

RESEARCH ARTICLE

Biophobia: A Hidden Dimension of Human-Nature Relationships



Threatening stimuli have differential effects on movement preparation and execution—A study on snake fear

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Abstract

1. How people experience nature influences their attitudes and actions towards it. Having had a negative encounter with an animal may facilitate avoidance and freezing responses which may encourage negative feelings towards it and the environment in which it is found. Animals associated with fear, such as snakes, are often the victims of hunting and killing, possibly in part due to an overperception of their inherent danger.
2. Past research has shown that fear affects approach-avoidance response at both the preparatory and executive stages of movement. However, the way one reacts to different threats may also depend on its proximity and how fearful one is of that specific threat.
3. We employed a mouse-tracking paradigm where participants ($N=40$) categorized pictures of threatening and non-threatening animals (snakes and butterflies respectively). The picture could appear at the middle, top or bottom of the screen. Participants initiated the movement from the centre of the screen and the category labels appeared on the top of the screen. Participants therefore had to either move towards the picture on the top or move away from the picture (presented centrally or at the bottom). Participants were split into fearful and non-fearful groups based on self-report snake fear.
4. Non-fearful participants were generally slower when a threat was present. But, in the fearful group, we found longer movement initiation times for central threats and shorter initiation times for off-centre threats (compared to neutral targets). Fearful participants were also slower to initiate movement when moving away from the threat, but faster when moving towards it (compared to neutral targets). The slower start and execution may be due to the lack of active planning and/or may imply the presence of a passive temporary freezing response.
5. Strong negative emotions towards nature and animals serve as crucial factors both in animal phobias and anti-animal behaviours (i.e. the purposeful decimation of certain species). Understanding the action dynamics of approach-avoid behaviours in response to threatening animals may help to inform both

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the prevention and treatment of phobias, and relatedly, the promotion of conservationist endeavours.

KEYWORDS

approach–avoidance, biophobia, categorization, fear, mouse tracking, movement programming, snake phobia

1 | INTRODUCTION

People's experiences with nature influence their relationship with it and actions towards it. Pleasant experiences can lead to increased environmental responsibility and connection to nature (Berenguer et al., 2005; Engemann et al., 2019; Rosa et al., 2019). In contrast, people can also experience strong negative emotions, such as fear and disgust, towards nature—termed *biophobia*, which are crucial factors in the aetiology and maintenance of specific phobias, such as *ophidiophobia*, the fear of snakes (Åhs et al., 2011; LeDoux & Daw, 2018; Matchett & Davey, 1991; Polák et al., 2020). Prevalence of animal phobia is the most prevalent form of specific phobia (Wardenaar et al., 2017), with a cross-national average lifetime prevalence of 3.8% (range: 1.4%–8.1%, though this is likely an underestimation; Zimmerman et al., 2010). Negative emotions towards animals (and in a more generic sense biophobia) may reduce conservationist attitudes and pro-environmental behaviour. Indeed, conservation efforts and substantial financial support primarily go to species that are perceived as visually attractive (Frynta et al., 2010; Landová, Bakhshaliyeva, et al., 2018; Marešová & Frynta, 2008), while animals associated with negative emotions (e.g. fear, disgust) are often the victims of systematic hunting and killing (Yorek, 2009; Zsido et al., 2022). According to the International Union for Conservation of Nature and Natural Resources Red List of Threatened Species, 12% of the assessed snake species are threatened and their populations declining. Several studies from various countries across the globe (e.g. Brazil, Turkey, Slovakia, and the United States) found that the majority of young adults do not like snakes (Alves et al., 2012; Prokop et al., 2009; Yorek, 2009). People are generally okay with the idea that snakes should be killed and their skins used to make shoes, wallets and belts. The perception of other reptiles is similar, which is even more striking when considering that many children (aged 7–14 years) across the globe like snakes and want to see them protected (Ballouard et al., 2013). Therefore, understanding the mechanisms by which people acquire and maintain animal fears and phobias is key to informing efforts at prevention and treatment, and ultimately, the promotion of conservationist endeavours.

Threatening stimuli, like snakes and spiders, processed in a preferential manner, possibly due to the existence of innate neural defensive circuits (LeDoux, 2022; LeDoux & Daw, 2018). For example, in visual search tasks, people are quicker to find task-relevant threats (than neutral or positive alternatives; Kawai & Qiu, 2020; March et al., 2017; Purkis & Lipp, 2007; Zsido, Deak, et al., 2018) and find it harder to ignore task-irrelevant threats (than neutral

or positive alternatives) because threat tends to draw and hold attention (Bretherton et al., 2017; Burra et al., 2019; Zinchenko et al., 2017; Zsido et al., 2021). Threats are detected and identified accurately even under cognitively demanding circumstances (Gao & Jia, 2017; Gao et al., 2017; Liddell et al., 2005; March et al., 2022). Threatening objects also claim greater attentional resources, inhibiting other processes and ongoing actions—such as solving a task, trying to remember something or starting and executing movement (Buodo et al., 2002; Gokce et al., 2021; Holmes et al., 2014; Lindström & Bohlin, 2012). The visual system is especially vulnerable to the interference of threats, especially if that threat is one that the individual has an acute fear of—for example, a snake-phobic person seeing a snake (Cisler et al., 2007; Gerdes et al., 2008; Pflugshaupt et al., 2005; Pissiota et al., 2003).

Recent research on threat processing has begun exploring mechanisms underlying approach–avoidance responses—such as fight or flight—to threats. All animals, humans included, rely on past experiences to predict future events and use models based on past experience to take action when presented with new related situations. The cognitive system then adjusts future predictions and models based on the success of previous outcomes. This action–perception cycle (Fuster, 2004; Williams et al., 2020) is one example of the connection between attention (e.g. detecting a threat) and movement dynamics (e.g. planning and execution of a behavioural response). The presence of a threat also impacts movement programming (Blakemore & Vuilleumier, 2017), for example, by activating a defensive preparatory state, termed *freezing* (Gladwin et al., 2016), or promoting *avoidance* in movement execution (Buetti et al., 2012). Both freezing and avoidance proved adaptive in the evolutionary past and are still present to help the organism appraise the danger, prepare the defensive response and execute the movement quickly (Blakemore & Vuilleumier, 2017; Bradley et al., 2001; Klaassen et al., 2021; Löw et al., 2015). A body of recent research has argued that the mere perception of a threat may cause a temporary halt in any ongoing movement (i.e. freezing) that in some cases causes a slower reaction time—that is, delayed avoidance, presumably because the threat automatically draws attentional and cognitive resources (Battaglia et al., 2021; Borgomaneri et al., 2015; Cao & Liu, 2021; de Houwer & Tibboel, 2010; Liu et al., 2017; Mancini et al., 2020; Mirabella, 2018). The freezing response is adaptive because it can help hide the prey from a threat via reduced visibility (due to the lack of movement) and/or help in preparing for the subsequent escape from the threat by giving the cognitive system some extra time to assess the environment and prepare for the following movements

(Gladwin et al., 2016; Rösler & Gamer, 2019). In such cases, attention to the threat captured automatically, and that capture can vary as a function of the imminence of the threat. Indeed, threats moving towards the person, that are close to them or that are close to the focus of attention have been shown to be particularly arresting (Arnaudova et al., 2017). A temporary freezing response would therefore presumably be more pronounced to images presented closer than further to the centre of attention.

Based on past studies directly observing approach and avoidance behaviour, we would also expect to find that movement initiation times are faster when moving away from a threat than when moving towards them (Garcia-Guerrero et al., 2022). A study exploring approach and avoidance responses used a modification of the Go-NoGo task utilized for a touchscreen device (Rinck et al., 2021). Participants placed their hand on a given spot on the screen. On NoGo trials (signalled by a butterfly), they did not move their hand. On Go trials (signalled by a spider or a leaf), they had to 'grab' and 'drag' the appearing picture either away from (*avoidance*) or towards themselves (*approach*). Threat-related (spider) pictures resulted in slower movement initiation and 'grabbing' times compared to neutral (butterfly) stimuli, and this pattern was more pronounced for spider-fearful than non-fearful participants. The authors suggest these patterns reflect avoidance behaviour. The longer RTs may also signal temporary motor freezing. In another recent study (March et al., 2021), participants had to make speeded categorization of facial targets in a mouse-tracking paradigm. After participants clicked on a start button at the bottom of the screen, a picture of the face of a person appeared in the middle. The task was to categorize the faces by moving the mouse to one of the prepositioned labels (i.e. calm or dangerous) and clicking on them as quickly as possible. The results showed that the initiation time for the categorization of faces that people perceived as dangerous (i.e. angry faces) was faster compared to other faces. Other work has used this method to assess animal phobias (Teachman et al., 2001; Teachman & Woody, 2003), showing quicker categorization of a feared object as dangerous among fearful than non-fearful individuals. In a previous study (Lebowitz et al., 2015), avoidance was indexed by measuring the time a participant-controlled avatar remained close to a threat (spider). Relative to a threatening object, people both approached a neutral object more closely and spent more time in its proximity. This was more pronounced for fearful compared to non-fearful participants. Across all this work, individuals' initial reaction speed often varies depending on the goal of the movement; that is, whether they need to approach or move away from a threat. When they need to approach a threat, people may temporarily freeze, slowing initiation. Alternatively, avoidance of a threat tends to be initiated quickly. What is clear is that the location of the threat relative to the perceiver helps determine the type of defensive behaviour that maximizes the possibility of escaping the situation unharmed (Blanchard et al., 1990; Coelho et al., 2022; Kozłowska et al., 2015; Qi et al., 2018).

In the current investigation, our main goal was to test how threat-relevant stimuli affect movement preparation and execution as a function of (1) the direction of the movement relative to the threat (towards or away) and (2) individual differences in the threat

relevance of the specific object. For this purpose, we utilized a novel categorization task with mouse tracking (Borkar & Fadok, 2021; Garcia-Guerrero et al., 2022; March et al., 2021). On every trial, a picture appeared either centrally (middle of the screen) or off-centre (top or bottom of the screen) from the starting point; category labels always appeared on the top of the screen (see Figure 1). Participants were tasked with simply categorizing the object as safe or dangerous. Participants experienced three types of trials: they either had to approach or move away from a threat presented parafoveally (top and bottom positions respectively) or move away from a threat presented centrally (middle position). This was a manipulation adopted from the human translation of the Mouse Defense Test Battery (Blanchard, 2017; Blanchard et al., 2003) and previous studies utilizing computer game protocols (Mobbs et al., 2007; Perkins et al., 2009, 2013). Perceived distance of visual objects largely depends on the visual angle of presentation, spatial frequency and size of retinal projection (Loftus & Harley, 2005; Murray et al., 2006; Song et al., 2021). That is, targets presented centrally appear closer compared to those presented parafoveally (e.g. the top or bottom positions). Furthermore, previous studies suggest that using the computer mouse extends people's representation of their peripersonal space (Bassolino et al., 2010). Consequently, as participants initiated the movement from the centre of the screen and the category labels appeared on the top of the screen, they either had to (1) move towards the picture on the top or (2) move away from the picture that was presented centrally or at the bottom of the screen. Figure 1 shows the possible positions and related movement directions. The middle condition (starting from the picture) was designated to simulate an imminent threat, while the top and bottom conditions were designed to simulate more proximal threats. This design allowed us to test movement initiation and execution effects when (a) moving away from a close or distant threat and (b) moving towards a distant threat.

Our first hypothesis was that movement initiation time would (1) be the longest when participants have to initiate movement from near to the threatening picture (i.e. the centrally presented condition), (2) be shorter when forced to move towards a threat and (3) be the shortest when moving away from a threat. Our second hypothesis was that movement execution (i.e. total reaction time) will be faster when participants move away from a threat than when they initiate movement from or have to move towards the threat. We also expected these effects to be larger in the fearful compared to the non-fearful group.

2 | METHODS

2.1 | Participants

We conducted an a priori power analysis using G*Power (Faul et al., 2007) to test for mixed-design analyses of variance (within-between interaction) with 6 (2×3) correlated repeated measures ($r=0.5$) and two groups (high and low fearful). The analysis, based on



FIGURE 1 Panel (a) shows the trial structure of the paradigm used. First, a fixation cross was shown. Once participants clicked the fixation, a picture appeared. The picture could appear at three possible locations (see panel b). Participants categorized the stimulus by moving the mouse to click one of the two labels. (Note that the pictures had been slightly resized for demonstrative purposes.)

previous studies on threat categorization (Huijding & de Jong, 2007; March et al., 2021; Teachman & Woody, 2003), indicated a required total minimum sample size of 28 with a conservative approach ($f=0.25$, $1-\beta=0.95$). We collected data from 40 undergraduate students at the university in which the data were collected. They were split into two groups (nonfearful and fearful) based on self-report questionnaire scores (Snake Questionnaire—SNAQ, see below). There were 20 participants in both groups (SNAQ score $M=1.2$ for the nonfearful and $M=5.7$ for the fearful group). The majority of the participants identified as female (72%). Their mean age was 21.1 ($SD=2.16$). Participants primarily identified as White (80%). The remaining participants either identified as Asian (15%) or more than one race (5%).

All participants reported normal or corrected-to-normal vision and intact colour vision, and none reported a history of neurocognitive disorder. Data from two participants were excluded due to failure to follow instructions. Research protocol was approved by

the Hungarian United Ethical Review Committee for Research in Psychology and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided written informed consent.

2.2 | Questionnaire

We assessed participants' fear of snakes using the short version of the Snake Questionnaire (SNAQ-12). The SNAQ-12 (Zsido, 2017; Zsido, Arato, et al., 2018) is a 12-item self-report measure of fear and phobia of snakes, consisting of one scale. Respondents answer by indicating whether statements are true or false and the score is given by the sum of 'true' responses (range 0–12). Higher scores indicate a higher level of fear of snakes. The McDonald's omega on the present sample was 0.85 indicating that questionnaire scores were reliable.

2.3 | Experimental design and stimuli

We used a novel categorization task with mouse-tracking similar to previous research investigating the effect of the presence of various threats to movement preparation and execution (Borkar & Fadok, 2021; Garcia-Guerrero et al., 2022; March et al., 2021). In the present study, each experimental block started with the two labels ('Snake' and 'Butterfly') appearing at the top right and left corners of the screen respectively. The labels were present throughout the block. To begin a trial, participants clicked the fixation cross appearing in the centre of the screen which was replaced with a picture that could appear at three possible locations. See Figure 1 for the trial structure of the paradigm used and the three possible positions for the picture. The picture to be categorized (target picture) was threatening (various snakes) or non-threatening (butterflies). Participants categorized the stimulus by moving the mouse to click one of the two labels. An important change in our study relative to previous ones using categorization tasks concerns the location of our targets. Specifically, possible locations of the target picture were the bottom, middle or top of the screen vertically, while they were always centred horizontally. This resulted in a $2 \times 3 \times 2$ design with the target (snake or butterfly) and the place of the picture (bottom, middle or top) as within-subject factors, and snake fear (fearful and nonfearful) as a between-subject factor. Participants completed three experimental blocks in randomized order. The place of the target picture was manipulated between blocks; that is, the place of the picture did not change within the experimental blocks. Each block started with 40 practice trials (which were not analysed) that mirrored the experimental trials (e.g. if targets were to appear at the top of the picture, that was also the case for practice trials). This was followed by three blocks, each containing 96 experimental trials. Participants always received feedback on whether their answer was correct or not; trials with incorrect responses were not analysed. After each experimental block, the category labels presented in the top corners changed sides; participants saw a warning message about this before starting a new block.

All pictures used were taken from the Affective Standardized Set of Animal Images (ASSAI) picture database (Grimaldos et al., 2021). The pictures were resized to the same size maintaining the original proportions.

2.4 | Apparatus and procedure

Stimuli were presented on 23-inch TFT colour monitors, with a resolution of 1920×1080 , 16:9 aspect ratio, a refresh rate of 60 Hz and a colour depth of 16.7M. We used the PsychoPy Software v3.0 for Windows (Peirce, 2007) to present the stimuli and to collect responses from participants. Behavioural responses were recorded via the mouse of the computer.

Data were collected in groups of up to 8 on individual computer stations. The study was conducted in dim and quiet rooms. Participants were seated at a distance of approximately 60 cm

from the monitor. Participants received both oral and written task instructions.

Each trial started with a white fixation cross on white background appearing for 500 ms. After clicking the fixation, a target picture appeared; the labels were presented throughout the entire experimental block. Participants were instructed to categorize the pictures as quickly and accurately as possible and move mouse to click on the correct label. Participants were allowed to take a short break between the blocks if they felt it was necessary. One session of data collection lasted about 30 min.

2.5 | Statistical analysis

Statistical analyses were performed using the JAMOVI Statistics Program version 2.0 for Windows (Jamovi Project, 2022). We first identified and removed outlier trials, defined as those greater than ± 2 standard deviations of the group mean separately for initiation and movement time (resulting in the removal of less than 1% of all the collected data). We then checked to ensure that the distribution of the variables did not deviate significantly from a normal distribution (Shapiro-Wilk test $p > 0.05$).

Participants were split into two groups based on their SNAQ-12 scores using the median split procedure. We decided to use this method instead of entering SNAQ-12 as a continuous variable into the analysis to facilitate analytic and communication clarity, and because the median split procedure is more parsimonious (Iacobucci et al., 2015).

Our behavioural measures included examining RTs (in seconds) for the time needed to initiate the movement, and the total movement time to reach the target. The main effect and interactions are reported separately. Movement initiation and execution times were analysed separately. In both cases, we used $2 \times 3 \times 2$ mixed-design analysis of variances with the target (snake, butterfly) and place of the picture (bottom, middle, top) as within-subject factors, and group (fearful, nonfearful) as the between-subject factor. These findings are supplemented with relevant follow-up ANOVAs or *t*-tests to further decompose significant interaction effects. Effect sizes are presented as partial eta squared (η_p^2) for the ANOVAs. Tukey corrections were used to account for multiple comparisons. Statistical results will be presented in tables to make the description of the results easier to follow. The dataset that includes computed study variables is available on the Open Science Framework: <https://osf.io/zrbq5>.

3 | RESULTS

3.1 | Initiation time

We began by examining initiation time to test our prediction that movement preparation time will be longer when participants have to initiate the movement from the threatening picture (i.e. centrally

located stimuli), be shorter when they move towards a threat and be shortest when moving away from a threat. This is tested by the two-way interaction between target and place. See Table 1 for all statistical results, and Table S1 for the descriptive statistics. We found a significant interaction between target and place showing a slight difference in the neutral and threatening target conditions. If the target was threatening, participants initiated movements faster moving towards it (picture at the top) than when moving away from it (picture at the bottom and centre). Specifically, participants were slowest to initiate movement when the stimuli appeared at

the bottom of the screen, somewhat faster to initiate movement when the picture appeared in the middle and the fastest to initiate movement when the target appeared at the top of the screen. For neutral targets, initiation times were faster moving away from the off-centre picture (at the bottom) compared to starting from the picture or moving towards it. In line with our hypothesis, participants initiated movements faster when a threatening versus neutral picture appeared off-centre.

We also expected these effects to be more pronounced in the fearful than nonfearful group. This is tested by the three-way

TABLE 1 Detailed statistical results for movement initiation time with main effects, interactions, follow-up ANOVAs, and pairwise comparisons.

Initiation	<i>df</i>	<i>F</i>	<i>p</i>	η^2_p		
Target	1, 36	1.802	0.188	0.048		
Place	2, 72	19.543	<0.001	0.352		
	Pairwise comparison			<i>df</i>	<i>t</i>	<i>p</i>_{tukey}
	Bottom	–	Middle	36	3.04	0.012
		–	Top	36	6.31	<0.001
	Middle	–	Top	36	3.21	0.008
Group	1, 36	0.751	0.392	0.020		
Target * Group	1, 36	0.170	0.683	0.005		
Place * Group	2, 72	0.176	0.839	0.005		
Target * Place	2, 72	3.610	0.032	0.091		
Snake	2, 72	10.90	<0.001	0.223		
Butterfly	2, 72	13.50	<0.001	0.263		
	Pairwise comparison			<i>df</i>	<i>t</i>	<i>p</i>_{tukey}
	Snake	Bottom	Middle	36	1.269	0.799
			Top	36	4.314	0.002
		Middle	Top	36	3.601	0.011
	Butterfly	Bottom	Middle	36	3.515	0.014
			Top	36	6.028	<0.001
		Middle	Top	36	1.942	0.394
Target * Place * Group	2, 72	3.687	0.030	0.093		
Nonfearful group		<i>df</i>	<i>F</i>	<i>p</i>	η^2_p	
	Target	1, 19	1.5629	0.226	0.076	
	Place	2, 38	9.7152	<0.001	0.338	
	Target * Place	2, 38	0.0286	0.972	0.002	
Fearful group		<i>df</i>	<i>F</i>	<i>p</i>	η^2_p	
	Target	1, 17	0.817	0.379	0.046	
	Place	2, 34	10.647	<0.001	0.385	
	Target * Place	2, 34	4.606	0.017	0.213	
	Pairwise comparison			<i>df</i>	<i>t</i>	<i>p</i>_{tukey}
	Snake	Bottom	Middle	17	-0.116	1.000
			Top	17	2.205	0.099
		Middle	Top	17	2.576	0.049
	Butterfly	Bottom	Middle	17	3.474	0.029
			Top	17	4.500	0.004
		Middle	Top	17	0.399	0.998

interaction between target, place, and group, which was significant. Figure 2 shows the three-way interaction. There was no two-way interaction in the *Nonfearful* participants group. These participants were slowest to start the movement when the picture appeared off-centre and they had to move away from it (bottom of the screen), they were faster when the picture appeared in the middle and the fastest when they had to approach the target—regardless of the type of target.

While the main effects were similar in the *Fearful group*, the interaction between target and place was significant. For *neutral targets*, fearful participants initiated movements slower when the picture appeared at the bottom compared to when it was in the middle or top positions, while the latter two did not differ from each other. For *threatening targets*, the place effect was different: Participants initiated movement faster when the picture appeared at the top compared to when it was in the middle position, while movement initiation to the top and bottom positions and bottom and middle positions did not differ from each other.

The main effect of the group and the target×group interaction were nonsignificant. The place×group interaction was also nonsignificant.

In line with our hypothesis, the initial reaction of snake-fearful versus nonfearful participants was more pronounced, and in line with our prediction, snake-fearful participants initiated movements slower when beginning the movement from the snake picture (and had to move away from the snake) compared to butterflies. Their initiation time was shorter for snakes compared to butterflies when the picture was presented parafoveally compared to when it was presented foveally. However, in contrast to our expectation, fearful participants showed the shortest initiation times when they had to approach the threat.

3.2 | Movement time

We then examined movement execution time to test our hypothesis that total movement times will be faster when participants are moving away from a threat (bottom) compared to when they initiate the movement from the threatening picture (centre) or have to move towards it (top). This is tested by the two-way interaction between target and place. The interaction between target and place was nonsignificant, but the main effect

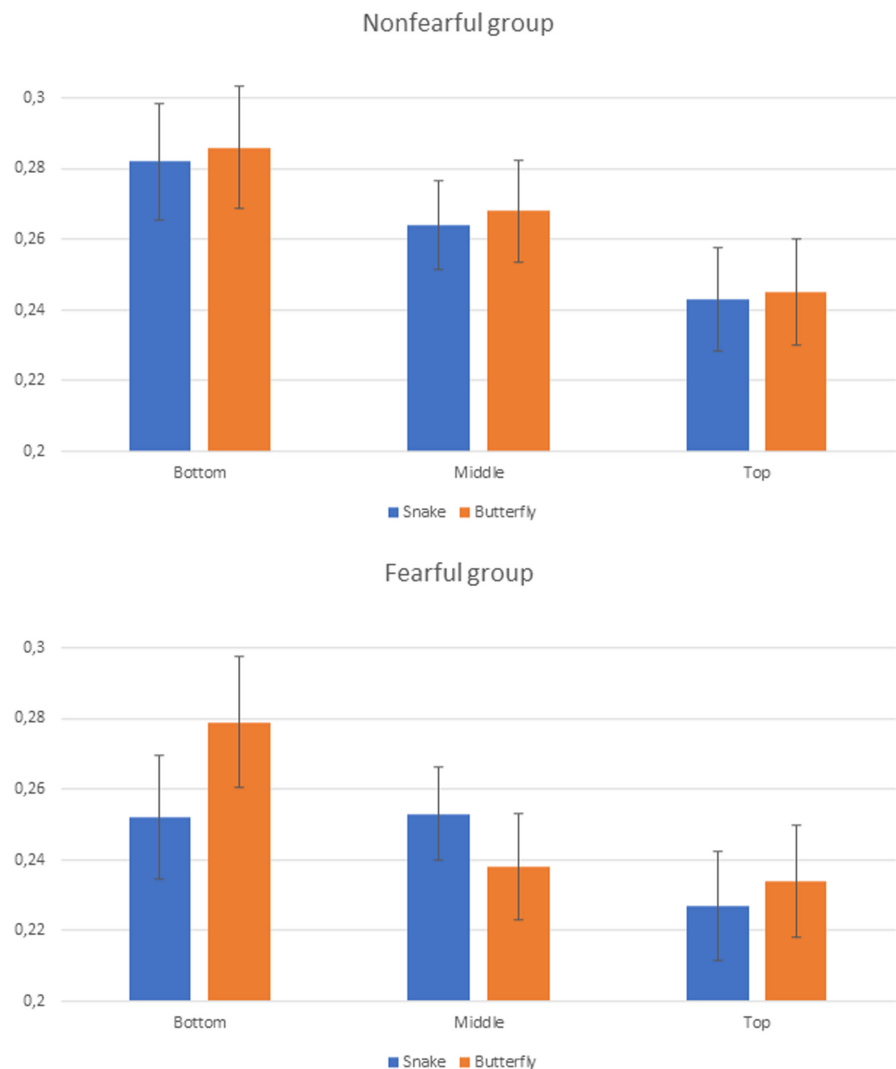


FIGURE 2 Movement initiation times (in seconds) are presented across the place of the picture using separate bars for the target type and separate panels for group. Error bars represent 95% confidence intervals.

of place was significant. In line with our hypothesis, movement times were shorter when participants moved away from the target (picture appeared on the bottom) compared to when they started from it (middle) or moved towards it (top). However, this pattern was not unique to threats. See Table 2 for all statistical results and Table S1 for the descriptive statistics.

We also expected these results to be more pronounced in the fearful compared to the nonfearful group. This is tested by the three-way interaction between target, place and group, which was significant. Figure 3 shows the three-way interaction. *Nonfearful* participants' movement times were generally slower when categorizing *threats* compared to *neutral targets* as evidenced by the target main effect. This was true regardless of the place of the targets. In contrast, in the *Fearful* group, the interaction between target and place was significant. For *neutral targets*, the movement times of fearful participants were slower when the picture appeared in the middle and top positions compared to the bottom position. The

middle and top positions did not differ. For *threats*, the movement times of fearful participants were slower when the picture appeared in the middle compared to the bottom position, while the difference between middle–top and bottom–top was not significant.

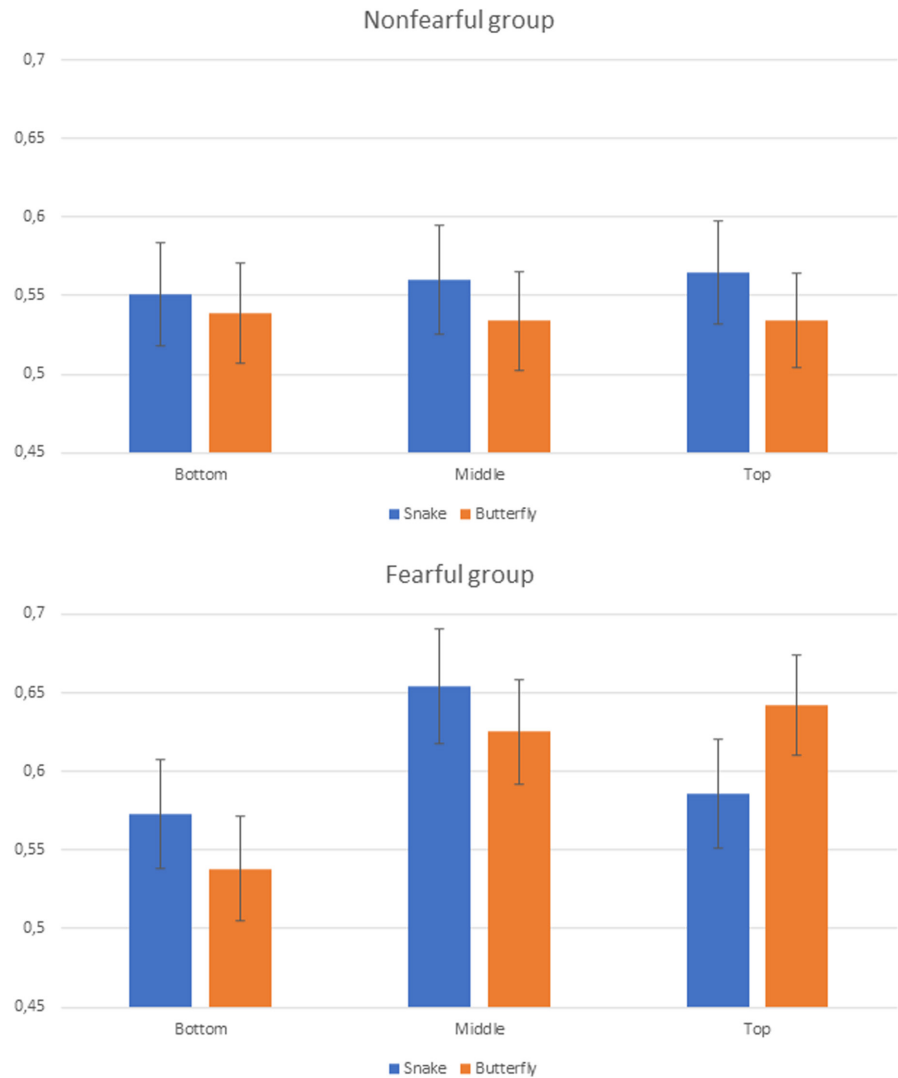
The main effect of target, the group and the target \times group interaction was nonsignificant. The place \times group interaction was also significant meaning that the place effect was only evident in the fearful but not in the nonfearful group.

Again, we found evidence that the reaction of snake-fearful participants was more pronounced compared to nonfearful participants. However, contrary to our prediction, movement execution time in the fearful group was slower on trials when they began the movement from a threat (compared to a neutral target) and had to move away from the snake. This was also true on trials when participants moved away from a threat presented off-centre (bottom). Fearful participants were faster moving towards a threat compared to trials with neutral pictures.

TABLE 2 Detailed statistical results for movement execution time with main effects, interactions, follow-up ANOVAs and pairwise comparisons.

Movement	df	F	p	η^2_p		
Target	1, 36	3.79	0.060	0.095		
Place	2, 72	6.03	0.004	0.143		
	Pairwise comparison			df	t	p_{tukey}
	Bottom	–	Middle	36	3.13	0.009
		–	Top	36	2.94	0.015
	Middle	–	Top	36	0.834	0.685
Group	1, 36	1.720	0.198	0.046		
Target * Group	1, 36	2.46	0.125	0.064		
Place * Group	2, 72	5.20	0.008	0.126		
<i>Nonfearful</i>	2, 34	8.72	<0.001	0.0339		
<i>Fearful</i>	2, 38	0.04	0.959	0.002		
Target * Place	2, 72	2.89	0.062	0.074		
Target * Place * Group	2, 72	5.24	0.008	0.127		
Nonfearful group	df	F	p	η^2_p		
Target	1, 19	11.6075	0.003	0.379		
Place	2, 38	0.0419	0.959	0.002		
Target * Place	2, 38	0.7080	0.499	0.036		
Fearful group	df	F	p	η^2_p		
Target	1, 17	0.0450	0.835	0.003		
Place	2, 34	8.7219	<0.001	0.339		
Target * Place	2, 34	4.6212	0.017	0.214		
	Pairwise comparison			df	t	p_{tukey}
	Snake	Bottom	Middle	17	-2.587	0.048
			Top	17	-0.599	0.822
		Middle	Top	17	1.971	0.150
	Butterfly	Bottom	Middle	17	-3.313	0.011
			Top	17	-4.984	<0.001
		Middle	Top	17	-0.845	0.681

FIGURE 3 Movement times (in seconds) are presented across the place of the picture using separate bars for target type and separate panels for group. Error bars represent 95% confidence intervals.



4 | DISCUSSION

The main goal of the defensive system is to help avoid threatening objects and situations (LeDoux & Daw, 2018). Thus, fear affects movement (Blakemore & Vuilleumier, 2017), sometimes causing temporary freezing or initiating avoidance depending on the distance and properties of the threat (Arnaudova et al., 2017; Gladwin et al., 2016; Gross & Canteras, 2012; Mobbs & Kim, 2015). Thus, in the present investigation, we sought to test how threatening stimuli affect movement preparation and execution when moving towards, starting from or away from a threat and whether this reaction changes by personal level of fear. Our results showed that snake-fearful participants initiated movements faster when beginning the trial from a picture of a snake (i.e. moving from the snake) compared to butterflies and when moving away from a threat presented off-centre. Fearful participants were slower to execute movement from the snake compared to the butterfly, while they were faster to move away from the snake. This is in line with previous studies showing that fear affects movement both at the early (preparatory) and late (execution) stages (Blakemore & Vuilleumier, 2017; Buetti et al., 2012; Gladwin et al., 2016). The fact that effects were not

observed in nonfearful participants converges with previous studies showing that the interference of threats is more pronounced in more fearful and phobic individuals (Cisler et al., 2007; Gerdes et al., 2008; Pflugshaupt et al., 2005; Pissioti et al., 2003).

We found longer movement preparation times in snake-fearful participants when the movement was initiated from the snake picture. This is in line with previous studies showing that threats perceived as more imminent capture attention involuntarily (Arnaudova et al., 2017), and this could result in a temporary motor freezing (Battaglia et al., 2021; Borgomaneri et al., 2015). The freezing response—if active—can help potential prey when assessing the threat and preparing for subsequent movements (Gladwin et al., 2016; Rösler & Gamer, 2019). However, the relatively slow initiation times for centrally presented threats may be contextualized in light of previous studies examining pray–snake interactions (Coelho et al., 2019; Penning et al., 2016; Whitaker & Shine, 2000). When a snake is near the person, moving (e.g. running away) is often not beneficial (nor feasible) because the strike kinematics of snakes is so quick that people have no chance of avoiding the strike. In fact, the vast majority of snake bites happen when people do not detect the snake and make a quick movement within its striking range. So, a passive

state of freezing (tonic immobility) when close to a snake may be an adaptive response in such cases because the lack of movement may discourage the snake from carrying out the strike (Campbell et al., 1997; Coelho et al., 2019; Eilam, 2005). Furthermore, the initiation time was also shorter for snakes compared to butterflies when it was presented outside of foveal vision compared to when it was presented centrally. These results are in line with studies defining freezing as an active defensive preparatory state (Cao & Liu, 2021; Gladwin et al., 2016; Mancini et al., 2020; Rösler & Gamer, 2019).

However, in contrast to our expectation, fearful participants showed the shortest initiation times when they had to approach the threat. This was somewhat unexpected based on previous results showing that the defensive temporary freezing primarily occurs when the threat appears outside of foveal vision (Arnaudova et al., 2017; Battaglia et al., 2021; Borgomaneri et al., 2015; Gladwin et al., 2016). As previous studies showed, an escapable threat may cause active avoidance (Wendt et al., 2017). A study with rats (Blanchard et al., 1986) showed that in situations where there is a possibility to escape, the primary response is to run away. Participants might have perceived the threat at the top of the screen being further away from their peripersonal space compared to the one at the bottom (Bassolino et al., 2010), and thus, as a more controllable situation.

Deducing whether this response pattern was due to a passive or active freezing response requires considering the results of movement execution. Comparing threats at various positions, movement execution times were the slowest when the picture was presented centrally, in the foveal vision, and faster in the parafoveal, off-centre positions (regardless of movement direction). This is contradictory to our hypothesis that avoidance behaviour will be faster for distant threats and moving away from threats (Mobbs & Kim, 2015; Qi et al., 2018). For the centrally presented threats, slower initiation times were paired with slower movement times. This is in line with a study where participants had to grab and move the threatening picture appearing on a touchscreen device with their hands (Rinck et al., 2021). Taken together, this might point to a passive (rather than an active) temporary freezing response because the lack of active planning results in a slower execution, perhaps a sign of temporary tonic immobility (Kozłowska et al., 2015; Roelofs, 2017). Of course, since threats only appeared as pictures on the screen and not as real-life animals, a true tonic immobility response can hardly be expected; instead, the inhibition only hindered conscious movement execution instead of fully stopping it (Gross & Canteras, 2012). The slower movement time (paired with faster initiation time) when threat appearing at the bottom may imply that participants involuntarily started the movement (Gross & Canteras, 2012), and then had to plan the course of it during the execution phase (a common dynamic in mouse-tracking research (March & Gaertner, 2021)). In contrast, distant threats might seem more escapable and the situation controllable even if one has to move towards them, and thus, may cause an active avoidance, which has been evidenced as startle inhibition and heart rate acceleration (Wendt et al., 2017). Nevertheless, comparing our results to previous studies is difficult because our experimental design is novel in the sense that participants initiated

the movement 'from' the threat or farther away from it, and had to move both away from and towards a threat, instead of only moving away from it or grabbing it (Wendt et al., 2017), or shooting a threat (Gladwin et al., 2016). Taken together, future research is needed to understand what exactly fearful participants see as imminent. Such work could go beyond conventional stimuli presentation using technology, such as VR or AR, enabling the 3D representation of stimuli where the imminence of a threat can be manipulated.

We found evidence for defensive responses only in participants who reportedly feared the threatening target (i.e. snakes). While previous studies found significant effects of threat interference on movement regardless of fear (Cao & Liu, 2021; de Houwer & Tibboel, 2010; Gladwin et al., 2016; Rinck et al., 2021), then and now, results were more pronounced for participants who feared the stimulus or when the arousal level of the stimulus was higher (Cisler et al., 2007; Gerdes et al., 2008; Pflugshaupt et al., 2005; Pissioti et al., 2003). The discovery of such individual differences could be important in helping people overcome fears, as seen in attention modification training as a treatment for various phobias (Hakamata et al., 2010; Mogg & Bradley, 2018). Attenuating fears is important because avoidance is less typical in people with lower levels of fear (Frynta et al., 2010; Landová, Poláková, et al., 2018; Marešová & Frynta, 2008; Zsidó et al., 2022), and they are also more inclined to approach and experience positive affective responses when in proximity with nature (Hartmann & Apaolaza-Ibáñez, 2010; Joye & van den Berg, 2011).

Another implication of the current work regards attitudes towards animals both in terms of phobic fear and their presence in the environment. Animals, humans included, are thought to have neural networks—survival circuits—shaped by evolution, entailing innate physiological responses to the elements of nature tailored to help minimize the possibility of bodily harm and increase the chances of survival by, for instance, avoiding a natural predator or an organism that may cause harm (Gu et al., 2020; LeDoux, 2022). Within individuals, there are great differences in both the sensitivity of this circuit and the degree to which people perceive the harm potential of any given threat. Heightened sensitivity coupled with overperceiving the threat potential of specific objects may lead to enhanced fear and the acquisition (and later maintenance) of phobias (Mathews & Mackintosh, 1998; Mogg et al., 2000). Besides potential negative health consequences (Aquin et al., 2017; Witthauer et al., 2016), negative emotions towards animals (and in a more generic sense biophobia) reduce conservationist attitudes and pro-environmental behaviour. Due to the generally bad reputations in many regions of the world, the conservation of snakes and reptiles is more difficult than other vertebrate groups (Alves et al., 2012; Prokop et al., 2009; Yorek, 2009). In the end, understanding how animal-related fears and phobias are acquired and maintained could lead to the development of better prevention and treatment, and the promotion of conservationist endeavours. Consequently, future lines of research should focus on the effectiveness of preventive work and educational strategies that involve direct contact with snakes (and reptiles), exploring cognitive factors—such as emotion regulation strategies—that could be targeted in treatment to reduce fear levels

and existing phobia, and investigate the mechanisms of fear inoculation (Coelho et al., 2021) and habituation to these animals during safe and controlled exposure.

In sum, in line with prior work, we found evidence that the processing of threatening stimuli can affect action–perception dynamics at multiple stages of movement. Temporary freezing and faster avoidance were found in participants with relevant fears. Furthermore, we found that both the presentation centrality of the threat and the direction of personal movement are also important factors. Temporal freezing was observed for close threats. This is in line with evolutionary theories arguing that when the threat is perceived too late, and, consequently, it is close to the organism, the best option is tonic immobility waiting for the danger to pass. We observed quick movement times towards threats, which at first might seem contradictory, but if these threats are perceived escapable (which they were), and thus, the situation is more controllable, then movements will be more quickly executed. Future studies are necessary to determine whether physiological changes and reactions observed at the level of the central nervous system are also different in fearful and nonfearful participants.

From a broader perspective, it seems that by attenuating fears of certain animals, people may be less poised to interpret them as harmful and something to fight or destroy to make sure they will not be encountered in the future. Although this study focused only on snakes, it contributes to a better understanding of how animal fears can take hold of our decisions, behaviour and attitudes towards nature. Future work will be needed to determine whether the attenuation of fears may lead to more controlled behaviour, and thus, a more positive attitude towards animals and, in general, nature.

AUTHOR CONTRIBUTIONS

Andras N. Zsidó was involved in conceptualization; formal analysis; funding acquisition; investigation; methodology; project administration; supervision; validation; roles/writing—original draft; writing—review & editing; Orsolya Inhof was involved in investigation; methodology; roles/writing—original draft; writing—review & editing; Botond L. Kiss was involved in data curation; project administration; roles/writing—original draft; writing—review & editing; Cintia Bali was involved in data curation; roles/writing—original draft; writing—review & editing; David S. March was involved in conceptualization; supervision; roles/writing—original draft; writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data set that includes computed study variables is available on the Open Science Framework: <https://osf.io/zrbq5>.

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REFERENCES

- Åhs, F., Palmquist, Å. M., Pissioti, A., Appel, L., Frans, Ö., Liberzon, I., Furmark, T., & Fredrikson, M. (2011). Arousal modulation of memory and amygdala-parahippocampal connectivity: A PET-psychophysiology study in specific phobia. *Psychophysiology*, *48*(11), 1463–1469. <https://doi.org/10.1111/j.1469-8986.2011.01231.x>
- Alves, R. R. N., Vieira, K. S., Santana, G. G., Vieira, W. L. S., Almeida, W. O., Souto, W. M. S., Montenegro, P. F. G. P., & Pezzuti, J. C. B. (2012). A review on human attitudes towards reptiles in Brazil. In *Environmental monitoring and assessment* (Vol. 184, Issue 11, pp. 6877–6901). Springer. <https://doi.org/10.1007/s10661-011-2465-0>
- Aquin, J. P., El-Gabalawy, R., Sala, T., & Sareen, J. (2017). Anxiety disorders and general medical conditions: Current research and future directions. *Focus*, *15*(2), 173–181. <https://doi.org/10.1176/appi.focus.20160044>
- Arnudova, I., Kryptos, A.-M., Effting, M., Kindt, M., & Beckers, T. (2017). Moving threat: Attention and distance change interact in threat responding. *Emotion*, *17*, 251–258. <https://doi.org/10.1037/emo0000219>
- Ballouard, J. M., Ajtic, R., Balint, H., Brito, J. C., Crnobrnja-Isailovic, J., Desmots, D., Elmouden, E. H., Erdogan, M., Feriche, M., Pleguezuelos, J. M., Prokop, P., Sánchez, A., Santos, X., Slimani, T., Tomovic, L., Uşak, M., Zuffi, M., & Bonnet, X. (2013). Schoolchildren and one of the most unpopular animals: Are they ready to protect snakes? *Anthrozoös*, *26*(1), 93–109. <https://doi.org/10.2752/175303713X13534238631560>
- Bassolino, M., Serino, A., Ubaldi, S., & Ládavas, E. (2010). Everyday use of the computer mouse extends peripersonal space representation. *Neuropsychologia*, *48*(3), 803–811. <https://doi.org/10.1016/j.neuropsychologia.2009.11.009>
- Battaglia, S., Serio, G., Scarpazza, C., D'Ausilio, A., & Borgomaneri, S. (2021). Frozen in (e)motion: How reactive motor inhibition is influenced by the emotional content of stimuli in healthy and psychiatric populations. *Behaviour Research and Therapy*, *146*, 103963. <https://doi.org/10.1016/j.brat.2021.103963>
- Berenguer, J., Corraliza, J. A., & Martin, R. (2005). Rural-urban differences in environmental concern, attitudes, and actions. *European Journal of Psychological Assessment*, *21*(2), 128–138. <https://doi.org/10.1027/1015-5759.21.2.128>
- Blakemore, R. L., & Vuilleumier, P. (2017). An emotional call to action: Integrating affective neuroscience in models of motor control. *Emotion Review*, *9*(4), 299–309. <https://doi.org/10.1177/1754073916670020>
- Blanchard, D. C. (2017). Translating dynamic defense patterns from rodents to people. In *Neuroscience and biobehavioral reviews* (Vol. 76, pp. 22–28). Pergamon. <https://doi.org/10.1016/j.neubiorev.2016.11.001>
- Blanchard, D. C., Griebel, G., & Blanchard, R. J. (2003). The mouse defense test battery: Pharmacological and behavioral assays for anxiety and panic. *European Journal of Pharmacology*, *463*(1–3), 97–116. [https://doi.org/10.1016/S0014-2999\(03\)01276-7](https://doi.org/10.1016/S0014-2999(03)01276-7)
- Blanchard, R. J., Blanchard, D. C., Rodgers, J., & Weiss, S. M. (1990). The characterization and modelling of antipredator defensive behavior. *Neuroscience and Biobehavioral Reviews*, *14*(4), 463–472. [https://doi.org/10.1016/S0149-7634\(05\)80069-7](https://doi.org/10.1016/S0149-7634(05)80069-7)
- Blanchard, R. J., Flannelly, K. J., & Blanchard, D. C. (1986). Defensive behavior of laboratory and wild *Rattus norvegicus*. *Journal of*

- Comparative Psychology* (Washington, DC: 1983), 100(2), 101–107. <https://doi.org/10.1037/0735-7036.100.2.101>
- Borgomaneri, S., Vitale, F., & Avenanti, A. (2015). Early changes in corticospinal excitability when seeing fearful body expressions. *Scientific Reports*, 5(1), 1–9. <https://doi.org/10.1038/srep14122>
- Borkar, C. D., & Fadok, J. P. (2021). A novel pavlovian fear conditioning paradigm to study freezing and flight behavior. *Journal of Visualized Experiments*, 2021(167), 1–13. <https://doi.org/10.3791/61536>
- Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion*, 1(3), 276–298. <https://doi.org/10.1037/1528-3542.1.3.276>
- Bretherton, P. M., Eysenck, M. W., Richards, A., & Holmes, A. (2017). Target and distractor processing and the influence of load on the allocation of attention to task-irrelevant threat. *Neuropsychologia*, 145, 106491. <https://doi.org/10.1016/j.neuropsychologia.2017.09.009>
- Buetti, S., Juan, E., Rinck, M., & Kerzel, D. (2012). Affective states leak into movement execution: Automatic avoidance of threatening stimuli in fear of spider is visible in reach trajectories. *Cognition & Emotion*, 26(7), 1176–1188. <https://doi.org/10.1080/02699931.2011.640662>
- Buodo, G., Sarlo, M., & Palomba, D. (2002). Attentional resources measured by reaction times highlight differences within pleasant and unpleasant, high arousing stimuli. *Motivation and Emotion*, 26(2), 123–138. <https://doi.org/10.1023/A:1019886501965>
- Burra, N., Pittet, C., Barras, C., & Kerzel, D. (2019). Attentional suppression is delayed for threatening distractors. *Visual Cognition*, 27(3–4), 185–198. <https://doi.org/10.1080/13506285.2019.1593272>
- Campbell, B. A., Wood, G., & McBride, T. (1997). Origins of orienting and defensive responses: An evolutionary perspective. In P. J. Lang, R. F. Simons, & M. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 41–67). Lawrence Erlbaum Associates, Inc.
- Cao, G., & Liu, P. (2021). Arousal modulates the motor interference effect stimulated by pictures of threatening animals. *PeerJ*, 9, e10876. <https://doi.org/10.7717/peerj.10876>
- Cisler, J. M., Ries, B. J., & Widner, R. L. (2007). Examining information processing biases in spider phobia using the rapid serial visual presentation paradigm. *Journal of Anxiety Disorders*, 21(8), 977–990. <https://doi.org/10.1016/j.janxdis.2006.10.011>
- Coelho, C. M., Araújo, A. S., Suttiwan, P., & Zsido, A. N. (2022). An ethologically based view into human fear. *Neuroscience & Biobehavioral Reviews*, 154(4), 105017. <https://doi.org/10.1016/j.neubiorev.2022.105017>
- Coelho, C. M., Polák, J., Suttiwan, P., & Zsido, A. N. (2021). Fear inoculation among snake experts. *BMC Psychiatry*, 21(1), 1–8. <https://doi.org/10.1186/s12888-021-03553-z>
- Coelho, C. M., Suttiwan, P., Faiz, A. M., Ferreira-Santos, F., & Zsido, A. N. (2019). Are humans prepared to detect, fear, and avoid snakes? The mismatch between laboratory and ecological evidence. *Frontiers in Psychology*, 10(September), 2094. <https://doi.org/10.3389/fpsyg.2019.02094>
- de Houwer, J., & Tibboel, H. (2010). Stop what you are not doing! Emotional pictures interfere with the task not to respond. *Psychonomic Bulletin and Review*, 17(5), 699–703. <https://doi.org/10.3758/PBR.17.5.699>
- Eilam, D. (2005). Die hard: A blend of freezing and fleeing as a dynamic defense—Implications for the control of defensive behavior. *Neuroscience and Biobehavioral Reviews*, 29(8), 1181–1191. <https://doi.org/10.1016/j.neubiorev.2005.03.027>
- Engemann, K., Pedersen, C. B., Arge, L., Tsirogianis, C., Mortensen, P. B., & Svenning, J. C. (2019). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. *Proceedings of the National Academy of Sciences of the United States of America*, 116(11), 5188–5193. <https://doi.org/10.1073/pnas.1807504116>
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral and biomedical sciences. *Behavior Research Methods*, 39(2), 175–191. <https://doi.org/10.3758/BF03193146>
- Frynta, D., Lišková, S., Bültmann, S., & Burda, H. (2010). Being attractive brings advantages: The case of parrot species in captivity. *PLoS ONE*, 5(9), 1–9. <https://doi.org/10.1371/journal.pone.0012568>
- Fuster, J. M. (2004). Upper processing stages of the perception-action cycle. In *Trends in cognitive sciences* (Vol. 8, Issue 4, pp. 143–145). Elsevier Current Trends. <https://doi.org/10.1016/j.tics.2004.02.004>
- Gao, H., & Jia, Z. (2017). Detection of threats under inattentive blindness and perceptual load. *Current Psychology*, 36(4), 733–739. <https://doi.org/10.1007/s12144-016-9460-0>
- Gao, X., LoBue, V., Irving, J., & Harvey, T. (2017). The effect of spatial frequency information and visual similarity in threat detection. *Cognition and Emotion*, 31(5), 912–922. <https://doi.org/10.1080/02699931.2016.1180280>
- García-Guerrero, S., O'Hara, D., Zgonnikov, A., & Scherbaum, S. (2022). The action dynamics of approach-avoidance conflict during decision-making. *Quarterly Journal of Experimental Psychology*, 76, 160–179. <https://doi.org/10.1177/17470218221087625>
- Gerdes, A. B. M., Alpers, G. W., & Pauli, P. (2008). When spiders appear suddenly: Spider-phobic patients are distracted by task-irrelevant spiders. *Behaviour Research and Therapy*, 46(2), 174–187. <https://doi.org/10.1016/j.brat.2007.10.010>
- Gladwin, T. E., Hashemi, M. M., van Ast, V., & Roelofs, K. (2016). Ready and waiting: Freezing as active action preparation under threat. *Neuroscience Letters*, 619, 182–188. <https://doi.org/10.1016/j.neulet.2016.03.027>
- Gokce, A., Zinchenko, A., Annac, E., Conci, M., & Geyer, T. (2021). Affective modulation of working memory maintenance: The role of positive and negative emotions. *Advances in Cognitive Psychology*, 17(2), 107–116. <https://doi.org/10.5709/ACP-0321-7>
- Grimaldos, J., Duque, A., Palau-Batet, M., Pastor, M. C., Bretón-López, J., & Quero, S. (2021). Cockroaches are scarier than snakes and spiders: Validation of an affective standardized set of animal images (ASSAI). *Behavior Research Methods*, 53, 2338–2350. <https://doi.org/10.3758/s13428-021-01577-7>
- Gross, C. T., & Canteras, N. S. (2012). The many paths to fear. *Nature Reviews Neuroscience*, 13(9), 651–658. <https://doi.org/10.1038/nrn3301>
- Gu, Y., Piper, W. T., Branigan, L. A., Vazey, E. M., Aston-Jones, G., Lin, L., LeDoux, J. E., & Sears, R. M. (2020). A brainstem-central amygdala circuit underlies defensive responses to learned threats. *Molecular Psychiatry*, 25(3), 640–654. <https://doi.org/10.1038/s41380-019-0599-6>
- Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., Ernst, M., & Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*, 68(11), 982–990. <https://doi.org/10.1016/j.biopsych.2010.07.021>
- Hartmann, P., & Apaolaza-Ibáñez, V. (2010). Beyond savanna: An evolutionary and environmental psychology approach to behavioral effects of nature scenery in green advertising. *Journal of Environmental Psychology*, 30(1), 119–128. <https://doi.org/10.1016/j.jenvp.2009.10.001>
- Holmes, A., Mogg, K., De Fockert, J., Nielsen, M. K., & Bradley, B. P. (2014). Electrophysiological evidence for greater attention to threat when cognitive control resources are depleted. *Cognitive, Affective, & Behavioral Neuroscience*, 14(2), 827–835. <https://doi.org/10.3758/s13415-013-0212-4>
- Huijding, J., & de Jong, P. J. (2007). Beyond fear and disgust: The role of (automatic) contamination-related associations in spider phobia. *Journal of Behavior Therapy and Experimental Psychiatry*, 38(2), 200–211. <https://doi.org/10.1016/j.jbtep.2006.10.009>
- Iacobucci, D., Posavac, S. S., Kardes, F. R., Schneider, M. J., & Popovich, D. L. (2015). Toward a more nuanced understanding of the statistical properties of a median split. *Journal of Consumer Psychology*, 25(4), 652–665. <https://doi.org/10.1016/j.jcps.2014.12.002>

- Jamovi Project. (2022). *Jamovi*. (version 2.3 for Windows). <https://www.jamovi.org>
- Joye, Y., & van den Berg, A. (2011). Is love for green in our genes? A critical analysis of evolutionary assumptions in restorative environments research. *Urban Forestry and Urban Greening*, 10(4), 261–268. <https://doi.org/10.1016/j.ufug.2011.07.004>
- Kawai, N., & Qiu, H. (2020). Humans detect snakes more accurately and quickly than other animals under natural visual scenes: A flicker paradigm study. *Cognition and Emotion*, 34(3), 614–620. <https://doi.org/10.1080/02699931.2019.1657799>
- Klaassen, F. H., Held, L., Figner, B., O'Reilly, J. X., Klumpers, F., de Voogd, L. D., & Roelofs, K. (2021). Defensive freezing and its relation to approach-avoidance decision-making under threat. *Scientific Reports*, 11(1), 1–12. <https://doi.org/10.1038/s41598-021-90968-z>
- Kozłowska, K., Walker, P., McLean, L., & Carrive, P. (2015). Fear and the defense cascade: Clinical implications and management. In *Harvard review of psychiatry* (Vol. 23, Issue 4, pp. 263–287). Taylor and Francis Ltd. <https://doi.org/10.1097/HRP.000000000000065>
- Landová, E., Bakhshaliyeva, N., Janovcová, M., Peléšková, Š., Suleymanova, M., Polák, J., Guliev, A., & Frynta, D. (2018). Association between fear and beauty evaluation of snakes: Cross-cultural findings. *Frontiers in Psychology*, 9(March), 1–15. <https://doi.org/10.3389/fpsyg.2018.00333>
- Landová, E., Poláková, P., Rádlová, S., Janovcová, M., Bobek, M., & Frynta, D. (2018). Beauty ranking of mammalian species kept in the Prague zoo: Does beauty of animals increase the respondents' willingness to protect them? *Science of Nature*, 105(11–12), 69. <https://doi.org/10.1007/s00114-018-1596-3>
- Lebowitz, E. R., Shic, F., Campbell, D., Basile, K., & Silverman, W. K. (2015). Anxiety sensitivity moderates behavioral avoidance in anxious youth. *Behaviour Research and Therapy*, 74, 11–17. <https://doi.org/10.1016/j.brat.2015.08.009>
- LeDoux, J. E. (2022). As soon as there was life, there was danger: The deep history of survival behaviours and the shallower history of consciousness. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 377(1844), 20210292. <https://doi.org/10.1098/rstb.2021.0292>
- LeDoux, J. E., & Daw, N. D. (2018). Surviving threats: Neural circuit and computational implications of a new taxonomy of defensive behaviour. *Nature Reviews Neuroscience*, 19(5), 269–282. <https://doi.org/10.1038/nrn.2018.22>
- Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A., Gordon, E., & Williams, L. M. (2005). A direct brainstem-amygdala-cortical 'alarm' system for subliminal signals of fear. *NeuroImage*, 24(1), 235–243. <https://doi.org/10.1016/J.NEUROIMAGE.2004.08.016>
- Lindström, B. R., & Bohlin, G. (2012). Threat-relevance impairs executive functions: Negative impact on working memory and response inhibition. *Emotion (Washington, DC)*, 12(2), 384–393. <https://doi.org/10.1037/a0027305>
- Liu, P., Cao, R., Chen, X., & Wang, Y. (2017). Response inhibition or evaluation of danger? An event-related potential study regarding the origin of the motor interference effect from dangerous objects. *Brain Research*, 1664, 63–73. <https://doi.org/10.1016/j.brainres.2017.03.025>
- Loftus, G. R., & Harley, E. M. (2005). Why is it easier to identify someone close than far away? *Psychonomic Bulletin and Review*, 12(1), 43–65. <https://doi.org/10.3758/BF03196348>
- Löw, A., Weymar, M., & Hamm, A. O. (2015). When threat is near, get out of here: Dynamics of defensive behavior during freezing and active avoidance. *Psychological Science*, 26(11), 1706–1716. <https://doi.org/10.1177/0956797615597332>
- Mancini, C., Falciati, L., Maioli, C., & Mirabella, G. (2020). Threatening facial expressions impact goal-directed actions only if task-relevant. *Brain Sciences*, 10(11), 1–18. <https://doi.org/10.3390/brainsci10110794>
- March, D. S., & Gaertner, L. (2021). A method for estimating the time of initiating correct categorization in mouse-tracking. *Behavior Research Methods*, 53(6), 2439–2449. <https://doi.org/10.3758/s13428-021-01575-9>
- March, D. S., Gaertner, L., & Olson, M. A. (2017). In Harm's way: On preferential response to threatening stimuli. *Personality and Social Psychology Bulletin*, 43(11), 1519–1529. <https://doi.org/10.1177/0146167217722558>
- March, D. S., Gaertner, L., & Olson, M. A. (2021). Danger or dislike: Distinguishing threat from negative valence as sources of automatic anti-black bias. *Journal of Personality and Social Psychology*, 121(5), 984–1004. <https://doi.org/10.1037/pspa0000288>
- March, D. S., Gaertner, L., & Olson, M. A. (2022). On the automatic nature of threat: Physiological and evaluative reactions to survival-threats outside conscious perception. *Affective Science*, 3(1), 135–144. <https://doi.org/10.1007/s42761-021-00090-6>
- Marešová, J., & Frynta, D. (2008). Noah's ark is full of common species attractive to humans: The case of bovid snakes in zoos. *Ecological Economics*, 64(3), 554–558. <https://doi.org/10.1016/j.ecolecon.2007.03.012>
- Matchett, G., & Davey, G. C. L. (1991). A test of a disease-avoidance model of animal phobias. *Behaviour Research and Therapy*, 29(1), 91–94. [https://doi.org/10.1016/S0005-7967\(09\)80011-9](https://doi.org/10.1016/S0005-7967(09)80011-9)
- Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cognitive Therapy and Research*, 22(6), 539–560. <https://doi.org/10.1023/A:1018738019346>
- Mirabella, G. (2018). The weight of emotions in decision-making: How fearful and happy facial stimuli modulate action readiness of goal-directed actions. *Frontiers in Psychology*, 9(August), 1334. <https://doi.org/10.3389/fpsyg.2018.01334>
- Mobbs, D., & Kim, J. J. (2015). Neuroethological studies of fear, anxiety, and risky decision-making in rodents and humans. In *Current opinion in behavioral sciences* (Vol. 5, pp. 8–15). Elsevier. <https://doi.org/10.1016/j.cobeha.2015.06.005>
- Mobbs, D., Petrovic, P., Marchant, J. L., Hassabis, D., Weiskopf, N., Seymour, B., Dolan, R. J., & Frith, C. D. (2007). When fear is near: Threat imminence elicits prefrontal-periaqueductal gray shifts in humans. *Science*, 317(5841), 1079–1083. <https://doi.org/10.1126/science.1144298>
- Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: Cognitive-motivational framework and treatment. In *Trends in cognitive sciences* (Vol. 22, Issue 3, pp. 225–240). Elsevier Ltd.. <https://doi.org/10.1016/j.tics.2018.01.001>
- Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. *Cognition & Emotion*, 14(3), 375–399. <https://doi.org/10.1080/026999300378888>
- Murray, S. O., Boyaci, H., & Kersten, D. (2006). The representation of perceived angular size in human primary visual cortex. *Nature Neuroscience*, 9(3), 429–434. <https://doi.org/10.1038/nn1641>
- Peirce, J. W. (2007). PsychoPy—Psychophysics software in python. *Journal of Neuroscience Methods*, 162(1–2), 8–13. <https://doi.org/10.1016/J.JNEUMETH.2006.11.017>
- Penning, D. A., Sawvel, B., & Moon, B. R. (2016). Debunking the viper's strike: Harmless snakes kill a common assumption. *Biology Letters*, 12(3), 20160011. <https://doi.org/10.1098/rsbl.2016.0011>
- Perkins, A. M., Ettinger, U., Davis, R., Foster, R., Williams, S. C. R., & Corr, P. J. (2009). Effects of lorazepam and citalopram on human defensive reactions: Ethopharmacological differentiation of fear and anxiety. *Journal of Neuroscience*, 29(40), 12617–12624. <https://doi.org/10.1523/JNEUROSCI.2696-09.2009>
- Perkins, A. M., Ettinger, U., Weaver, K., Schmechtig, A., Schranter, A., Morrison, P. D., Sapara, A., Kumari, V., Williams, S. C. R., & Corr, P. J. (2013). Advancing the defensive explanation for anxiety disorders: Lorazepam effects on human defense are systematically modulated by personality and threat-type. *Translational Psychiatry*, 3(4), e246. <https://doi.org/10.1038/tp.2013.20>

- Pflugshaupt, T., Mosimann, U. P., von Wartburg, R., Schmitt, W., Nyffeler, T., & Müri, R. M. (2005). Hypervigilance–avoidance pattern in spider phobia. *Journal of Anxiety Disorders*, 19(1), 105–116. <https://doi.org/10.1016/J.JANXDIS.2003.12.002>
- Pissiota, A., Frans, Ö., Michelgård, Å., Appel, L., Långström, B., Flaten, M. A., & Fredrikson, M. (2003). Amygdala and anterior cingulate cortex activation during affective startle modulation: A PET study of fear. *European Journal of Neuroscience*, 18(5), 1325–1331. <https://doi.org/10.1046/j.1460-9568.2003.02855.x>
- Polák, J., Rádlová, S., Janovcová, M., Flegr, J., Landová, E., & Frynta, D. (2020). Scary and nasty beasts: Self-reported fear and disgust of common phobic animals. *British Journal of Psychology*, 111(2), 297–321. <https://doi.org/10.1111/bjop.12409>
- Prokop, P., Özel, M., & Uşak, M. (2009). Cross-cultural comparison of student attitudes toward snakes. *Society and Animals*, 17(3), 224–240. <https://doi.org/10.1163/156853009X445398>
- Purkis, H. M., & Lipp, O. V. (2007). Automatic attention does not equal automatic fear: Preferential attention without implicit valence. *Emotion*, 7(2), 314–323. <https://doi.org/10.1037/1528-3542.7.2.314>
- Qi, S., Hassabis, D., Sun, J., Guo, F., Daw, N., & Mobbs, D. (2018). How cognitive and reactive fear circuits optimize escape decisions in humans. *Proceedings of the National Academy of Sciences of the United States of America*, 115(12), 3186–3191. <https://doi.org/10.1073/pnas.1712314115>
- Rinck, M., Dapprich, A., Lender, A., Kahveci, S., & Blechert, J. (2021). Grab it or not? Measuring avoidance of spiders with touchscreen-based hand movements. *Journal of Behavior Therapy and Experimental Psychiatry*, 73, 101670. <https://doi.org/10.1016/j.jbtep.2021.101670>
- Roelofs, K. (2017). Freeze for action: Neurobiological mechanisms in animal and human freezing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372(1718), 20160206. <https://doi.org/10.1098/rstb.2016.0206>
- Rosa, C. D., Collado, S., Profice, C. C., & Larson, L. R. (2019). Nature-based recreation associated with connectedness to nature and leisure satisfaction among students in Brazil. *Leisure Studies*, 38(5), 682–691. <https://doi.org/10.1080/02614367.2019.1620842>
- Rösler, L., & Gamer, M. (2019). Freezing of gaze during action preparation under threat imminence. *Scientific Reports*, 9(1), 1–9. <https://doi.org/10.1038/s41598-019-53683-4>
- Song, J., Bennett, P. J., Sekuler, A. B., & Sun, H. J. (2021). The effect of apparent distance on peripheral target detection. *Journal of Vision*, 21(10), 8. <https://doi.org/10.1167/jov.21.10.8>
- Teachman, B. A., Gregg, A. P., & Woody, S. R. (2001). Implicit associations for fear-relevant stimuli among individuals with snake and spider fears. *Journal of Abnormal Psychology*, 110(2), 226–235. <https://doi.org/10.1037/0021-843X.110.2.226>
- Teachman, B. A., & Woody, S. R. (2003). Automatic processing in spider phobia: Implicit fear associations over the course of treatment. *Journal of Abnormal Psychology*, 112(1), 100–109. <https://doi.org/10.1037/0021-843X.112.1.100>
- Wardenaar, K. J., Lim, C. C. W., Al-Hamzawi, A. O., Alonso, J., Andrade, L. H., Benjet, C., Bunting, B., de Girolamo, G., Demyttenaere, K., Florescu, S. E., Gureje, O., Hisateru, T., Hu, C., Huang, Y., Karam, E., Kiejna, A., Lepine, J. P., Navarro-Mateu, F., Oakley Browne, M., ... de Jonge, P. (2017). The cross-national epidemiology of specific phobia in the World Mental Health Surveys. *Psychological Medicine*, 47(10), 1744–1760. <https://doi.org/10.1017/S0033291717000174>
- Wendt, J., Löw, A., Weymar, M., Lotze, M., & Hamm, A. O. (2017). Active avoidance and attentive freezing in the face of approaching threat. *NeuroImage*, 158, 196–204. <https://doi.org/10.1016/j.neuroimage.2017.06.054>
- Whitaker, P. B., & Shine, R. (2000). Sources of mortality of large elapid snakes in an agricultural landscape. *Journal of Herpetology*, 34(1), 121–128. <https://doi.org/10.2307/1565247>
- Williams, J. H. G., Huggins, C. F., Zupan, B., Willis, M., Van Rheenens, T. E., Sato, W., Palermo, R., Ortner, C., Krippel, M., Kret, M., Dickson, J. M., Li, C.-S. R., & Lowe, L. (2020). A sensorimotor control framework for understanding emotional communication and regulation. *Neuroscience and Biobehavioral Reviews*, 112, 503–518. <https://doi.org/10.1016/j.neubiorev.2020.02.014>
- Witthauer, C., Ajdacic-Gross, V., Meyer, A. H., Vollenweider, P., Waeber, G., Preisig, M., & Lieb, R. (2016). Associations of specific phobia and its subtypes with physical diseases: An adult community study. *BMC Psychiatry*, 16(1), 155. <https://doi.org/10.1186/s12888-016-0863-0>
- Yorek, N. (2009). The only good snake is a dead snake: Secondary school students' attitudes toward snakes. *Biotechnology and Biotechnological Equipment*, 23, 31–35. <https://doi.org/10.1080/13102818.2009.10818358>
- Zimmerman, M., Dalrymple, K., Chelminski, I., Young, D., & Galione, J. N. (2010). Recognition of irrationality of fear and the diagnosis of social anxiety disorder and specific phobia in adults: Implications for criteria revision in DSM-5. *Depression and Anxiety*, 27(11), 1044–1049. <https://doi.org/10.1002/da.20716>
- Zinchenko, A., Al-Amin, M. M., Alam, M. M., Mahmud, W., Kabir, N., Reza, H. M., & Burne, T. H. J. (2017). Content specificity of attentional bias to threat in post-traumatic stress disorder. *Journal of Anxiety Disorders*, 50, 33–39. <https://doi.org/10.1016/j.janxdis.2017.05.006>
- Zsido, A. N. (2017). The spider and the snake – A psychometric study of two phobias and insights from the Hungarian validation. *Psychiatry Research*, 257, 61–66. <https://doi.org/10.1016/j.psychres.2017.07.024>
- Zsido, A. N., Arato, N., Inhof, O., Janszky, J., & Darnai, G. (2018). Short versions of two specific phobia measures: The snake and the spider questionnaires. *Journal of Anxiety Disorders*, 54, 11–16. <https://doi.org/10.1016/j.janxdis.2017.12.002>
- Zsido, A. N., Coelho, C. M., & Polák, J. (2022). Nature relatedness: A protective factor for snake and spider fears and phobias. *People and Nature*, 4, 669–682. <https://doi.org/10.1002/pan3.10303>
- Zsido, A. N., Deak, A., Losonci, A., Stecina, D., Arato, A., & Bernath, L. (2018). Investigating evolutionary constraints on the detection of threatening stimuli in preschool children. *Acta Psychologica*, 185, 166–171. <https://doi.org/10.1016/j.actpsy.2018.02.009>
- Zsido, A. N., Stecina, D. T., Cseh, R., & Hout, M. C. (2021). The effects of task-irrelevant threatening stimuli on orienting- and executive attentional processes under cognitive load. *British Journal of Psychology*, 113, 412–433.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Descriptive data for initiation time and movement time presented separately across the two groups and different conditions. Mean times, standard errors, and 95% confidence interval values are presented in seconds.

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