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The cost of fear: Impairments of decision-making in specific phobia

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ABSTRACT

Background: Decision-making processes may play a pivotal role in the etiology and maintenance of specific phobia. However, empirical evidence is limited. This study examined whether decision-making is only impaired in presence of fear-related stimuli or whether general impairments exist but are more pronounced in the presence of fear-related stimuli. Further, we examine which components of the decision-making process might be impaired.

Methods: We examined a spider phobia group (SP, n = 109) relative to matched healthy controls (HC, n = 81) using a virtual decision game. To tap the approach-avoidance-conflict, either a fear-related version (using spiders) or a non-phobic version of the task was used in a between-subjects design to measure how the presence of fear-related or non-phobic stimuli was associated with optimal decision-making (collecting rewards). Based on drift diffusion modelling, underlying decision-making processes such as processing ability and cautiousness were investigated.

Results: No clear evidence for general impairments of decision-making for SP participants relative to HC in the absence of fear-related stimuli was found, but a strong phobia-specific impairment when fear-related stimuli were present. These avoidant decisions were associated with a reduced ability to process the optimal choice option and increased cautiousness in the SP group.

Conclusions: Decision-making processes in specific phobia are specifically impaired in the presence of fear-related stimuli, which might contribute to maladaptive, costly avoidance behavior.

1. Introduction

With lifetime and 12-month prevalence rates of 7.4 and 5.5% (Wardenaar et al., 2017) specific phobia is a highly prevalent mental disorder. Affected people experience fear and/or avoidance of specific objects or situations that is disproportionate to the actual threat. In daily life, an approach-avoidance conflict may occur, for example, if a person with spider phobia has to choose between a satisfying activity like a walk in the park or avoiding such a situation because of the threat of coming in contact with a spider. The conflict between the possible rewarding approach behavior and the costly avoidance behavior can be seen as a decision-making process (Ball & Gunaydin, 2022; Boschet et al., 2022; Pittig, Schulz et al., 2014; Stein & Paulus, 2009).

Research has shown that besides a genetic disposition (Muris &

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Merckelbach, 2012), cognitive and learning processes such as conditioning, modeling and observational learning and negative information transfer may play a role in the etiology and maintenance of specific phobias (Craske et al., 2011; Hettema et al., 2001; Mineka & Zinbarg, 2006; Treanor et al., 2021). At the cognitive level, impaired decision-making processes might be of pivotal interest. A predisposition for phobic fears may interact with a general impairment of decision-making due to impaired evidence evaluation and a more cautious decision style, so that individuals may miss positive, correcting experiences in ambiguous situations. This may reinforce a tendency of a more cautious decision style in potentially threatening situations and a vicious circle may start that perpetuates and maintains anxiety. However, it is also possible that the pathway of risk occurs the other way around: Anxiety may lead to impaired decision-making in potentially threatening situations that leads to a preference of choosing to avoid potentially threatening situations resulting in the missing of correcting experiences as well. In this context, it is relevant to investigate whether impairments of decision-making are specific to the fear-related stimulus (e.g., a spider in spider phobia, SP) or if decision-making is also altered in the absence of fear-related stimuli in individuals with specific phobia. The latter relates to the question whether and how *general* decision-making processes are involved in the etiology and maintenance of specific phobia. As there is limited research about the role of decision-making in specific phobia including SP, we review literature on the association between decision-making and anxiety.

Previous research on decision-making in the absence of fear-related stimuli has mainly focused on risky decision-making (choice between low-risk, low-value and high-risk, high-value options, and delay discounting (choice between sooner, small-value and delayed, large-value options). For risky decision-making, individuals with high-trait anxiety have been shown to prefer low risk options, even if that means receiving a smaller reward, compared to non-anxious controls (Maner et al., 2007; Maner & Schmidt, 2006; Raghunathan & Pham, 1999). In delay discounting, findings are mixed. Xia and colleagues found stronger preferences for immediate rewards in people with high as compared to low trait anxiety (Xia et al., 2017), whereas Steinglass and colleagues (2017) found the opposite pattern. For social anxiety, some studies did not find differences in delay discounting compared to healthy controls (Jenks & Lawyer, 2015; Steinglass et al., 2017), while other studies found higher rates of discounting (Rounds et al., 2007).

The impact of a fear-related stimulus on decision-making has also been studied in risky decision-making or approach-avoidance-conflict-tasks. Here, the presence of a fear-related stimulus was associated with avoidant decisions in highly trait-anxious participants relative to low trait-anxious participants in gambling tasks, resulting in fewer gains (Miu et al., 2008; Pittig, Schulz et al., 2014). Additionally, spider-fearful participants were found to avoid advantageous decisions when these were paired with spider stimuli (Pittig, Brand, Pawlikowski, & Alpers, 2014). Studies testing delay discounting with fear-related stimuli are rare. Rounds et al. (2007) tested high and low socially anxious participants in a paradigm with hypothetical social threat or non-threat situation and found that discounting was higher in the high social anxiety group, but only in the absence of social threat (Rounds et al., 2007). However, Jenks and Lawyer (2015) failed to replicate these findings and found neither social anxiety status nor anxiogenic laboratory procedures to impact decision-making in a delay discounting task.

Taken together, there is very little knowledge about decision-making in specific phobia. Prior research related more broadly to anxiety suggests that participants with anxiety disorders may be impaired in their decision-making in the presence of fear-relevant cues (maladaptive/costly avoidance, Ball & Gunaydin, 2022) as well as in the absence of fear-relevant cues (general impairment), even though results are somewhat mixed and partly based on trait-anxiety rather than anxiety disorder diagnoses. Further, it is unclear which components of the decision-making process may be impaired in individuals with SP. Are individuals with SP not able to identify optimal choices because of an *impaired ability to process choice attributes* (slower accumulation of choice information)? Or are they overly *cautious* in their decision-making, and hence miss out on optimal choices?

The present study aimed to investigate whether and how decision-making is impaired in participants with spider phobia. We compared participants with SP with healthy controls (HC) in a decision-making paradigm that allows us to measure optimal decision-making (Scherbaum et al., 2018). Optimal choices were based on individualized cost-benefit-ratios of the decision options. In addition, we employed drift diffusion, a computational modeling approach that allows us to investigate specific components of the underlying decision-making process. Here, the decision-making process is divided into separate components, for example how quickly information about the decision options is accumulated (so-called drift rate) or how much evidence or value in favor of one option is necessary to make a decision indicating how cautious they were in their decision-making (so-called decision boundary) (Ratcliff, 1978; for more details see Methods). Furthermore, given prior findings on trait-anxiety, which has been shown to be associated with anxiety disorders including specific phobia (Knowles & Olatunji, 2020), as well as prior findings in groups with anxiety disorder diagnoses, we were interested in whether these decision-making processes are impaired in general and whether and how fear-related stimuli impact these processes.

Regarding the general impairments, we assumed that participants with SP.

1. Would make fewer optimal choices than HC.
2. Would show impairments in processing the optimal choices compared to HC.
3. Would be more cautious in their decisions than HC.

We expected these effects to be more pronounced in the presence of fear-related stimuli (hypotheses 4–6).

2. Methods

2.1. Study design

This study is part of a larger study[2] consisting of a cross-sectional case-control comparison (SP participants versus HC) followed by a behavioral intervention (single session exposure therapy) and follow-up in the SP group.

Here, we focus on one paradigm—a decision game—that was applied during the first session in both groups at pre-treatment.

2.2. Participants

Power calculations were run for a 2 x 2 ANOVA, as most paradigms assessed in this study used a 2 x 2 design. Using G-Power version 3.1.9.2 (Faul et al., 2007), the power calculations indicated that we would need 45 participants per group/condition to achieve a power of 80% with an effect size of $f = 0.25$ and an alpha level of 0.05. Participants were recruited between May 2017 and February 2020 via the university home page and mailing list as well as through distribution of flyers and advertisements placed in local television and radio. Inclusion criteria were age 18–50 years, sufficient German language skills, absence of heavy smoking (>10 cigarettes per day or equivalent), no use of chronical or psychopharmacological medication, eligibility for magnetic resonance imaging and not having participated in a psychotherapeutic intervention during the last four weeks. We screened for SP severity using the Fear of Spider Questionnaire (FSQ; Rinck et al., 2002). We included

[2] The overall purpose of the study was to investigate the role of cognitive control in specific phobia related avoidance behavior and its capacity to predict treatment outcome.

participants in the SP group with a minimum FSQ-score of 73 and HC not exceeding a score of six based on other studies (Cochrane et al., 2008; Mosig et al., 2014; Muris & Merckelbach, 1996; Rinck et al., 2002; Teachman & Woody, 2003). After online and telephone screenings, potential participants of the SP group were invited to take part in a standardized clinical interview (DIA-X-5/CIDI; Hoyer et al., 2020; a DSM-5 adapted research-version of the DIA-X/M-CIDI; Wittchen & Pfister, 1997). We included individuals who presented with manifest DSM-5 defined SP with at least mild suffering or impairment. We excluded individuals in case of severe comorbid conditions (major depressive or manic episode, psychotic disorder) or acute suicidality, presence of another specific phobia subtype of greater severity than the SP, and if exposure therapy was not indicated. For the HC, we included individuals who did not confirm any items of the DIA-X-5 stem screening-questionnaire (SSQ; Wittchen & Perkonigg, 1997) during the online screening, or who confirmed any stem screening items but were confirmed to be free of any DSM-5 lifetime mental disorders according to DIA-X-5. The HC was recruited after the SP group. A matching regarding age, sex, educational level and handedness[3] was targeted, but not achieved for age and educational level due to feasibility restrictions; the HC was younger and had a higher educational level (Table 1 and S 1), but the groups did not differ with regards to sex and handedness. Thus, we included age and educational level as covariates in additional analyses (see statistical analyses). In addition, 15 participants of the SP group met DSM-5 criteria for other mental disorders within the last 12 months (obsessive compulsive disorder n = 2, attention-deficit/hyperactivity disorder n = 1, anxiety disorder other than SP n = 10, somatic symptom or related disorder n = 2). Comorbidity did not affect task performance (see Supplement).

The final sample consisted of 110 SP participants and 82 HC. For HC, this is slightly less than the sample size identified by the power calculation due to feasibility reasons. Two participants (one from each group) did not perform the decision-making task due to technical issues. Sample characteristics are presented in Table 1. The study protocol was accepted by the local ethics committee (EK543122015) and the study was performed in accordance with the Declaration of Helsinki.

2.3. Study procedure

The study took place at TU Dresden, Germany. On the assessment day, participants first gave informed consent, and then underwent a series of tasks (see Fig. 1). The overall assessment duration at that day was approximately 1.5 h.

2.4. Decision-making task

The task was a virtual decision game in which participants navigated an avatar in a two-dimensional world (Scherbaum et al., 2018). Participants had to accumulate rewards in a limited amount of time. They were paid in cash based on their overall accumulated reward score. In each trial, two coins appeared that were either smaller in value, but closer to the avatar, or larger in value but further away from the avatar. Hence, participants had to decide if it was worth investing the extra time to collect the larger over the smaller reward. The nature of the task allowed us to compare participants' decisions to an individualized model of optimal decisions, classifying every decision as optimal or nonoptimal based on the ratio of reward value to time of each option (for more details see Computational modeling section below).

We presented two different versions of the decision-making task, a phobia version and a non-phobic version. We randomly assigned half of each participant group to each version in a between-subjects design. The phobia version of the task included fear-related (spider) stimuli and the non-phobic version of the task included non-phobic (turtle) stimuli next to one of the coins in a subset of trials (see Fig. 2 for the spider version and Figure S 1 for the turtle version; supplementary materials for a video of the task). The stimuli (animals) were irrelevant for the task and the most efficient strategy to gain as much money as possible would be to ignore them. We manipulated the within-subjects factor animal position such that the animal was behind the smaller coin in one third of trials, behind the larger options in one third of trials, and there was no animal in the remaining trials. We combined all reward combinations with all distances for the small and the large coin (which resulted in 3 (distance small coin) x 4 (distance large coin) x 5 (reward combinations) x 3 (animal position) = 180 unique combinations), and presented them in randomized order. The number of trials that participants completed within the time limit of the task varied due to individual differences in choices, decision times and clicking speed, but was comparable for both groups (HC and SP participants) with on average 340.43 trials (SD = 43.07 trials) for SP participants and 348.08 trials (SD = 33.52 trials) for HC, t (188) = 1.32, p = .19. Details on apparatus and stimuli can be found in the supplementary materials.

2.5. Task procedure

First, participants received written instructions and underwent a 30 s tutorial. They were informed that small animals would appear behind the coins in some trial, but that these animals had no impact on the value of the coins and participants could ignore them, During the experiment, participants played the game for four blocks of 6 min. Within a trial, two coins always appeared at the same time. Participants made their decision by moving the avatar field-by-field via mouse clicks until it reached the chosen coin. Then, both coins disappeared and the accumulated credit collected so far appeared. The avatar remained in the position of the last coin. The next trial started with the appearance of two new coins after 1.3 s. During this inter-trial interval, the mouse cursor was locked to the position of the avatar; it could only be moved again when the next trial started and new coins appeared.

2.6. Computational modeling

2.6.1. Optimal choice model

One crucial advantage of our decision game is that it allows us to look at optimal decision-making. We identified the "optimal" choice as the option with the higher benefit to cost ratio (benefit: reward value; cost: invested time). For the option that was not chosen, we calculated how much time it would have taken the participant to collect that option based on their clicking speed in that trial (see the supplement for a formal description). By taking the speed of clicking into account, this allowed us to build an individualized model of optimal decision-making for each participant. Hence, if participants chose the option with the higher benefit-to-cost ratio, their choice was defined as optimal; if they chose the option with the smaller benefit-to-cost ratio, their choice was defined as nonoptimal.

2.6.2. Drift diffusion modeling

The drift diffusion model is a sequential sampling model of binary decisions that was originally introduced by Ratcliff (1978). The core assumption of the model is that decisions are based on noisy evidence accumulation processes. If the evidence for either option exceeds a certain threshold, a decision is made (see Fig. 3). The diffusion model can be described by four parameters: drift rate (speed of evidence accumulation, i.e. ability to process the value of an option), threshold or boundary (amount of evidence that is needed to elicit a response; symmetrical for optimal and nonoptimal choices), start bias (indicating if there is a general bias towards one option), and non-decision time (all processes that are not part of the decision-making process, e.g. motor response).

Of these parameters, we identified two parameters of interest that might explain the differences between people with and without SP. The

[3] Due to tasks in the MRI scanner.

Table 1
Demographic data for participants with spider phobia and the healthy control group in the two different task conditions (phobic/non-phobic).

	Condition	*N*	Mean age (*SD*)	*n* female (%)	Mean FSQ score (*SD*)	Mean % optimal choice (*SD*)	Mean response times (*SD*)
Total Sample		190	25.05 (6.29)	174 (91.58%)	46.65 (39.56)	77.83% (0.09)	878.06 ms (164.87)
SP	Phobic (spider)	55	27.75 (7.61)	50 (90.91 %)	80.47 (11.63)	72.39% (10.46)	950.56 ms (179.73)
	Non-phobic (turtle)	54	24.24 (5.64)	51 (94.44 %)	79.07 (13.12)	77.84% (0.07)	840.31 ms (180.29)
HC	Phobic (spider)	41	22.92 (4.67)	37 (90.24 %)	1.80 (1.76)	82.09% (0.05)	856.82 ms (117.40)
	Non-Phobic (turtle)	40	24.60 (5.48)	36 (90.00 %)	2.88 (3.55)	80.95% (0.07)	851.06 ms (134.42)

Note: *SD* = standard deviation; FSQ =Fear of Spider Questionnaire, SP = spider phobia, HC = healthy controls.

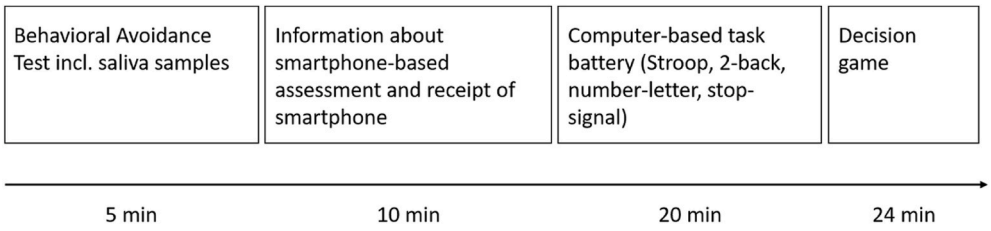

Fig. 1. Study procedure.

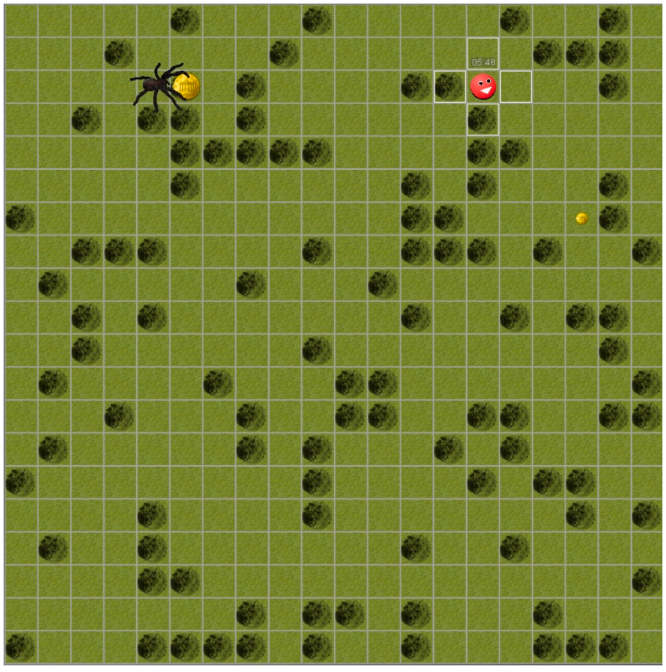

Fig. 2. Decision-making game in the spider condition. Participants controlled the red avatar by using the computer mouse and clicking into adjacent fields (up, down, left, right; outlined in white). The golden coins are the reward options (value represented by size). Above the avatar, the remaining time within the current block was displayed. In two thirds of trials, an animal (spider or turtle, depending on the task version) was positioned behind one of the rewards. The animal did not block the path to the coin. The animal moved slightly back and forth in its place. Dark green spots (representing trees) were included to provide better spatial orientation; they did not obstruct movement, participants could cross freely through all fields. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

first parameter is the drift rate, which indicates the speed of evidence accumulation and usually corresponds to how strong the evidence for a decision option is. In the context of our task, participants need to process each choice option's attributes (reward value and distance) and to integrate this into a subjective value. A higher drift rate means that this process is quicker, whereas a lower drift rate would indicate that this process is slower or impaired, which would make it more difficult to identify the optimal choice option. As stated in hypotheses 2 and 5, for participants with SP we expected both a general impairment in this processing ability (i.e., a lower drift rate) as well as a more pronounced specific impairment when faced with a fear-related stimulus. The second parameter was the decision boundary. A larger decision boundary indicates a conservative, cautious style of decision-making because a lot of evidence in favor of one of the choice options is necessary before a response is made. Hence, for participants with SP, we expected an increased boundary in general as well as when faced with a fear-relevant stimulus (hypotheses 3 and 6). We did not expect to see differences between SP and HC for the other two parameters. For start bias, the nature of our paradigm meant that participants were unable to predict where the options would appear in the next trial and which option would be the optimal option; therefore, systematic differences in the start bias between the two groups seemed implausible. For non-decision time, we did not expect SP and HC participants to differ with regards to their sensory processing and motor execution time and hence did not expect systematic differences in this parameter.

We performed drift diffusion modeling using the fast-dm 30 toolbox (Voss & Voss, 2007) in Matlab R2017b. We fitted the model to each participant's response times in optimal (upper boundary) and nonoptimal choices (lower boundary) to find the parameter set that best matched their data based on a maximum likelihood algorithm (Voss et al., 2015; Voss & Voss, 2007). Response times were defined as the time until the first decision (i.e., first click), as this indicated the final choice in 98.87% of trials (i.e., participants only changed their minds and pursued the alternative choice option after the first click in 1.13% of trials (*SD* = 0.95%)). We fitted three separate models for each within-subject condition of animal position. This allowed us to analyze how the presence and position of the animal was associated with the decision-making process. We excluded trials where response times were faster than 300 ms or longer than 10 s in order to remove outliers (which could impair the model fit). We set the start bias, non-decision time, drift rate and boundary as free parameters, all other parameters were set to 0. We conducted model fit and parameter recovery analyses which showed that the empirical parameters and the simulation-based parameters correlated highly (all *r*s > 0.80). Further details are presented in the supplement.

2.7. Statistical analyses

We used Matlab R2017b for data processing and additional *t*-tests and JASP 0.16.3.0 for statistical analyses. We performed mixed ANOVAs

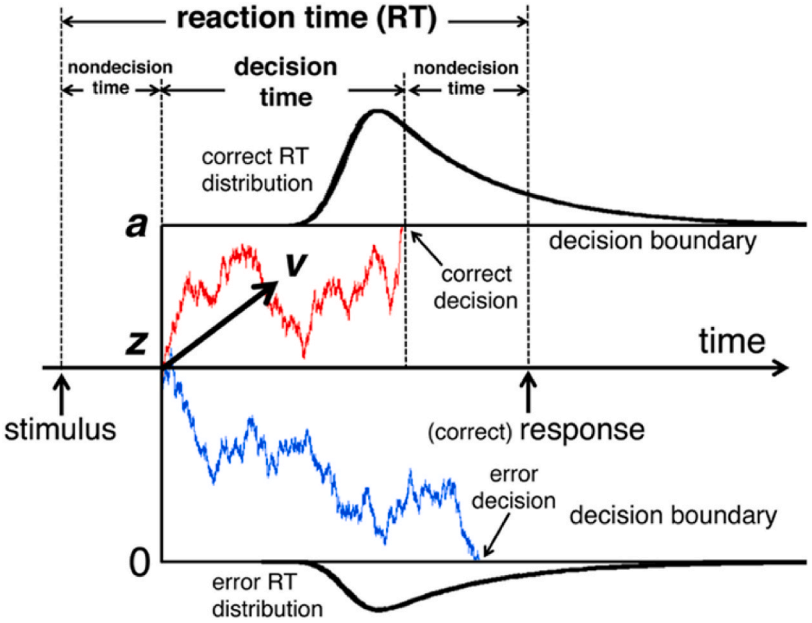

Fig. 3. Illustration of the drift diffusion model. The model assumes that the overall reaction or response time (RT) can be divided into a decision time (during which the decision-making process takes place), and a nondecision time (additional processes such as sensory processing and motor response). During the decision time, evidence for the correct decision (upper boundary) or the incorrect decision (lower boundary) is accumulated over time. This accumulation process can start at a neutral position or can be shifted in favor of one option by the start bias (**z**). Here, it is shifted towards the correct decision (upper boundary). The red (blue) line indicates the noisy accumulation process for a single correct (error) trial. Once evidence for the correct or incorrect decision has hit a decision boundary (**a**), a decision is made. The drift rate (**v**) indicates the average strength and direction of evidence accumulation across trials. In combination, these parameters can be used to fit choice and response time distributions as found in the data (correct and error RT distributions). The model is able to describe typical RT distrubutions, where correct responses have a higher frequency and faster response times, whereas error responses have a lower frequency and slower response times. Adapted from Murata, Hamada, Shimokawa, Tanifuji & Yanigada (2014). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

with the between-subjects factors Group (SP vs. HC) and Condition (spider vs. turtle), and the repeated-measures factor Animal Position (optimal option vs. nonoptimal option vs. no animal). For the analyses of the diffusion model parameters, we used Bonferroni-correction (Bonferroni-corrected threshold: $p < .0125$). In addition, we ran all analyses again while controlling for dummy-coded education level and age. We will discuss these analyses only when their results qualitatively differ from the main analyses, all results and exploratory analyses on the other drift diffusion model parameters start bias and non-decision time are presented in the supplement. We also present exploratory analyses of response times in the supplement (see Table S 11 and Figure S 3).

2.8. Transparency and Openness

This study was not preregistered. We report how we determined our sample size, all data exclusions (if any), all manipulations, and all relevant measures for the current study. Data and analysis scripts for this manuscript are openly accessible at https://osf.io/dztjp/?view_only=e9cd8473f9e04499a1b7fe47a937790d/

3. Results

3.1. General impairment of decision-making

All analyses addressing general impairments of decision-making were tested in the non-phobic task version (turtle). We hypothesized that SP relative to HC would make fewer optimal choices in general (hypothesis 1), which was supported by our analysis, t (92) = −2.01, p = .048, g = −0.42 (SP: M = 77.91 %, SD = 7.06 %; HC: M = 80.95 %, SD = 7.52 %). However, when including age and education as covariates in an ANCOVA, this group effect was no longer significant, F (1,88) = 1.54, p = .217, η_p^2 = 0.02 (see Table S 1).

We did not find any significant differences with regards to drift rate, t (92) = 1.52, p = .132, g = 0.32 (SP: M = 1.09, SD = 0.39; HC: M = 1.23, SD = 0.45), or with regards to boundary, t (92) = 0.62, p = .537, g = 0.13 (SP: M = 1.40, SD = 0.25; HC: M = 1.43, SD = 0.19) (hypotheses 2 and 3).

3.2. Specific impairment in presence of fear-relevant stimuli

We expected SP participants to show specific impairments in decision-making in the presence of a spider relative to non-phobic conditions (absence of animal, presence of turtle) compared to HC.

First, we tested this for optimal choices (hypothesis 4) using a mixed ANOVA (see Table 2 and Fig. 4). We expected a significant three-way interaction of Group, Condition, and Animal. Indeed, this three-way interaction was significant, F (2,372) = 52.49, $p < .001$, η_p^2 = 0.22. Notably, this effect had the largest effect size. Hence, the non-phobic and the fear-related stimuli affected optimal decision-making differently depending on the position of the animal for both groups. Bonferroni-corrected paired t-tests showed the expected pattern for the fear condition: SP participants' decision-making was impaired when the spider was at the optimal decision, t (54) = −7.08, $p < .001$, dz = −0.95, and their decision-making was improved when the spider was at the nonoptimal decision, t (54) = 3.11, p = .036, dz = 0.42. We found the opposite effect for HC, where the spider improved optimal decision-making when it was positioned at the optimal decision, t (40) = 10.31, $p < .001$, dz = 1.61. In the non-phobic condition, both SP participants and HC showed largely the same pattern: Both groups made fewer optimal choices when the turtle was at the nonoptimal decision option as compared to when no animal was present (SP: t (53) = −4.09, p = .002, dz = −0.56; HC: t (39) = 3.93, p = .004, dz = 0.62). When the non-phobic stimulus was at the optimal decision option, SP participants made more optimal choices (vs. no animal present, t (53) = 3.02, p =

Table 2
Results of the mixed ANOVAs with between-subjects factors Group (SP, HC) and Condition (fear – spider, non-phobic - turtle), and repeated-measures factor Animal position (optimal, nonoptimal, no animal), with dependent variables optimal choice, drift rate and boundary.

effect	Optimal choice	Drift rate	Boundary
Animal position x Condition x Group	**$F(2,372) = 52.49$, $p < .001$, $\eta_p^2 = .22$**	**$F(2,372) = 44.09$, $p < .001$, $\eta_p^2 = .19$ ***	**$F(2,372) = 13.77$, $p < .001$, $\eta_p^2 = .07$ ***
Animal position	**$F(2,372) = 10.09$, $p < .001$, $\eta_p^2 = .05$**	**$F(2,372) = 6.54$, $p = .002$, $\eta_p^2 = .03$ ***	**$F(2,372) = 17.89$, $p < .001$, $\eta_p^2 = .09$ ***
Animal position x Condition	**$F(2,372) = 20.18$, $p < .001$, $\eta_p^2 = .10$**	**$F(2,372) = 15.59$, $p < .001$, $\eta_p^2 = .08$ ***	**$F(2,372) = 16.01$, $p < .001$, $\eta_p^2 = .08$ ***
Animal position x Group	**$F(2,372) = 46.73$, $p < .001$, $\eta_p^2 = .20$**	**$F(2,372) = 42.17$, $p < .001$, $\eta_p^2 = .19$ ***	**$F(2,372) = 16.10$, $p < .001$, $\eta_p^2 = .08$ ***
Condition	$F(1,186) = 3.57$, $p = .060$, $\eta_p^2 = 0.02$	$F(1,186) = 0.49$, $p = .483$, $\eta_p^2 = 0.003$	**$F(1,186) = 23.81$, $p < .001$, $\eta_p^2 = .11$ ***
Group	**$F(1,186) = 29.91$, $p < .001$, $\eta_p^2 = .14$**	**$F(1,186) = 19.66$, $p < .001$, $\eta_p^2 = .10$ ***	**$F(1,186) = 17.51$, $p < .001$, $\eta_p^2 = .09$ ***
Condition x Group	**$F(1,186) = 8.23$, $p = .005$, $\eta_p^2 = .04$**	$F(1,186) = 5.90$, $p = .016$, $\eta_p^2 = 0.03$	**$F(1,186) = 21.57$, $p < .001$, $\eta_p^2 = .10$ ***

Note: significant results in bold; * Bonferroni-corrected significance ($p < .0125$).

.047, $dz = 0.41$), whereas there was no significant difference for HC, $t(39) = 0.15$, $p = 1.00$, $dz = 0.02$. Overall, effect sizes were much smaller for the non-phobic than for the fear-related condition. All other effects of the ANOVA were significant as well (except for the main effect of animal), likely driven by the interaction effect (see Table S 5).

Next, we expected specific impairments in the ability to process the choice options (hypothesis 5) such that SP participants would be less able to process the optimal choice in the presence of the spider (indicated by a lower drift rate) relative to the conditions turtle and no animal than HC. We performed a mixed ANOVA on drift rate with the between-subjects factors Group and Condition and the repeated-measures factor Animal position. All effects in the ANOVA reached significance, except for the main effect of Condition and the interaction Condition x Group (see Table 2 and Fig. 5A; for additional *t*-tests, see Table S 6). Of note, similar to the results for optimal choice, the three-way interaction between Group, Condition and Animal Position had the largest effect size, $F(2,372) = 44.09$, $p < .001$, $\eta_p^2 = 0.19$. As Fig. 5A shows, the presence of the spider clearly affected the drift rate in both groups (but especially strongly for SP participants). For SP participants, the presence of the spider biased the drift rate away from the option with the spider: Bonferroni-corrected paired *t*-tests showed that the drift rate was severely decreased when the spider was at the optimal decision option (vs. no animal, $t(54) = -6.65$, $p < .001$, $dz = -0.90$), while the drift rate was increased when the spider was at the nonoptimal decision (vs. no animal, $t(54) = 4.06$, $p = .002$, $dz = 0.55$). In the non-phobic task version, SP participants showed a decreased drift rate when the turtle was at the nonoptimal option, $t(53) = -3.05$, $p = .043$, $dz = -0.41$, but the difference between turtle at optimal option vs. no animal was not significant, $t(53) = 1.60$, $p = 1.00$, $dz = 0.22$. For the HC, there were no significant effects in the non-phobic task version (see Table S 6).

Further, we expected SP participants to be overly cautious in the presence of the spider (indicated by a higher boundary) relative to the conditions turtle and no animal than HC (hypothesis 6). As for hypotheses 4 and 5, we ran a mixed ANOVA with the between-subject factors Group and Condition and the within-subjects factor Animal Position (see Fig. 5B). We found a significant interaction between Group, Condition and Animal Position, $F(2,372) = 13.77$, $p < .001$, $\eta_p^2 = 0.07$. All other effects also reached significance (see Table 2). As Fig. 5B shows, the position of the spider affected the boundary when the fear-related stimulus was present. Bonferroni-corrected paired *t*-tests revealed that, for SP participants, the presence of the spider increased the boundary for both the optimal, $t(54) = 4.29$, $p < .001$, $dz = 0.58$, and nonoptimal decision, $t(54) = 5.70$, $p < .001$, $dz = 0.77$ (compared to no animal). Interestingly, the boundary was higher when the spider was at the nonoptimal as compared to the optimal option, $t(54) = 3.06$, $p = .041$, $dz = 0.41$. For HC, the boundary was increased only for the condition with the spider at the optimal condition (as compared to no animal), $t(40) = 7.14$, $p < .001$, $dz = 1.11$, but there was no difference between spider at the nonoptimal option vs. no animal, $t(40) = -1.32$, $p = 1.00$, $dz = -0.21$. For both participant groups, none of the t-tests in the non-phobic task version (turtle) reached significance (see Table S 7).

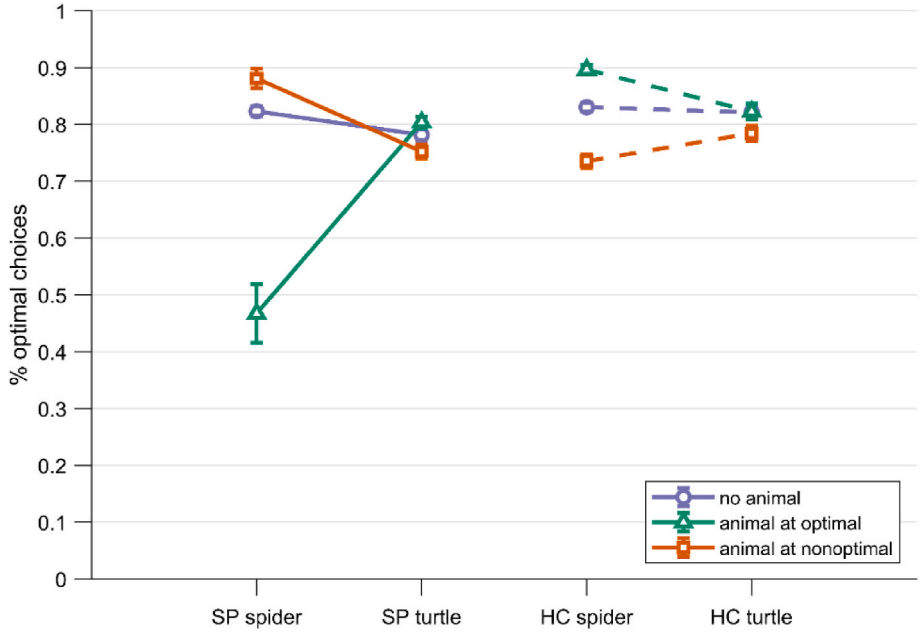

Fig. 4. Mean optimal choice percentages. Solid lines indicate participants with spider phobia (SP), dashed lines indicate healthy controls (HC). Error bars represent standard errors.

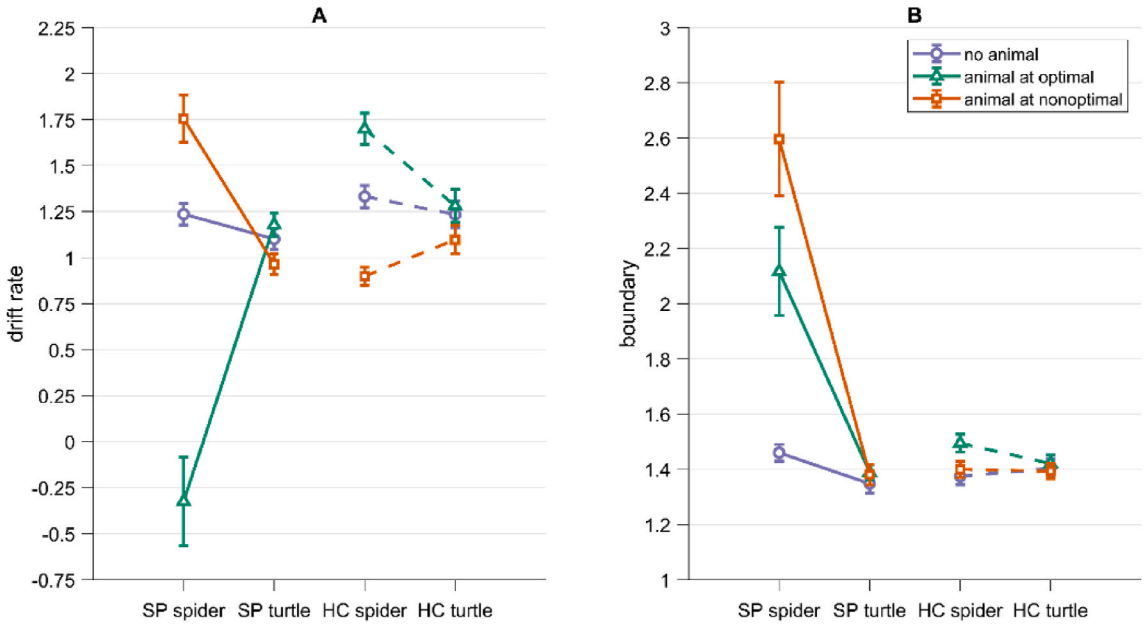

Fig. 5. Results of diffusion model analysis for A) drift rate and B) boundary. Solid lines indicate participants with spider phobia ("SP"), dashed lines indicate healthy controls ("HC"). Error bars represent standard errors.

4. Discussion

In our study, we did not find evidence for general impairments of decision-making, i.e. in the absence of fear-related stimuli in adults with spider phobia (SP) relative to healthy controls (HC). However, we found a strong phobia-specific impairment when fear-related stimuli were present. Hence, relative to HC, SP participants showed impaired decision-making when the spider was at the optimal decision option, suggesting costly avoidance. In contrast, HC seemed to be drawn to the spider, which led to improved decision-making when the spider was at the optimal option. Our examination of the underlying decision-making processes suggests that, in the presence of the spider, SP participants were less able to process the optimal choice option and were more cautious in their decision-making relative to HC.

Previous studies showed that anxious individuals are characterized by less risky decision-making in terms of preferring low risk options and immediate rewards, compared to non-anxious controls in non-phobic tasks, resulting in disadvantageous decisions (Ho et al., 2022; Maner et al., 2007; Maner & Schmidt, 2006; Raghunathan & Pham, 1999). We found no evidence for generally impaired decision-making in a sample of SP participants compared to HC. However, previous studies found associations between *trait anxiety* and risky decision-making. In contrast to specific phobia that implicates anxiety in regard to a specific stimulus, trait anxiety may have a stronger capacity to impair general decision-making processes as it is defined as a "*stable tendency to (…) report negative emotions (…) across many situations*" (Gidron, 2013, p. 1989), and as such, may relate to all aspects of life. This explanation fits the findings of Steinglass et al., 2017 showing no differences in delay discounting between participants with obsessive–compulsive disorder, social anxiety disorder and healthy participants, but a positive association between trait anxiety and a preference for delayed rewards across the whole sample (including additionally patients with anorexia nervosa). Moreover, to our best knowledge, this is the first study investigating components (processing of choice attributes, being cautious during decision-making) of the decision-making process in SP participants. With this approach we investigate decision-making in more detail than classical delay discounting paradigms assuming that the option with the longer distance and larger reward is always the best option.

In the presence of the spider, SP participants made fewer optimal choices than HC. This is in line with prior studies, showing participants with SP avoid advantageous decisions when these were paired with a spider stimuli, resulting in significant costs (Pittig, Schulz, et al., 2014). In addition, we found that SP participants showed distinct changes in both their drift rate and in their boundary when the spider was present, as compared to HC. This helps to pinpoint the decision processes that led to impaired decision-making. Specifically, SP participants' drift rate was highly sensitive to the presence of the spider, leading to a severely decreased drift rate when the spider was at the optimal decision option. This means that the presence of the spider disrupts the ability to process the decision options' attributes and hence impairs the ability to identify the optimal choice option. There are several possible explanations for this finding. First, this might be caused by SP participants' avoidance of the fear-related stimulus. This interpretation would be in line with a study also finding SP participants to avoid spider cues in a card sorting test (Mohlman et al., 2004). Second, SP participants might perceive the spider as an acute threat, which may impair cognitive information processing, e.g. due to a freezing reaction (cf. Hamm, 2020; Livermore et al., 2021). Specifically, the presence of the spider may activate more conditioned responses of neural areas such as the amygdala and may slow down responses of the prefrontal cortex, responsible also for decision-making processes (Arnsten, 2009). Third, the presence of the spider may trigger dysregulation in attention characterized by fluctuations between attentional bias towards the spider (motivated by the urge to control it) followed by attentional bias away (motivated by efforts to downregulate negative emotions elicited through exposure) (Zvielli et al., 2015). SP participants also showed an increase in their decision boundary when the spider stimulus was present, indicating that the presence of the spider made them more cautious. Interestingly, this was the case both when the spider was at the optimal option and when it was at the nonoptimal option. Hence, in contrast to the drift rate results discussed above, the presence of a fear-related stimulus seems to lead to a general tendency towards more hesitant and cautious decision-making, independent of which decision option is affected by the stimulus and which choice participants make. Exploratory analyses of the non-decision time did not reveal any effects. This implies that the presence of the fear-related stimulus did not lead to a general delay in sensory processing or motor execution and supports our interpretation that SP participants make fewer optimal choices in the presence of a fear-related stimulus because their ability to identify the optimal choice option is impaired, both due to an impaired ability to process the choice

options and an overly cautious decision style. In general, our findings align well with literature on costly and avoidant decision-making under threat conditions (e.g., Boschet et al., 2022; Hulsman et al., 2021; Pittig et al., 2021; Pittig & Scherbaum, 2020; Wong & Pittig, 2022), which is given in SP participants in the presence of spiders.

Interestingly, we observed reserved effects in HC. Here, the presence of the spider improved decision-making. The drift diffusion analysis revealed that the drift rate was increased when the spider was positioned at the optimal decision, and decreased when the spider was positioned at the nonoptimal decision. This might be due to an attention capture effect that leads to more attention (and therefore faster processing of the choice attributes) on the option with the spider. Similarly to SP participants, HC were also more cautious when the spider was at the optimal option, as indicated by a higher boundary.

Our findings may have important practical implications. First, it may explain to some extent psychological burden and negative consequences of SP for individuals. For example, while driving, SP individuals might not be able to find the optimal decision when they are confronted with a spider moving over the windshield (i.e., calmly driving the car to a safe place to remove the spider instead of stopping the car immediately and leaving it). Second, usually, during exposure therapy, patients are required to make numerous small decisions regarding the next steps, i.e. "do you want to come a little bit closer?". Approaching the spider is the basis for inhibitory learning, which leads to reduced symptoms in the long run (Craske et al., 2022). Practical experiences show that some patients have problems to make these decisions and find the optimal decision, i.e. showing approach behavior towards the feared stimulus. Further research may test whether it may help to decide before the exposure starts about each step that will be part of the exposure exercise. It might be important to have a good handling of any failure by an adaption of the steps in the next trial of exposure. Third, our drift diffusion model analyses raise interesting questions about how therapy can improve decision-making in SP individuals. Our results imply that SP individuals are generally more cautious in their decisions when a fear-related stimulus is present, and that their ability to identify and process the optimal option is impaired by the fear-related stimulus. In light of these findings, it would be interesting to investigate if therapy has different effects on these decision-making parameters. For example, one might speculate that successful exposure therapy might improve the ability to identify the optimal option as individuals' ability to tolerate the fear-related stimulus increases (i.e. maladaptive avoidance decreases), but their caution in the presence of fear-related stimuli might remain. This could have implications for short-term and long-term therapy success and provide indications for further optimization of exposure treatments including relapse prevention (Craske et al., 2022).

Unexpectedly, we found that the non-phobic stimuli also influenced the decision-making process and improved decision-making. Crucially, this was true for both groups, again indicating that SP individuals do not show general impairments in decision-making. For the HC group, the effect of the non-phobic stimulus was weaker than the effect of the phobic stimulus, suggesting spiders to be a more salient stimuli than a turtle, potentially due to their evolutionary significance (Berdica et al., 2018; LoBue, 2010; Seligman, 1971; Vromen et al., 2016).

Our study has some limitations. First, generalizability to other anxiety disorders might be limited. While we believe that SP is a reasonable prototype for specific phobia and expect our findings to hold for other types of specific phobia, there are differences between specific phobia and other anxiety disorders in terms of phenomenology and etiopathogenesis that need to be considered. Second, our findings should be replicated in a more real-life setting as spiders are agents that are able to move freely – a fact that we did not represent in our decision-making game. Third, due to feasibility restrictions, we applied a between-subjects design for assessing decision-making processes and presented either a phobia version using fear-related stimuli or a non-phobic version; a within-subjects design would offer a more rigorous test. In addition, the study was powered for a two-factorial design instead of the three-factorial design analyzed here. Third, it has to be noted that our paradigm confounds time and effort. This is because the further participants have to move their avatar, the more effort (in the form of mouse clicks) they have to invest. Therefore, one could argue that instead of reward-time trade-offs, participants engaged in reward-effort trade-offs. Future research is necessary to disentangle time and effort. This also raises the question whether what we define as optimal choices based on reward-time trade-offs are truly optimal choices, because what constitutes an optimal choice for a specific individual might be influenced by other factors (e.g., motivation, effort). However, as participants chose the option that our model declared as "optimal" in a large percentage of trials and optimal choices were made faster on average than nonoptimal choices, we argue that this supports our optimal choice model (regardless if reward and time or reward and effort were traded off).

In conclusion, our study suggests no impaired general decision-making process in individuals with specific phobia compared to healthy controls, but a strong impairment in decision-making in the presence of a fear-related stimulus. Further improving knowledge about the underlying processes of maladaptive avoidance has the potential to improve interventions. We hope that our findings may help to illuminate the understanding of the role of decision-making in the development and maintenance of specific phobia.

CRediT authorship contribution statement

Ulrike Senftleben: Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation. **Esther Seidl:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Data curation, Conceptualization. **Lieselotte Leonhardt:** Writing – review & editing, Investigation, Data curation. **Kevin Hilbert:** Writing – review & editing, Investigation, Conceptualization. **Stefan Scherbaum:** Writing – review & editing, Supervision, Methodology, Formal analysis. **Markus Muehlhan:** Writing – review & editing, Funding acquisition, Conceptualization. **Katja Beesdo-Baum:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Judith Schäfer:** Writing – review & editing, Writing – original draft, Project administration, Investigation.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2025.104688.

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