly avoided the aversive stimulus in the absence of competing rewards. This consistent avoidance in the *No-Reward Group* illustrates the significant negative value of the aversive stimulus. This negative value was most likely equal for the two reward groups. In support, ratings of US unpleasantness and objective US intensity did not differ between groups. To explain the reduction of avoidance in the reward group, it can thus be inferred that the high reward entailed a positive value that competed with the negative value of the US. This reduction of avoidance is noteworthy as rewards were hypothetical in nature (i.e., not associated with real money). In this regard, the positive value of the competing rewards may be linked to a task-related goal (i.e., maximizing task performance). These findings support previous studies showing that hypothetical rewards and alternative goals are sufficient to reduce avoidance of a feared or aversive stimulus (Aupperle et al., 2011; Bublatzky et al., 2017; Pittig, Hengen, et al., 2018a; Sierra-Mercado et al., 2015; Talmi et al., 2009).

In addition, the present study provided insight into the temporal onset of the attenuation of avoidance. Immediate avoidance was investigated as the number of avoidance choices after experiencing the aversive stimulus for the first time (i.e., the number of CS− option selections). Immediate avoidance was significantly lower when avoidance was associated with the loss of high rewards. Thus, competing rewards may attenuate behavioral avoidance as early as after the first experience of an aversive event.

Under some conditions, omitting positive outcomes to avoid an aversive event represents an adaptive behavior (e.g., avoid driving to a friend under severe weather conditions). Ongoing costly avoidance in the absence of the aversive event, however, becomes maladaptive (i.e., when weather is safe). Importantly, avoidance differed when no aversive event occurred anymore (i.e., during test). In the absence of the aversive stimulus, avoidance persisted when not linked to rewards, but avoidance remained attenuated when competing rewards were present. Interestingly, the same reduction of avoidance was found when rewards were discontinued in the absence of the aversive stimulus. Avoidance attenuation thus did not depend on reward continuation during test. These results are against a “better safe than sorry” strategy and not in line with previous research showing a return of avoidance after successful fear extinction (Vervliet & Indekeu, 2015). Introducing positive outcomes competing with avoidance may thus result in a more stable reduction of avoidance than mere fear reduction by means of extinction learning. This interpretation, however, requires direct comparison of both procedures.

In contrast to these behavioral effects, presence vs. absence of competing rewards did not modulate the level of physiological and cognitive fear responding. All groups showed elevated indicators of fear acquisition to the CS+ compared to the CS−. Fear acquisition to the CS+ did, however, not differ between groups. For the present data, Bayesian analyses indicated that the relative likelihood for groups not differing in fear responses (H0) was 5–12 times higher compared to groups differing in fear responses (H1). This lack of differences in fear responses suggest that reduced avoidance cannot be simply explained by lower levels of physiological fear or US expectancies to the CS+. These findings thus indicate a clear divergence between cognitive and physiological fear responses on the one side and behavioral responding on the other side. In sum, competing rewards for approach did not buffer the acquisition of fear, but the development of avoidance.

Theoretically, this divergence highlights that the imperative process of fear and avoidance acquisition proposed by two-factor theory (Miller & Matzel, 1989; Mowrer, 1960) may hold true for behaviors linked to single aversive outcomes (avoid US vs. not avoid US), but needs to be expanded for behaviors related to more complex and competing outcomes. Specifically, while fear learning may be one contributing factor to guide action selection, alternative processes such as reward learning need to be considered. Other theories of avoidance need to be extended in a similar manner. For example, the expectancy model of avoidance assumes that expectancies about the consequences of avoidance as well as non-avoidance are essential to guide behavior (Lovibond, 2006). While expectancies were mostly related to occurrence versus omission of an aversive event, expectancies about competing outcomes may overwrite these threat expectancies and need to be accounted for in a broader theoretical framework (see also Balleine & Dickinson, 1998; Goschke, 2014; Schlund et al., 2016).

The lack of differences in fear responses warrants further investigation. It is noteworthy as the amount of aversive experience substantially differed between groups. Due to the self-chosen approach, participants experienced the aversive stimulus more frequently in the presence of competing rewards. Still, they did not show elevated fear responses. Although fear responses typically increase with increasing experiences of an aversive stimulus, an upper limit may be achieved after a relatively small number of trials. A ceiling effect may have concealed a differentiation in fear responses, especially for high levels of US expectancy ratings. However, SCRs were responsive to other factors of the design (i.e., forced vs. free choice), limiting the explanation by a mere ceiling effect. Furthermore, fear responses were only measured in close proximity to the US, i.e., only to a predictive stimulus immediately before the US. Past research provided evidence that proximal and distal threat are linked to different physiological and behavioral responses (Löw, Weymar, & Hamm, 2015; Mobbs et al., 2009, 2007; Wendt, Löw, Weymar, Lotze, & Hamm, 2017). Although competing rewards did not reduce proximal responses, they may impact responses in earlier, more distal stages of the decision process. Future research may thus investigate changes in valence of the CS+ and investigate anteceding responses, which may help to further understand a divergence between fear and avoidance learning.

### 3.1. Clinical implications

Clinical implications may be drawn from the present findings. Previous studies demonstrated that persistent avoidance prevents the extinction of fear and even reinstates fear after successful fear reduction (Lovibond et al., 2009; Vervliet & Indekeu, 2015). In addition, avoidance of exposure exercises may result in refusal and drop-out of exposure-based treatments, in which a patient is required to approach a feared stimulus (e.g., 11.4% refusal and 19.6% drop-out; Fernandez, Salem, Swift, & Ramtahal, 2015). Persistent avoidance thereby contributes to the maintenance of maladaptive fear and anxiety as seen in anxiety disorders. Different strategies to overcome avoidance have therefore been discussed. For example, the judicious use of safety signals and behaviors has been discussed to reduce avoidance of exposure exercises (Levy & Radomsky, 2014; Milosevic & Radomsky, 2008; Rachman, Radomsky, & Shafran, 2008). However, the use of safety signals and behaviors may impair subsequent fear extinction learning (Lovibond et al., 2009; Powers, Smits, & Telch, 2004). Thus, strategies that simultaneously reduce avoidance and do not impair fear extinction during exposure exercises may be an important asset to exposure-based treatments. In the present study, exploratory analyses indicated that the presence of competing rewards did not impair fear reduction. Fear reduction was, however, experienced earlier in the presence of competing rewards. The present results thus provide first evidence that introducing rewards for approaching a feared stimulus attenuates avoidance while keeping fear extinction unharmed and may even temporally accelerate fear extinction learning. However, as these analyses were

exploratory, replication is warranted.

In a clinical context, a straightforward implication would be to introduce competing rewards as early as possible to buffer the development of sustained avoidance or help to overcome acquired avoidance. However, the effects of the present study rest upon the presence of competing rewards during aversive experience. Such competing rewards may not be present during the fear acquisition history for all individuals with anxiety disorders. In addition, treatments usually commence a long time after aversive experiences that triggered fear acquisition. However, avoidance reducing effects of competing reward for stimuli, which were already feared for a longer time period, was shown in individuals with specific fears and phobias (e.g., Kirsch, 1982; Pittig, Hengen, et al., 2018a). The underlying mechanisms of this effect, however, need to be further investigated.

In addition to such one-to-one translation, competing rewards may function as a laboratory model for positive outcomes and goals competing with avoidance of fear-relevant stimuli during treatment. Craske and Barlow (1988) have highlighted inter- and intra-individual differences in avoidance, which are influenced by individual and situational factors. For example, extensive and minimal avoiders may be equally fearful after an initial panic attack, but differ in the decision to re-approach due to social demands or expected positive outcomes of approach. Such factors have informed therapeutic strategies such as motivational interviewing (Miller & Rollnick, 2012) or value-based exposure in Acceptance-Commitment therapy (Hayes, Strosahl, & Wilson, 2003). Laboratory approach-avoidance conflict models may help to provide controlled insights into these inter- and intra-individual differences in avoidance. The present model may be useful as rewards were hypothetical and their avoidance reducing effect thus be linked to a task-related goal. Thus, the model may help to test the utility of therapeutic goals competing with avoidance behavior. Future research, however, should pinpoint the goal-related effects of hypothetical rewards (e.g., by manipulating the task-related goal).

### 3.2. Limitations and future directions

In addition to the limitations discussed above, the present study comprises further limitations. First of all, to assess fear responses for all participants, participants who consistently avoided during test had to be forced to select the CS+ option. This manipulation introduces an additional factor Freedom of Choice (free vs. forced CS+ choice), which was accounted by separating statistical analyses. This approach reduced the number of participants in each cell. Whereas group comparison of responses to free CS+ choices yielded sufficient samples, sample sizes was smaller for the comparison of forced CS+ choices. For frequentist results, the lack of group differences might have been explained by a lack of statistical power. However, Bayesian analyses indicated that the probability of the data coming from the null hypothesis with a mean group difference of zero (H0) was more than five times more likely than data coming from the alternative hypothesis with a mean group difference unequal to zero (H1). Moreover, the introduction of the factor Freedom of Choice descriptively yielded results of SCRs being higher for participants who were forced to choose the CS + option compared to participants who freely chose this option. However, an impact of freedom of choice on fear responses cannot be inferred as the present study did not aim and was not designed to test these effects. Individuals were not randomized to free or forced decisions, but grouped post-hoc following their performance in the task. Thus, differences in fear responses cannot be causally interpreted. Future studies need to explicitly manipulate the availability of forced and free decisions to provide compelling evidence on the effect of freedom of choice. Studying the effect of forced versus free choice may provide important methodological and theoretical insights. Fear learning is mostly studied using passive-viewing paradigms, i.e., participants are typically forced to observe the CS+. Differences between free and forced viewing may thus question the validity of traditional fear learning paradigms for complex real-life situations including free choice.

As the present study was designed to test avoidance and attenuation of initial fear acquisition, fear extinction analyses were exploratory and only focused on the CS+. Future studies may adapt the experimental paradigm to directly test the impact of competing rewards on fear extinction in approach-avoidance decisions (and also account for responses to the CS−). As another limitation, reward magnitude was equal for all participants and no responses to rewards were assessed. It thus remains unclear how responses to rewards interacted with approach-avoidance behavior. Subjective ratings indicated a reduction of avoidance motivation, which may thus be linked to the modulation of approach-avoidance. Assessing responses to rewards may help to test whether the modulation of approach-avoidance behavior is also linked to increased approach motivation. Moreover, the match between individual arousal and valence between rewards and the US was not directly assessed. Subjective motivation to avoid the US did not differ from motivation to approach high rewards and both ratings were at a medium level. These findings offer evidence that neither of the stimuli was too strong and thereby eradicated the impact of the other stimulus. However, future studies may assess individual responses to rewards and manipulate the match between arousal and valence of the reward and US. Moreover, future studies may manipulate the intensity of positive and negative stimuli. For example, aversive USs and reward stimuli are usually more intense in real-life. Future research may thus test whether the present effects hold true for more intense stimuli.

The present study also did not assess individuals with clinical levels of anxiety. Results are therefore limited to a healthy sample and need to be replicated in individuals with clinical anxiety and avoidance symptoms. Pathological avoidance as seen in anxiety disorders is typically linked to severe impairments. In addition, previous studies showed that anxious individuals and patient will show elevated avoidance despite avoidance costs (Pittig et al., 2015; Pittig, Brand, et al., 2014a; Pittig, Pawlikowski, et al., 2014b). Thus, future research may determine whether alterations in the avoidance-reducing effect of competing rewards may be found in individuals with anxiety disorders and whether costly avoidance is already evident during initial acquisition or emerges after longer periods of clinical anxiety symptoms. Future research is also needed to evaluate the relation to treatment outcomes.

### 3.3. Conclusion

Insights into the mechanisms of fear and avoidance learning are crucial for our understanding of (dys-) functional fear regulation and the prevention and treatment of anxiety disorders. Using an approach-avoidance decision paradigm, the present study investigated the impact of competing rewards on the acquisition of fear and avoidance. Without competing rewards during acquisition, significant avoidance occurred and persisted in the absence of the US. Competing rewards markedly attenuated avoidance acquisition, which was evident as early as after the first US and remained stable even when rewards were discontinued. Fear acquisition was, however, not modulated by the presence of competing rewards. Competing rewards did also not modulate the level of fear reduction during extinction. Due to faster approach of the feared stimulus, fear reduction was experienced earlier in the presence rewards. Taken together, competing rewards for approach do not buffer the acquisition of fear, but can prevent the development of avoidance. This facilitation effect does not seem to depend on the presence of rewards during extinction learning. Competing rewards may be an important asset to exposure-based treatments of anxiety disorders.

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