Safety First:

Instrumentality for Reaching Safety Determines Attention Allocation under Threat

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Abstract

Theories of attention to emotional information suggest that attentional processes prioritize threatening information. Here, we suggest that attention will prioritize the events that are most instrumental to a goal in a given context, which in threatening situations typically is reaching safety. To test our hypotheses, we used an attentional cueing paradigm that contained cues signaling imminent threat (i.e., aversive noises) as well as cues that allowed to avoid threat (instrumental safety signals). Correct reactions to instrumental safety signals seemingly allowed participants to lower the presentation rate of the threat. Experiment 1 demonstrates that attention prioritizes instrumental safety signals over threat signals. Experiment 2 replicates this finding and additionally compares instrumental safety signals to other action-relevant signals controlling for action relevance as cause of the effects. Experiment 3 demonstrates that when actions towards threat signals permit to avoid threat, attention prioritizes threat signals. Taken together, these results support the view that instrumentality for reaching safety determines the allocation of attention under threat.

Key words: attention, motivation, emotion, threat, safety, instrumentality

Humans are well prepared to respond to threat. When encountering threat, several psycho-physiological systems enable defensive actions, leading to elevated heart, pulse, and respiration rate (Cannon, 1929; Lang, Davis, & Öhman, 2000), and coordinated activation in various cortical and subcortical parts of the brain (Calder, Lawrence, & Young, 2001; LeDoux, 1996). In line with these findings, attentional processes prioritize threat-related information in fear (Vuilleumier & Huang, 2009). It is commonly assumed that the threat value of a stimulus is the key factor in causing such prioritized attention to threat (e.g., Öhman & Mineka, 2001; Vuilleumier & Huang, 2009). In the present paper, however, we propose that, under threat, attention is guided by the relevance of information for reaching safety.

We assume that two classes of events are important when aiming to reach safety from danger (Derryberry & Tucker, 1994; Kruglanski et al., 2002). First, the threat itself: Monitoring of threat is functional for reaching safety because it allows observers to select and execute appropriate defensive reactions (Lang, Bradley, & Cuthbert, 1997). Crucially, we suggest that attentional sensitivity is not limited to signals of threat but will comprise a second class of events, that is, non-threatening events that provide the potential to reach safety. In most threatening situations it is important to identify and make use of means permitting to fight or flight such as potential weapons or an escape route. We ask how attention is allocated when both threat and safety signals compete for attentional priority.

Previous research suggests that attention will mostly prioritize processing of threat itself. Research comparing signals of threat to stimuli that signal the absence of threat has shown prioritization of threat (Derryberry & Reed, 2002; Koster, Crombez, Verschuere, Van Damme, & De Houwer, 2004). Importantly, in these studies cues signaling the non-occurrence of threat have no instrumental value as they do not offer the potential to fight or escape threat whereas in real life such stimuli (weapons or an escape route) are often present. Monitoring non-instrumental safety signals does not appear useful because they do not represent potential means that are helpful in overcoming threat. Supporting this reasoning, in contexts where safety can be reached, attention to more instrumental safety signals is amplified: Spider phobics who were in a room with a spider split attention between the spider and the door of the room (Thorpe & Salkovskis, 1998).

Based on this observation, we propose that the attentional inferiority of safety signals is not unconditional but depends on the *instrumentality* of safety signals for reaching safety. This is in line with models of attention describing the function of attention as the selection of information that is instrumental for achieving a goal (Allport, 1998; Lewin, 1926; Moskowitz, Li, & Kirk, 2004) which in fear is reaching safety (Roseman, Wiest, & Swartz, 1994). Supporting this assumption, several studies have shown that goal-relevant events attract attention automatically even when they have no history of motivational relevance to the observer such as neutral stimuli that are relevant for a current goal induced in the experimental session (e.g., Moskowitz, 2002; Vogt, De Houwer, Van Damme, & Crombez, 2013). Crucially, more instrumental stimuli receive attentional priority over less instrumental stimuli (Vogt, De Houwer, & Crombez, 2011; Vogt, De Houwer, & Moors, 2011). For instance, when the goal is to win as much tokens as possible, stimuli relevant to winning a high number of tokens attract attention over stimuli that are relevant to winning a low number of tokens (Vogt, De Houwer, & Crombez, 2011). From this perspective, attention should prioritize safety signals that are instrumental in reaching safety, for example, representing weapons to fight threat, over stimuli that are less instrumental for reaching safety.

Importantly, in some situations, monitoring threat will be more instrumental for reaching safety than monitoring potential weapons or escape routes. This will depend on the required or chosen strategy to achieve safety (cf. Notebaert, Crombez, Vogt, De Houwer, Van Damme, &

Theeuwes, 2011; Cesario, Plaks, Hagiwara, Navarrete, & Higgins, 2010). For instance, when having to monitor the movements of a threatening animal in order to attack it successfully, threat should be prioritized by the attentional system. We therefore expect that attention allocation varies depending on whether monitoring threat or safety stimuli is more instrumental for reaching safety (cf. Vogt & De Houwer, 2014). Such a pattern of data would support the proposal that the motivation to reach safety guides attention under threat and not a heightened ability to detect threat or safety information per se.

In Experiment 1, we compared signals of threat to two types of safety signals: First, safety signals that only indicated the absence of threat (i.e., CS-; cf. Christianson et al., 2012) and, second, safety signals that were instrumental in reaching safety. These instrumental safety signals required actions that (seemingly) allowed participants to avoid the threat. We hypothesized that attention would prioritize instrumental safety signals over non-instrumental safety and threat signals. This would support our suggestion that the instrumentality of information and not threat value or positive associations (i.e., absence of threat) determine the focus of attention. In Experiment 2, we compared instrumental safety signals to signals that also required action but without leading to any beneficial consequences for participants' safety. This allowed us to control whether the functional value of the safety signals - as a means to fight threat - caused the effects rather than the fact that they were linked to a motor action. If action relevance would underlie the effects, attention should not differentiate between these signals. This would be reflected in the absence of a systematic and significant pattern of attention allocation to one of the cues. Further, if the instrumentality for reaching safety and not a unique feature of instrumental safety signals is driving attention then 'instrumental' threat signals should be prioritized as well. To test this assumption, only actions towards the threat signal (seemingly) allowed participants to reach safety in Experiment 3 turning threat signals into the signal that is most instrumental in reaching safety.

In order to create a signal of imminent threat and a safety signal in the laboratory, we combined an attention task with a secondary task. In each trial of this task, a single colored patch appeared briefly in the middle of the screen. One color was occasionally followed by an aversive noise turning patches of this color into a signal of imminent threat (Koster et al., 2004; Notebaert, Crombez, Van Damme, De Houwer, Theeuwes, 2011). A patch in another color was turned into an instrumental safety signal which presumably permitted avoiding threat over the course of the experiment. To this end, we informed participants that correct reactions to this patch (i.e., pressing a particular key) would lead to less presentations of the aversive noise over the course of the experiment. We did not present aversive noises on trials with this color patch (e.g. that could be stopped on that trial by motor reactions, cf. Derryberry & Reed, 2002). By this, the color patch would only represent a means to avoid threat but would not signal threat itself. In Experiment 3, we informed participants that correct reactions to the *threat* patch would allow them to lower the number of presentations of the noise over the course of the experiment. Additionally, in Experiments 1 and 3, another colored patch represented a non-instrumental safety signal (CS-) that indicated the absence of threat. In Experiments 2 and 3, a third colored patch served as action signal requiring a motor reaction but without leading to any beneficial consequences.

To examine attention to the different signals, we implemented them as cues in a cueing paradigm. In each trial of the cueing task, two cues are simultaneously presented at two different spatial locations on the screen, immediately followed by a probe. If individuals selectively orient to a cue, responses are faster to probes at the location previously occupied by this stimulus. In order to investigate whether both threat and safety cues attract attention over non-instrumental safety cues, we employed trials comparing threat cues to non-instrumental safety cues and trials comparing instrumental safety to non-instrumental safety cues. Importantly, we also employed trials presenting instrumental safety cues together with threat cues. These trials allowed us to examine whether attention would prioritize instrumental safety cues over threat cues. In Experiments 2 and 3, we additionally compared instrumental safety and threat cues to cues that required a motor action in the secondary task. By comparing these cues to each other we could examine whether attention prioritizes cues that are instrumental in reaching safety over non-instrumental action signals.

We presented the cues for 200 ms cue presentation. This allowed us to measure attentional processing at a relatively early time because most emotional attention research uses presentation times around 500 ms or longer (Bar-Haim et al., 2007).

Experiment 1

Method

Participants.

Nineteen volunteers (7 men; *M* = 25 years; *SD* = 10 years) at the University of Reading participated in the experiment and received £5 as compensation. All participants had normal or corrected-to-normal vision and were naive as to the purpose of the experiment. The study was approved to be in line with the guidelines of the University of Reading Research Ethics (Protocol 2013-173-JV). The sample size for all three experiments was determined based on a previous experiment that also involved fear-conditioned threat stimuli and goal-relevant stimuli (Experiment 3 in Vogt, De Houwer, Crombez, & Van Damme, 2013). The design of the present experiments was based on this experiment. Because the crucial comparison in the present experiments is the comparison between cues that are instrumental for the goal of reaching safety and threatening cues, we referred to the effect size of the comparison between cues relevant for participants' goal and threatening cues. Based on this effect size (d = 0.83), we calculated that the minimum sample size should be 16 at an alpha of 0.05 and a power of 0.85.

Apparatus and Materials.

We presented the experiment on an Intel Core 2 computer with a 75 Hz, 17-inch LDT monitor using Inquisit 3.0 (2010) software. As threat, safety, and non-instrumental safety signals, we used colored patches in yellow, orange, and pink. Colors were matched for luminance using ImageJ (2011). We counterbalanced the distribution of colors to patch functions between subjects. Additionally, seven colored patches and 11 neutral pictures from the International Affective Picture System (Lang, Bradley, & Cuthbert, 1999) were used in the secondary task as filler stimuli. The colors were three shades of green, two shades of brown and two shades of grey. The IAPS numbers were: 7002, 7006, 7009, 7090, 7140, 7150, 7175, 7211, 7224, 7234, 7550. The aversive noise was a 460-ms white-noise burst delivered through a head phone at an intensity of 95 dBA (Koster et al., 2004).

Dot probe and secondary task.

Each trial in the *dot probe task* started with the presentation of a black fixation cross (5 mm high) in a white square in the middle of a black screen along with two white rectangles (4.6 cm high x 6.1 cm wide) above and below the fixation cross (Figure 1). The middle of each of the peripheral rectangles was 4.6 cm from the fixation cross. After 500 ms, two colored patches were presented within the rectangles for 250 ms (cf. Koster et al., 2004). A probe consisting of a black square (0.5 cm x 0.5 cm) appeared immediately after patch offset. Participants were required to locate the probe by pressing one of two keys (“4”, “5” on the number pad) with index and middle finger of the right hand. We counterbalanced the distribution of keys to probe locations between participants. A trial ended after a response was registered or 1500 ms had elapsed since probe onset. Each trial of the dot probe task was followed by a trial of the secondary task after an intertrial interval of 700 ms.

A trial in the *secondary task* started with the appearance of a colored patch or image in the middle of a black screen for 250 ms. A red question mark (8 mm high) appeared hereafter. A trial ended with a response or when 2000 ms had elapsed since the onset of the question mark. On 50% of the trials with threat signals, we presented an aversive noise in parallel with the question mark. After instrumental safety signals, participants had to press the spacebar with the left hand. After all other signals, a reaction was not required. Error feedback was presented for 200 ms after incorrect reactions (i.e., no reaction) to the instrumental safety signal and incorrect reactions to the other stimuli (i.e., pressing of the spacebar); correct reactions to the safety signal were followed by a feedback screen stating ‘correct’. We did not provide feedback after correct reactions (i.e., non-reactions) to goal-irrelevant stimuli because it would have prolonged the duration of the experiment. Please note that experiments 2 and 3 compare and find differences between instrumental safety stimuli and control stimuli that are all followed by positive feedback after correct reactions. We can thus conclude that the feedback is not driving the effects for instrumental safety signals.

Figure 1 about here

Procedure.

Practice phase.

Participants were seated approximately 60 cm from a computer screen. Instructions were presented on the screen. Participants practiced at first only the dot probe task in two practice phases of 12 trials and 36 trials, respectively. We asked participants to maintain attention at the fixation cross and to respond as quickly and as accurately as possible to the probe location.

Hereafter, participants practiced the secondary task. At first, we informed them that one colored patch would sometimes be followed by an unpleasant noise which would never be presented after another stimulus. Six practice trials followed this information. We instructed participants to find out which color would be followed by the aversive noise. Participants were then informed that fewer noises would be presented over the course of the experiment if they press the spacebar each time one particular colored patch is presented. The color was named and was always different from the color of the CS+ and the color of the CS-. 15 practice trials followed these instructions. During these two practice phases, threat, safety, and non-instrumental safety signals were presented five times; complemented by six filler trials. On filler trials, we presented filler stimuli. Hereafter, participants performed 24 practice trials of the combined procedure of dot probe and secondary task with 12 trials of each task. In the dot probe task, each trial type (threat vs. non-instrumental safety, instrumental safety vs. non-instrumental safety, instrumental safety vs. threat) was presented four times. In the secondary task, threat, safety, and non-instrumental safety signals were presented two times, complemented by six filler trials. The aversive noise was presented once.

Test phase.

In the test phase, participants performed 144 trials of each task. In the *dot probe task*, each of the three trial types was presented 48 times. Each cue category was presented equally often in the upper and lower location and predicted the probe location correctly on 50% of the trials. In the *secondary* task, each of the three signals was presented 24 times. The aversive noise was presented on 12 trials with the threat signal. The remaining 72 trials were filler trials. We included filler trials in order to prevent a high amount of presentations of the aversive noise which could have resulted in habituation.

After the experiment, participants indicated to what extent they expected the presentation of a noise after the appearance of threat, safety, and non-instrumental safety signal (1 = *never* to 7 = *always*), and how afraid they were during the presentation of threat, safety, and non-instrumental safety color (1 = *not at all* to 7 = *very much*). Further, they reported how unpleasant (1 = *not at all* to 7 = *very much*), threatening (1 = *not at all* to 7 = *very much*), and controllable (1 = *not at all* to 7 = *very much*) they experienced the noise to be. Additionally, they indicated how motivated they were to respond after the safety patch (1 = *not at all* to 9 = *very much*) and to which extent they had the impressions they could influence the presentation of the sound (1 = *not at all* to 7 = *very much*). In order to have an indication of the sample's trait anxiety levels, participants filled in the trait anxiety version of the State and Trait Anxiety Inventory (STAI-Trait, Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) after finishing the tasks. This questionnaire consists of 20 short items (e.g., "I feel secure") which have to be rated on a four-point scale (1 = *Almost never* to 4 = *Almost Always*).

Results

We excluded the data of two participants from analyses: Due to computer malfunction, one participant did not complete the entire set of trials in the test phase. Including her data does not change the conclusions reported below. The other participant indicated to have expected the presentation of the aversive noise more after non-instrumental safety signals (CS-) than after threat signals (CS+). Actually, the CS- was never followed by the noise which was also highlighted in the instructions and repeated by the experimenter. In contrast to the rest of the sample, his data showed an attentional bias towards non-instrumental safety signals on trials comparing them to threat signals.

Manipulation checks and trait anxiety levels.

Participants described the noise as threatening (M = 5.12, SD = 1.45), unpleasant (M = 6.06, SD = 1.03), and uncontrollable (M = 2.76, SD = 1.44). They reported to have expected the presentation of the noise after the appearance of a threat patch (M = 5.47, SD = 1.07) but not after non-instrumental safety or instrumental safety patch ($M_{\text{non-instrumental safety}}$ = 1.29, $SD_{\text{non-instrumental safety}}$ = 0.69; $M_{\text{instrumental safety}}$ = 1.24, $SD_{\text{instrumental safety}}$ = 0.97; ts (17) > 12.94, ps < .001); they reported that they were afraid during the presentation of the threat patch (*M* = 5.11, *SD* = 1.32) but not during the presentation of non-instrumental safety or instrumental safety patch ($M_{\text{non-instrumental safety}}$ = 1.29, $SD_{\text{non-instrumental safety}}$ = 0.69; $M_{\text{instrumental safety}}$ = 1.12, $SD_{\text{instrumental safety}}$ = 0.33; *t*s (17) > 10.15, *p*s < .001). This indicates that conditioning was successful. Expectancy and fear ratings did not differ significantly between non-instrumental and instrumental safety signals, *t*s (17) < 1.15, *p*s > .268. Finally, participants reported to have been very motivated to respond after the instrumental safety patch (*M* = 6.29, *SD* = 1.21). At the end of the experimental session, participants did not have a strong impression that reactions to the instrumental safety signal allowed them to reduce the number of presentations of the aversive noise (*M* = 2.47, *SD* = 1.63). However, given that participants made only very few errors (on 0.77% of trials) in the secondary task, it is clear they were motivated to perform this task and pursue the goal of avoiding threat. The average STAI trait score was 42.53 (*SD* = 9.53) indicating regular trait anxiety levels (Spielberger et al., 1983).

Dot probe task.

Trials with errors in the dot probe task were removed from the data (1.87%). Following Ratcliff (1993), the medians of the reaction times were used for the analyses.[1]

We performed three separate ANOVAs for each type of dot probe trial with congruence (congruent, incongruent) as within factor. For trials with an instrumental safety signal, congruent trials are trials in which the probe replaced the safety signal (i.e., safety congruency), whereas incongruent trials are trials in which the probe replaced the comparison signal (i.e., threat or non-instrumental safety). For the trials comparing threat and non-instrumental safety signals, congruent trials are trials in which the probe replaced the threat signal (threat congruence), whereas incongruent trials are trials in which the probe replaced the non-instrumental safety signal. Mean latencies and standard deviations of dot probe task responses can be found in Table 1 and attentional bias scores per trial type and experiment in Figure 2. We calculated Cohen's *d* to see if the expected differences had small (.20), medium (.50) or large effect (.80) sizes (Cohen, 1992).

Table 1 about here

The analysis on trials presenting threat with the non-instrumental safety signals revealed a significant main effect of threat congruence, $F(1, 16) = 7.09$, $p = .017$, $d = 0.64$, 95% CI [-0.05, 1.33], demonstrating an attentional bias to threat signals compared to stimuli that signal the absence of threat. On trials comparing instrumental safety to non-instrumental safety signals, we found a significant main effect of instrumentality congruence, $F(1, 16) = 11.41$, $p = .004$, $d = 0.82$, 95% CI [0.12, 1.52], indicating attention allocation towards instrumental safety signals when compared to non-instrumental safety signals. Of crucial importance were the trials comparing instrumental safety to threat signals. These analyses showed a significant main effect of safety congruence, $F(1, 16) = 14.96$, $p = .001$, $d = 0.93$, 95% CI [0.22, 1.64]. Hence, attention was biased towards instrumental safety signals when these were simultaneously presented with threat signals.

Discussion

The results of this experiment revealed an attentional bias towards threat and safety cues when these stimuli were presented together with non-instrumental safety cues. However, when instrumental safety and threat cues were presented together, attention was biased towards instrumental safety cues. These results thus support our hypothesis that both threat and safety signals guide attention and that safety signals will be prioritized when they are more instrumental in reaching safety.

In Experiment 2, we aimed to test whether instrumental safety cues will also be prioritized over safety-unrelated action cues. Previous evidence has shown that action-relevant signals guide attention (Bekkering & Neggers, 2002). Hence, instrumental safety signals might have evoked an attentional bias because they were action relevant and not because they were functional for reaching safety. To address this potential concern, participants had to give motor reactions also to non-instrumental safety cues in the secondary task but we did not say that these reactions would lower the presentations of the noise. If action relevance would underlie the effects, no significant effect should emerge on those trials because both cues would attract attention. In contrast, if instrumentality for reaching safety is guiding attention, instrumental safety cues should be prioritized over mere action signals.

Experiment 2

Participants.

A sample of 27 students (22 women; *M* = 20 years; *SD* = 2 years) at Ghent University received 7€ for participating in the experiment. All participants had normal or corrected-to-normal vision and were naive as to the purpose of the experiment. The study was approved by the ethics committee of the Faculty of Psychology at Ghent University (2010/37, JV). Data collection was scheduled for one week and finished by the end of this week.

Apparatus, Materials, and Procedure.

The experiment remained the same except for the following changes. Importantly, we used again three color patches in the dot probe and in the secondary task. One color patch was associated with threat, one color patch served as instrumental safety cue, and one color served as non-instrumental action cue. After practicing the attention task, we told participants that after two of the colored patches they were required to press the spacebar with the left hand. Importantly, participants were informed that correctly reacting after one of these two colors (i.e. instrumental safety cue) would lead to less presentations of the noise over the course of the experiment. To make sure that participants picked up this information, the program included two questions ("Correct reactions after which color lead to less noises?" and "Which other color requires you to press the spacebar?"). Participants had to type the name of a color in response to each question. They received feedback on the screen whether they were correct.

As before, participants learned which color was associated with aversive noises and they practiced the secondary task in two subsequent practice phases with 21 practice trials all together. During these practice trials, the threat patch was presented six times and the instrumental safety and the mere action patch four times each, additionally there were seven filler trials. The aversive noise followed the threat patch three times during the practice trials.

After the task, participants were asked separately for the instrumental safety color and the mere action color how motivated they were to respond after each stimulus (1 = *not at all* to 7 = *very much*) and to what extent they had the impressions they could influence the presentation of the sound by reacting to it (1 = *not at all* to 7 = *very much*). They were also asked to indicate which color instrumental safety and action signal have had.

Results

We excluded the data of one participant from the analyses because he indicated afterwards to have expected the presentation of the aversive noise more after the instrumental safety signal than after the threat signal. Including his data did not change the conclusions reported in the following sections.

Manipulation checks, trait anxiety levels, and secondary task.

Participants expected the presentation of the noise after threat signals ($M = 5.12$, $SD = 0.82$) but not after safety or action signals ($M_{\text{safety}} = 1.34$, $SD_{\text{safety}} = 0.75$; $M_{\text{action}} = 1.15$, $SD_{\text{control}} = 0.46$; $ts(25) > 18.62$, $ps < .001$). They also reported to have been afraid during the presentation of threat signals ($M = 4.00$, $SD = 1.72$) but not during the presentation of safety and action signals ($M_{\text{safety}} = 1.35$, $SD_{\text{safety}} = 0.75$; $M_{\text{action}} = 1.16$, $SD_{\text{control}} = 0.46$; $ts(25) > 8.57$, $ps < .001$). These ratings did not differ between instrumental safety and action signals, *t*s(25) < 1.55, *p*s > .133. Participants reported the noise to be threatening (*M* = 4.62, *SD* = 1.73), unpleasant (*M* = 5.58, *SD* = 1.36), and slightly uncontrollable (*M* = 3.61, *SD* = 1.75). Further, participants reported to have been more motivated to respond after safety patches (*M* = 6.31, *SD* = 0.68) than after action patches (*M* = 4.92, *SD* = 1.23), *t*(25) = 6.04, *p* < .001, and they had the impression they could influence the presentation of the sound more by reactions to instrumental safety patches (*M* = 4.04, *SD* = 1.51) than to action patches (*M* = 1.88, *SD* = 1.03), *t*(25) = 5.87, *p* < .001. All participants reported the correct color to represent instrumental safety and action signals.

In the secondary task, participants made errors on 3.22% of the trials. Because participants did not make more errors (i.e., non-reactions) after the presentation of the mere action signal (*M* = 0.16%, *SD* = 0.82%) than after the presentation of the instrumental safety signal (*M* = 0.48%, *SD* = 2.45%), *t*(25) = .625, *p* > .537, any differences in the attentional processing of these signals cannot be due to participants simply being less motivated to react to the mere action signal. The average STAI trait score of this sample was 39.92 (*SD* = 10.31).

Dot probe task.

The same analyses as for Experiment 1 were performed. Mean latencies and standard deviations of dot probe task responses can be found in Table 1. Trials with errors were removed (2.32%). On trials comparing threat to mere action signals, we did not find a significant effect of congruence, *F*(1, 25) < 1, *p* = .384, *d* = 0.16, 95% CI [– 0.39, 0.70]. The analysis on trials with instrumental safety and threat signals revealed a significant main effect of safety congruence, *F*(1, 25) = 22.88, *p* < .001, *d* = 0.94, 95% CI [0.37, 1.51]. Crucially, also the trials comparing safety to mere action signals showed a significant main effect of safety congruence, *F*(1, 25) = 37.44, *p* < .001, *d* = 1.20, 95% CI [0.61, 1.79]. Hence, attention was biased towards safety signals when these were simultaneously presented with either threat or action signals.

Figure 2 at about here

Discussion

The results of this experiment replicate the first experiment: Instrumental safety cues evoked an attentional bias over threat cues. Importantly, attention also prioritized instrumental safety cues over mere action signals. This shows that the *functional* value of safety signals - as a means to avoid threat – guides attention and not their action relevance.

On trials comparing mere action signals to threat signals, no clear attentional pattern emerged but, if anything, attention seemed to lean towards action-relevant signals. In previous studies, such action-relevant signals have been prioritized over threat (Vogt et al., 2013; Correll, Guillermo, & Vogt, 2014). Crucially, in those studies, action signals were not competing with instrumental safety signals in the experimental context that provide more beneficial consequences for participants. The relevance of action signals and their capacity to guide attention thus appears to depend on the context. This means, when information is presented that is more beneficial for participants it will probably lower the value of other less beneficiary information. This is in line with research showing that attention to action-relevant signals is eliminated when signals that provide more beneficial consequences such as a higher reward are also present (Vogt, De Houwer, & Crombez, 2011).

The findings raise the question of how attention is allocated when threat signals become more important than action signals. In Experiment 1, threat signals were prioritized over non-instrumental safety signals probably because monitoring threat signals permits to predict when to expect threat, thus being more instrumental in coping with threat. In Experiment 3, we explored the possibility that when actions towards threat (seemingly) permit participants to avoid threat, threat signals will gain priority over action signals just as instrumental safety signals. This would support our proposal that it is the instrumentality of signals for reaching safety that guides attention and not a specific feature of instrumental safety signals only.

Experiment 3

Participants.

Twenty-seven volunteers (24 women; *M* = 22 years; *SD* = 7 years) at the University of Reading and were paid £5 for participating in the study. All participants had normal or corrected-to-normal vision and were naive as to the purpose of the experiment. The study was approved to be in line with the guidelines of the University of Reading Research Ethics (Protocol 2013-173-JV). Data collection was finished when the exams period started.

Apparatus, Materials, and Procedure.

The experiment remained the same as Experiment 2 except for the following changes: Most importantly, participants were instructed to react to the threat patch in the secondary task in order to lower the presentation rate of the sounds. As in the previous experiments, in reality but unbeknownst to the participants, the reactions did not have this effect. As comparison stimuli, we used again a signal requiring motor reactions without leading to any consequences and a signal indicating the absence of threat (CS-). This time, the experimenter repeated the instructions to make sure participants did pick up all information. Participants practiced the tasks again in 21 trials of practice phases. During these practice trials, the threat patch was presented six times, four times followed by an aversive noise. We presented non-instrumental safety patches, action patches, and filler stimuli five times each on the remaining practice trials. After the task, participants were only asked for the instrumental threat patch and not for the action patch how motivated they were to respond after it (1 = *not at all* to 7 = *very much*) and to what extent they had the impression they could influence the presentation of the sounds by reacting to it (1 = *not at all* to 7 = *very much*).

Results

Manipulation checks and secondary task.

Participants described the noise as threatening (*M* = 5.00, *SD* = 1.39), unpleasant (*M* = 5.89, *SD* = 1.22), and uncontrollable (*M* = 2.96, *SD* = 1.53). They reported to have expected the presentation of the noise after the appearance of a threat patch (*M* = 5.26, *SD* = 1.02) but not after action or non-instrumental safety patch (M_{action} = 1.37, SD_{action} = 1.04; $M_{\text{non-instrumental safety}}$ = 1.33, $SD_{\text{non-instrumental safety}}$ = 0.62; *t*s (26) > 17.00, *p*s < .001); they reported that they were afraid during the presentation of threat patches (*M* = 4.74, *SD* = 1.16) but not during the presentation of action or non-instrumental safety patches (M_{action} = 1.52, SD_{action} = 0.89; $M_{\text{non-instrumental safety}}$ = 1.56, $SD_{\text{non-instrumental safety}}$ = 1.05; *t*s (26) > 14.45, *p*s < .001). Expectancy and fear ratings did not differ significantly between non-instrumental and instrumental safety patches, *t*s (26) < 0.183, *p*s > .856. Finally, participants reported to have been very motivated to respond after the instrumental threat patch (*M* = 5.70, *SD* = 1.24). They reported to having had a moderate impression that reactions to the instrumental threat patch would lower the presentations of noise (*M* = 3.96, *SD* = 1.72).

Participants made errors on 1.49% of trials in the secondary task. They did not make significantly more errors (i.e., non-reactions) after action patches (*M* = 0.93%, *SD* = 2.11%) compared to instrumental threat patches (*M* = 0.31%, *SD* = 1.11%), *t*(26) = 1.69, *p* = .103. The average STAI trait score was 42.37 (*SD* = 9.08).

Dot probe task.

The same analyses as for Experiments 1 and 2 were performed. Trials with errors were removed (3.55%). Mean latencies and standard deviations of dot probe task responses can be found in Table 1. On trials comparing the threat signal to the non-instrumental safety signal, the analyses revealed a main effect of threat congruence, *F*(1, 26) = 57.16, *p* < .001, *d* = 1.46, 95% CI [0.86, 2.06]. The analysis on trials with the mere action signal and the non-instrumental safety signal showed a significant main effect of action relevance, $F(1, 26) = 10.22$, $p < .005$, $d = 0.61$, 95% CI [0.06, 1.16]. Most importantly, attention is biased towards threat on trials comparing the instrumental threat signal to action signals, main effect of threat congruence, $F(1, 26) = 16.76$, $p < .001$, $d = 0.79$, 95% CI [0.24, 1.34]. Hence, when actions towards threat patches are instrumental in reaching safety in the secondary task, threat signals gain attentional priority both over non-instrumental safety and action signals.

General Discussion

It has long been suggested that attentional processes play a crucial role in defensive reactions to threat (LeDoux, 1996; Öhman & Mineka, 2001), with predominant accounts arguing that imminent danger tunes attention towards threat. Our findings suggest that attention in the presence of threat is biased towards both threat and safety signals. Crucially, the signals that are most instrumental in reaching safety are prioritized over less useful signals suggesting that instrumentality for reaching safety is guiding attention under threat.

Our results lend support to motivational models of emotional attention (Pessoa & Adolphs, 2010; Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013; Vogt et al., 2013; Vromen, Lipp, & Remington, 2015). According to these accounts, attention is not only biased towards emotional events per se but also towards events that become only temporarily motivationally relevant such as means to fight or avoid threat in the present study. In threatening situations, the goal to reach safety is activated (Lerner & Keltner, 2001; Roseman et al., 1994). From a goal perspective, people should attend to both obstacles (i.e. threat) that need to be overcome to reach safety as well as to means that are helpful in reaching safety. This highlights that previous studies might have shown just one consequence of experiencing threat, which is that people become more attentive to threat. In line with previous studies, we observed that threat attracts attention when presented against non-instrumental safety signals in Experiment 1. From a motivational perspective, this is adaptive because it allows people to monitor and prepare for threat. Importantly, the present results show that instrumentality in reaching safety determines whether threatening or safety stimuli gain motivational and attentional priority. That is, instrumental safety and threat cues were prioritized over less instrumental safety and threat cues. Interestingly, we observed these patterns of selective attention towards cues that only matched the color of the instrumental safety signals but that were not instrumental when attention was measured.

Our conclusions are based on the various control signals that we implemented. These comparison stimuli allow us to rule out that our results are driven by mere associations with safety or the mere action-relevance of such signals (Bekkering & Neggers, 2002). For instance, if the fact that instrumental safety signals are associated with the absence of threat (i.e., safety) would drive attention we should not find a difference between non-instrumental safety signals and instrumental safety signals because both signal the absence of threat and both were evaluated as non-threatening. Relatedly, although our results in Experiment 3 confirm that action signals guide the allocation of attention we can rule out that action relevance by itself is responsible for the attentional prioritization of instrumental signals because attention prioritized instrumental safety cues over mere action signals. Further, threat signals were only prioritized over mere action signals when they were instrumental in reaching safety (Experiment 3) but not when they were non-instrumental (Experiment 2). This adds to previous findings (Notebaert et al., 2012) demonstrating that instrumental and action-relevant stimuli associated with pain cause greater attentional prioritization than action-relevant but non-instrumental stimuli associated with pain. This shows that the *functional* value of instrumental safety signals for the goal of reaching safety guides attention and not their action relevance. Finally, other evidence suggests that attention to threat is enhanced when threat is controllable (Brandstätter, Voss, & Rothermund, 2004). However, because threat was (presumably) controllable in all our experiments, this cannot explain that attentional processes prioritized instrumental threat signals as observed in our final experiment.

Our results are also in keeping with accounts suggesting that events with a high motivational value such as events that are or have been linked to a monetary reward gain attentional priority (e.g., Della Libera, & Chelazzi, 2009; Engelmann & Pessoa, 2007; Vogt, De Houwer, & Crombex, 2011). Importantly, our findings extend those findings by showing that events with high motivational value are prioritized over threatening events (cf. Correll et al., 2014; Vogt et al., 2013). Further, whereas previous studies have used monetary rewards to induce high motivational value, our study reveals that instrumentality for reaching safety has high motivational value by itself and subsequently guides attention under threat. By this, our findings shed light on the motivational priorities and motivational strategies that are activated when coping with threat and that guide attention.

Several questions remain with regard to the generalization of our findings to real-life threatening situations. Importantly, our approach does not speak to the question whether threat is detected in a stimulus-driven way when *first* encountering it. This means, the present data do not address the question whether people automatically allocate attention to an unexpected threat (e.g. a snake in the grass). Our account explores how attention is deployed when knowing threat is present. Further, it needs to be acknowledged that, in real-life situations, the most instrumental signal for reaching safety when fighting threat can change quickly across time and contexts. Whether threat or safety signals are more instrumental in reaching safety is therefore likely to fluctuate. For instance, attention to a weapon might be most instrumental when having to act towards it (e.g. grab it). However, when the weapon is in one's hands it seems more instrumental to monitor the attacker (i.e. the threat) in order to know when and how to use the weapon. Relatedly, when first encountering threat, attention should be deployed to the threat to identify it and come up with a judgement of what to do. This shows that it is probably the instrumentality of *monitoring* threat or safety signals that determines the attentional focus rather than the instrumentality of the stimulus itself.

Further, in our studies, the instrumental value of the different signals was clear and it was obvious to participants that they are most instrumental. We implemented such a design because it allowed us to test the basic principle that we are suggesting without individual differences in the perception of instrumentality biasing the results. However, in real life situations, a subjective judgment of instrumentality determines the instrumental value of (monitoring) both threat and instrumental safety signals for reaching safety (Mogg & Bradley, 1998). It might be, for instance, that participants with heightened levels of anxiety show different attentional patterns perhaps because they do perceive monitoring threat as the only and thus most instrumental way to cope with a threatening situation (cf. Lazarus & Folkman, 1984). Similarly, people might differ in their preference to fight or flight or how to fight a threat such as which weapons they would choose. This highlights the importance of investigating appraisals of threat and coping possibilities in relation to individual differences and particular anxiety, ideally in combination with measures of attention (cf. Aue & Okon-Singer, 2015; Notebaert, Maschelein, Wright, & MacLeod, 2016). In our data, participants indicated after the experiment that they did not believe that instrumental signals were instrumental in reaching safety. However, participants very likely realized at this point and especially when asked to answer this question that the signal was actually not instrumental in reaching safety. The fact that participants performed the task with very low error rates indicates that they pursued this goal. Importantly, experiment 2 shows that participants differentiate those signals even from other signals that require action (i.e., action signals) in their ratings. We would therefore recommend to gather such ratings at some point during the task in future research. Finally, when weapons or escape routes are not available monitoring threat is the only way of coping with it. Hence, what is most instrumental and thus attended under threat depends on the nature of the threat and how the individual can or aims to cope with it.

Future research should address some of the limitations of the present study. First, replicating the present experiments with sub clinically or clinically anxious sample could provide important insights into coping mechanisms and related attentional patterns in anxiety. For instance, in addition to displaying enhanced attention to threat, anxious participants might show weaker attentional bias to instrumental safety signals. Although we included anxiety measures here, sample sizes were too small to permit strong conclusions. Second, implementing even shorter stimulus presentation times would permit a more precise insight into the exact time course of attention allocation. For instance, threat monitoring and monitoring for safety might operate at different cognitive levels since the appraisal of instrumental safety signals is likely more complex. Hence, on the basis of the current data we cannot conclude whether attention might initially have only been allocated to signals of threat. In that sense, the current data might reflect attentional maintenance but not attentional orienting. However, it is important to note that we still find attention to threat signals on trials comparing threat signals to non-instrumental safety signals. This allows us to conclude that it is the comparison stimulus that drives the effect on trials comparing threat to instrumental safety signals (i.e., the presence of an instrumental safety signal) because threat signals grab attention in its absence.

In sum, three experiments show that the signals that are most instrumental in reaching safety receive attentional priority. This suggests that the motivation to reach safety guides the allocation of attention when encountering threat.

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Footnotes

[1] None of the conclusions reported for all experiments were changed when using means of reaction times after deleting reaction times shorter than 100 ms and longer than 1000 ms.

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Table 1

Mean RTs and Standard Deviations (in ms) as a Function of Trial Type and Congruence in Experiments 1, 2, and 3

	Congruent[a]		Incongruent[b]		ABI[c]	
Trial type	*M*	*SD*	*M*	*SD*	*M*	*SD*
			Experiment 1			
Threat vs. non-instrumental safety	399	92	418	106	19	30
Instrumental safety vs. non-instrumental safety	391	105	437	137	46	56
Instrumental safety vs. threat	396	104	431	132	35	37
			Experiment 2			
Threat vs. action	366	70	361	65	-6	32
Instrumental safety vs. threat	353	71	378	76	25	27
Instrumental safety vs. action	347	62	376	61	29	24
			Experiment 3			

Action vs. non-instrumental safety	443	74	492	129	49	80
Threat vs. non-instrumental safety	432	93	488	94	56	38
Threat vs. action	445	88	477	89	32	41

Note. [a]Congruent refers to trials in which the probe replaced the picture category first mentioned under trial type.
[b]Incongruent refers to trials in which the probe replaced the picture category mentioned second under trial type.
[c]Attentional bias indices (ABI) were calculated by subtracting RTs on congruent trials from RTs on incongruent trials.

Figure Captions

Figure 1. Schematic overview of a trial of the combined dot probe and secondary task. The first three boxes depict the dot probe task in which the presentation of two color patches was followed by a probe (black square) which had to be localized. The last two boxes display the secondary task in which the presentation of a single stimulus was followed by the appearance of a question mark. Participants had to react to the question mark by pressing the spacebar when the single stimulus presented had been the instrumental safety signal (Experiment 1 and 2), the action signal (Experiment 2 and 3), and/or the instrumental threat signal (Experiment 3).

Figure 2. Attentional bias indices for the different trials in Experiments 1, 2, and 3. Attentional bias indices were calculated by subtracting mean RTs of trials congruent to the category of cues mentioned first for each trial type from mean RTs of trials incongruent to the category of cues mentioned first for each trial type. Positive attentional bias scores indicate attention towards the category of cues mentioned first for each trial type, negative indices indicate attention towards the category of cues mentioned second for each trial type. Error bars indicate standard errors.

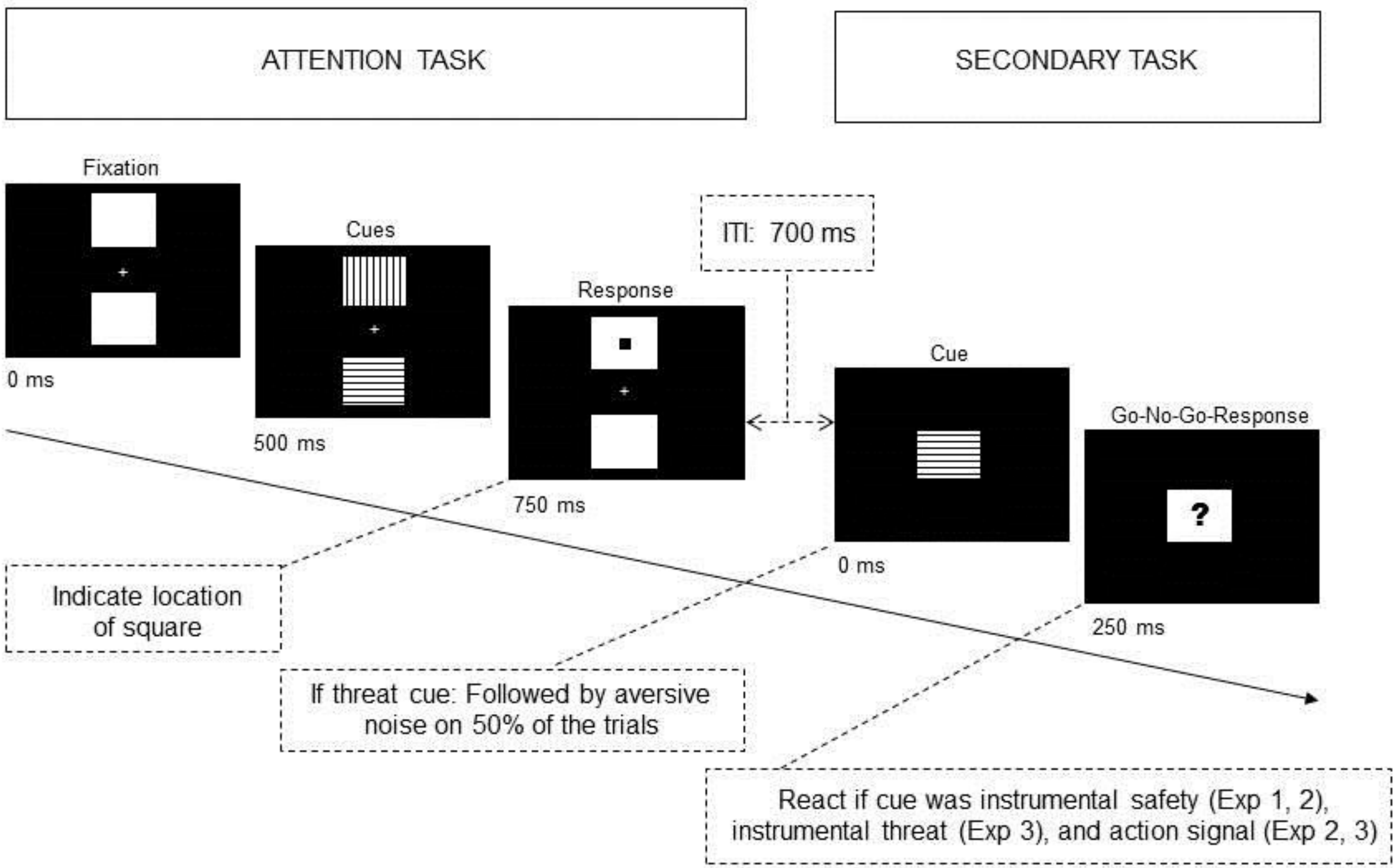
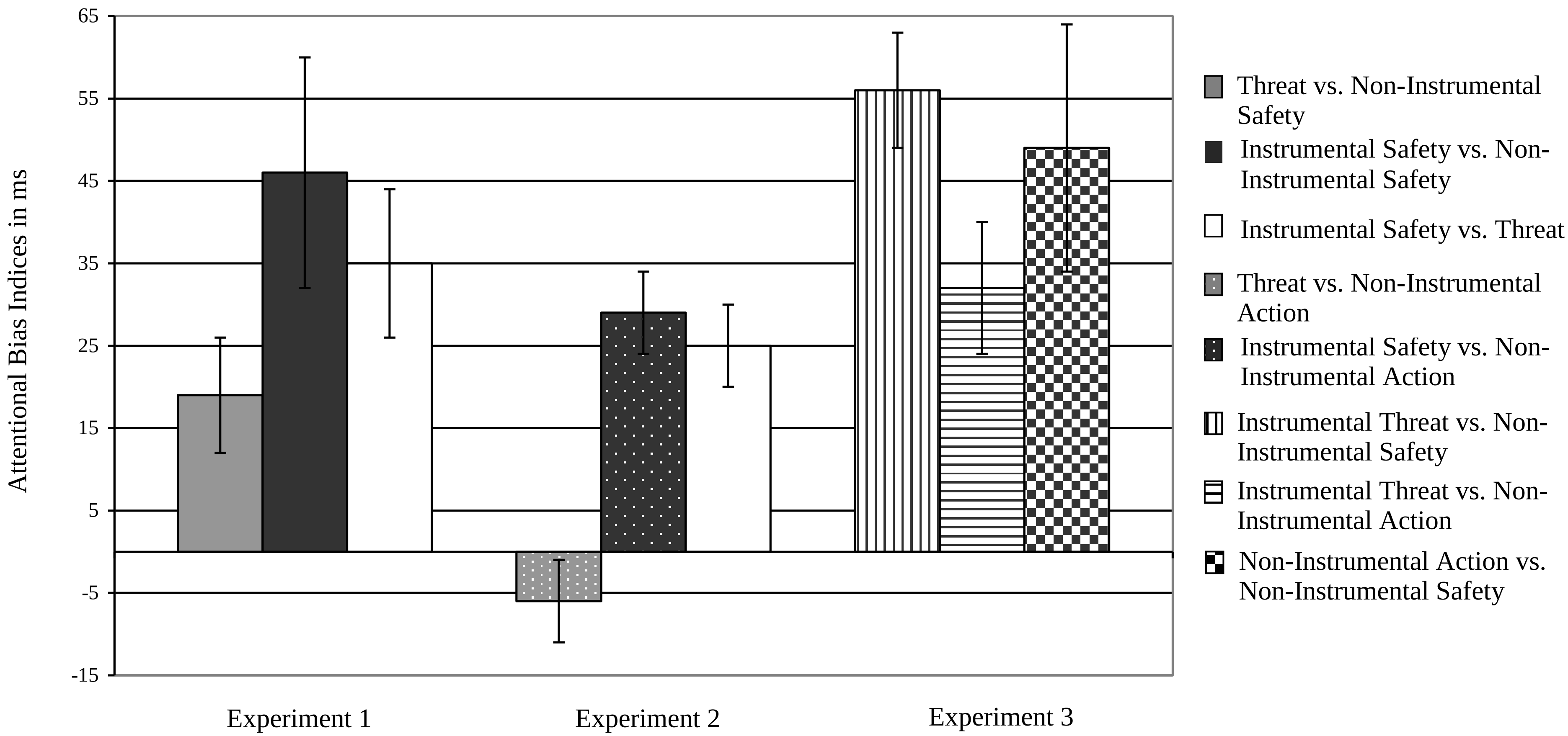

ATTENTION TASK
SECONDARY TASK
Fixation
0 ms
Cues
500 ms
Response
750 ms
ITI: 700 ms
Cue
0 ms
Go-No-Go-Response
?
250 ms
Indicate location of square
If threat cue: Followed by aversive noise on 50% of the trials
React if cue was instrumental safety (Exp 1, 2), instrumental threat (Exp 3), and action signal (Exp 2, 3)

Figure 2.


65
55
45
35
25
15
5
-5
-15
Attentional Bias Indices in ms
Experiment 1
Experiment 2
Experiment 3
Threat vs. Non-Instrumental Safety
Instrumental Safety vs. Non-Instrumental Safety
Instrumental Safety vs. Threat
Threat vs. Non-Instrumental Action
Instrumental Safety vs. Non-Instrumental Action
Instrumental Threat vs. Non-Instrumental Safety
Instrumental Threat vs. Non-Instrumental Action
Non-Instrumental Action vs. Non-Instrumental Safety