



## Of guns and snakes: testing a modern threat superiority effect\*

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### ABSTRACT

Previous studies suggest that ancient (i.e. evolutionary-based) threats capture attention because human beings possess an inborn module shaped by evolution and dedicated to their detection. An alternative account proposes that a key feature predicting whether a stimulus will capture attention is its relevance rather than its ontology (i.e. phylogenetic or ontogenetic threat). Within this framework, the present research deals with the attentional capture by threats commonly encountered in our urban environment. In two experiments, we investigate the attentional capture by modern threats (i.e. weapons). In Experiment 1, participants responded to a target preceded by a cue, which was a weapon or a non-threatening stimulus. We found a larger cuing effect (faster reaction times to valid vs. invalid trials) with weapons as compared with non-threatening cues. In Experiment 2, modern (e.g. weapons) and ancient threats (e.g. snakes) were pitted against one another as cues to determine which ones preferentially capture attention. Crucially, participants were faster to detect a target preceded by a modern as opposed to an ancient threat, providing initial evidence for a superiority of modern threat. Overall, the present findings appear more consistent with a relevance-based explanation rather than an evolutionary-based explanation of threat detection.

### ARTICLE HISTORY

Received 18 March 2016  
Revised 5 January 2017  
Accepted 9 January 2017

### KEYWORDS

Attentional capture; threat; relevance

Being able to deploy early attention to “special” stimuli is one of the most adaptive human functions. Within this broad class of stimuli, those related to danger or threat are of particular importance to the perceiver. For survival purposes, individuals are capable of rapidly and automatically detecting potential threats in their environment. However, which type of threat should be prioritised by our visual attention: Ancient threats (e.g. snakes) tagged by our visual system through evolution or modern threats (e.g. weapons) that represent a more frequent danger in our urban industrialised ecology? Interestingly, although attentional capture by ancient threats has been convincingly demonstrated, this is not as clear with modern threats. The present research speaks specifically to the issue of prioritisation of this class of threats. Our objective is thus twofold: first, to demonstrate that weapons – a common everyday instance of

modern threat – capture attention, and second, to test whether modern threats have an attentional advantage over ancient threats.

### Attentional capture by ancient threats: an evolutionary perspective

Until recently, research on attentional capture by threatening stimuli has been mainly guided by an evolutionary perspective. Threatening stimuli considered within this framework were predominantly biological: those representing a potential danger for our ancestors, such as noxious animals (e.g. Öhman, Flykt, & Esteves, 2001) or angry conspecific faces (e.g. Fox et al., 2000; Hansen & Hansen, 1988). In line with this, theoretical accounts of the threat superiority effect (i.e. defined as the faster detection of threatening stimuli among non-threatening ones) emphasised

the crucial role of evolutionary constraints on the threat detection mechanism and stipulated that organisms are biologically predisposed to detect ancient threats in their environment (Seligman, 1971). Consistent with this view, an evolved “fear module” has been hypothesised allowing individuals to quickly detect such threats in their environment. This module, involving a neural circuitry centred around the amygdala, has been shaped by evolutionary contingencies and is selectively devoted to threat-related stimuli that were present in our ancestors’ environment (LeDoux, 1996; Öhman & Mineka, 2001). Thus, a basic assumption of this perspective is that the fear module is attuned to the detection of evolutionary-based (i.e. ancient) threats. Conversely, evolutionary-irrelevant (i.e. modern) threats should not be preferentially processed by this fear module (e.g. Öhman, 1993).

### **Attentional capture by modern threats: a relevance-based detection perspective**

Although quite heuristic, several researchers have questioned the aforementioned assumption. Specifically, they dispute the fact that the amygdala is dedicated to the detection of threats and rather propose that this structure should be considered as a (more general) relevance-detection system (Pessoa & Adolphs, 2010; Sander, Grafman, & Zalla, 2003). The relevance/significance model posits that attention allocation is biased toward stimuli that have a broader affective and motivational significance for the individual (Broeren & Lester, 2013; Purkis, Lester, & Field, 2011). This relevance should be understood in a broad sense (e.g. including both negative and positive stimuli that are emotionally and socially charged) and could be exemplified by various instances such as a bottle of water for thirsty participants (e.g. Aarts, Dijksterhuis, & De Vries, 2001) or a smiling face for ostracised people (e.g. DeWall, Maner, & Rouby, 2009). Thus, attentional capture is primarily driven by the relevance of the stimulus for the perceiver. In this perspective, a threatening stimulus captures attention because it possesses harmful features that, at a given point in time, are most critical for the individual. Attentional capture by threat is thus conceived as more flexible, context-dependent, and serves therefore to prioritise the processing of particular stimulus features that emerge as the most relevant within a given situation (Pessoa & Adolphs, 2010). Consequently, attentional capture should not

be restricted to a specific class of threatening stimuli, such as ancient threats, but should also apply and even more so to modern threats (because they are relevant within many participants’ ecologies).

Several studies seem to support the hypothesis that modern threats also capture attention. First, Brosch and Sharma (2005) extended the previous work of Öhman et al. (2001) by including modern threatening stimuli (e.g. guns, syringes) in their study. The pattern of results indicated that modern threats capture attention. Additionally, Blanchette (2006) demonstrated an attentional capture of modern threatening stimuli, even with schematic representations of threats (e.g. cartoons, toys). Finally, Fox, Griggs, and Mouchlianitis (2007) replicated these findings by controlling the expected threat value of modern and ancient threatening stimuli. Overall, because these studies demonstrated an attentional bias for modern threats, they, at the very least, question the notion for these processes to be shaped by evolution.

All of the studies mentioned above, however, relied on the same experimental paradigm, namely the visual search task. Typically, in this task, an array of items is presented and participants indicate as quickly as possible whether all items belong to the same category (i.e. same category trials) or whether there is a discrepant target-item (i.e. discrepant trials). On discrepant trials, the target could be a threatening stimulus (e.g. a snake, a gun) surrounded by non-threatening distractors (e.g. flowers, toasters) or the reverse (i.e. a non-threatening target surrounded by threatening distractors). A threat superiority effect is inferred when participants are faster to detect the discrepant target-item when it is threatening rather than non-threatening.

Crucially, this paradigm suffers from several limitations (see Quinlan, 2013). First, the visual search task assesses goal-directed attention rather than stimulus-driven attention (Yantis, 1993). The displayed stimuli are central for the task at hand and participants are asked to process them in order to correctly complete the task. Thus, in this task, searching strategies and task demands – both reflecting top-down processes – greatly determine performance (Frischen, Eastwood, & Smilek, 2008). Yet, and importantly, attentional capture by threatening stimuli is defined as an unintentional process (e.g. Öhman & Mineka, 2001).

Second, the observed threat superiority effect is resulting from a comparison between reaction times (RTs) to detect threatening targets among non-

threatening distractors vs. non-threatening targets surrounded by threatening distractors (as targets and distractors are interchanged between trials). Thus, it is impossible to know whether the effect is due to a faster detection of threatening stimuli or to a faster rejection of non-threatening stimuli (Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005).

Third, previous studies did not carefully control for potential perceptual confounds between threatening and non-threatening stimuli (e.g. shape, colour, luminance), possibly allowing participants to rely on these characteristics in their search for the target (Cave & Batty, 2006; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2011). For instance, LoBue and DeLoache (2011) demonstrated that the coiled shape of snakes is the key feature that produces an attentional advantage: participants were faster to detect a coiled object compared to flowers, whereas a stretched snake did not yield this effect. In this case, the coiled shape is a critical feature that is associated with fear because it is highly predictive of a threat (i.e. a snake). However, some perceptual confounds could be more incidental, as the presence of flanges for a syringe compared with a pen as used in Blanchette's study (Quinlan, 2013).

Noteworthy, we are aware of one study that investigated the attentional capture by modern vs. ancient threats using a distinct paradigm, namely, the peripheral cuing task (Young, Brown, & Ambady, 2012). These authors showed a larger attentional capture for ancient threats in comparison to modern threats when participants were primed with a natural environment (e.g. a picture of hiking trails), and conversely, a larger attentional capture for modern threats in comparison to ancient threats when participants were primed with a human-made environment (e.g. a picture of a city street). Although this finding represents initial support for an attentional capture by modern threats in a paradigm devoid of the previous criticisms, their design does not allow drawing definitive conclusions concerning a potential superiority of modern threat. Specifically, the absence of control stimuli enables only the examination of the relative effects of types of threat (i.e. ancient vs. modern). And, because there was no main effect of the type of threat, the claim of an advantage of modern threats seems premature. Moreover, as the authors themselves acknowledged, their findings may reflect the operation of priming processes (due to the initial presentation of a particular environment in each trial). Indeed, research shows that initial conceptual

information can elicit involuntary attention allocation to semantically matching stimuli (e.g. Wyble, Folk, & Potter, 2013). Thus, although particularly important, these findings do not unequivocally support a relevance-detection mechanism.

### **Toward a relevance-based prioritisation of ancient vs. modern threats**

As just reviewed, previous research on the threat superiority effect does not allow a firm conclusion as to whether modern threats have the potential to capture attention more (or less) than ancient threats. A more stringent test of this notion would directly compare these two types of stimuli competing in the same visual scene. However, to date, no study has addressed this critical issue. If an individual is confronted in her/his immediate environment to both a modern and an ancient threat, which one will be prioritised by the visual system? This situation is particularly interesting regarding the two main theoretical accounts presented previously. On the one hand, from an evolutionary perspective one could derive either a strong or a "soft" prediction. The former would be that ancient threats are prioritised over modern threats, because the fear module preferentially processes this type of stimuli. The latter would rely on the additional assumption that modern threats can under certain conditions (e.g. repeated aversive experiences or intense traumatic event) gain access to the fear module (Öhman & Mineka, 2001). Therefore, it could be that modern and ancient threats capture attention somewhat to the same extent. Crucially, what seems relatively clear is that the evolutionary account would hardly predict that modern threats are prioritised over ancient threats. On the other hand, the relevance-detection hypothesis predicts that weapons have more potential to capture attention than snakes or spiders, because in our everyday ecology (i.e. modern urban environments), guns are more likely to represent an imminent threat than snakes.

### **Overview of the present research**

The present research is thus designed to test, across two experiments, the attentional capture of modern threats and to directly compare two classes of threatening stimuli: ancient and modern threats. The goal of Experiment 1 is to use a peripheral cuing task to investigate the attentional capture by modern

threats. In this task, a first display containing an orienting cue is presented briefly, followed by the measure display with the target to be detected. The cue indicates either the location of the target (valid cue) or another location thus representing an inaccurate predictor of the target (invalid cue). This typically produces a cuing effect with faster RTs for valid than for invalid cues (Posner, 1980)

The use of this paradigm solves the main issues raised by the visual search task. The peripheral cuing task is particularly appropriate to reveal an involuntary attentional capture for at least three reasons (e.g. Jonides, 1981). First, in this task, (un)intentionality is tapped by focusing on attentional shifts to cued locations: participants are not required to process the cues that can be made irrelevant for the task at hand. Second, the cues are outside the focus of attention, because they are displayed peripherally at unattended locations. Indeed, the onset of stimuli at peripheral locations is particularly adapted for looking at attentional capture (i.e. stimulus-driven processes). Third, the peripheral cuing task allows one to display separately threatening and non-threatening stimuli on each trial. This simplifies the interpretation of RTs as compared to the visual search task (i.e. it precludes the fact that RTs are either due to faster detection of the target or faster rejection of the distractors). The goal of Experiment 2 is to further our examination of attentional prioritisation. To do so, we directly compare the attentional capture by ancient and modern threats within the same visual display.

## Experiment 1

### Method

#### Participants and design

Participants were 30 French undergraduate students ( $M_{\text{age}} = 20.3$ ,  $SD = 1.68$ ; 21 females). All participants had normal or corrected-to-normal vision. The experimental design included two within-participants variables: cue type (weapon, neutral) and cue validity (valid, invalid).

#### Materials and procedure

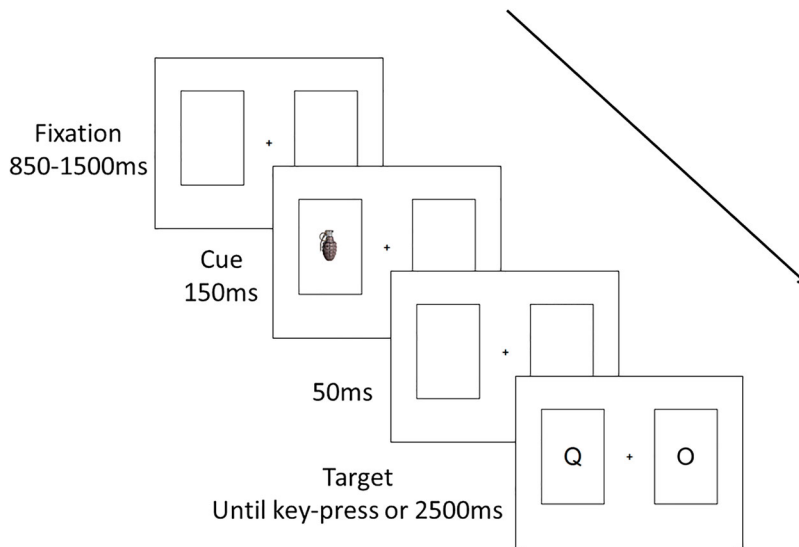
Participants were seated in an isolated cubicle 80 cm from a 17" monitor with a display rate of 60 Hz. All experiments were programmed and run using E-Prime software (Schneider, Eschman, & Zuccolotto, 2012). The cue stimuli consisted of 34 photos: 17 weapons (guns, knives, grenades, and assault rifles)

and 17 neutral objects (badminton-rackets, coat-hangers, hairbrushes, lights, and whisks). All photos presented an object on a white background ( $100 \times 100$  pixels, see Appendix).

Importantly, we took several systematic precautions for controlling perceptual confounds between threatening and non-threatening objects. First, as non-threatening stimuli we chose human-made graspable objects that are comparable in size to weapons. Second, we used objects sharing the same basic shape (e.g. wisks vs. knives). Finally, visual salience of the stimuli was controlled following the procedure of Crouzet, Joubert, Thorpe, and Fabre-Thorpe (2012). We computed for each photo mean and contrast luminance (Root Mean Square contrast) using estimates from Matlab. Indeed, these two perceptual features are strongly related to attentional capture (e.g. Bex & Makous, 2002; Proulx & Egeth, 2008). A *t*-test revealed that mean luminance did not differ significantly between weapons ( $M = 229.6$ ,  $SD = 9.75$ ) and neutral photos ( $M = 232.8$ ,  $SD = 11.6$ ),  $t(32) = 0.89$ ,  $p = .37$ ,  $d = 0.31$ , 95% CI  $[-0.37, 0.98]$ . Also, contrast luminance did not differ between weapons ( $M = 0.27$ ,  $SD = 0.06$ ) and neutral photos ( $M = 0.25$ ,  $SD = 0.09$ ),  $t(32) = 0.71$ ,  $p = .48$ ,  $d = 0.24$ , 95% CI  $[-0.43, 0.92]$ . Accordingly, the two sets of stimuli were comparable regarding these basic perceptual features.

The target stimulus was an Arial black letter ("O") on a white background with a height of 1.5 cm ( $1.1^\circ$ ) and a width of 1.5 cm ( $1.1^\circ$ ). Cue and target stimuli were presented inside white boxes that were 12 cm high ( $8.5^\circ$ ) and 8 cm wide ( $5.7^\circ$ ), delimited by a black border (0.1 cm) and displayed 9 cm ( $6.4^\circ$ ) to the left and the right of the central fixation cross. These squares remained on screen throughout the task.

On each trial, a fixation cross appeared for a random duration of 850–1500 ms. Next, a cue appeared either inside the right or the left box for 150 ms. The cue was then blanked out and after 50 ms the measure display was presented and consisted of two Arial black letters. These were 1 O and 1 Q for 136 trials (target present) and 2 Qs for 34 trials (target absent or "catch" trials). The display remained until the participant responded or 2500 ms elapsed. The participant's task was to press the space key using the dominant hand as quickly as possible if the target was present on either side of the screen. Alternatively, they were instructed to withhold their response on catch trials. The intertrial interval was 500 ms (see Figure 1 for a graphic example of an experimental trial). In this experiment, we used a detection task (i.e. pressing a single



**Figure 1.** Sequence of events for each trial (Experiment 1).

key whenever the target is present) rather than a localisation task (i.e. indicating the position of the target, left or right, by pressing the corresponding key), to ensure that the cue validity effect is due to attentional processes in the absence of motor-preparation mechanisms (Fox, Russo, Bowles, & Dutton, 2001; Töllner, Rangelov, & Müller, 2012).

There were 15 practice trials followed by a block of 170 experimental trials. Each of the 34 photos was presented 5 times: twice on the valid trials (once on the left, once on the right), twice on the invalid trials (once on the left, once on the right) and once on catch trials (i.e. targetless trials). To prevent a strategic use of the cue, we made it non predictive of target localisation. Thus, 40% of the trials were valid (i.e. the target appeared in the same location as the cue), 40% were invalid (i.e. the target appeared in the opposite location as the cue), and 20% were catch trials (i.e. the target did not appear). We report all manipulations, all measures, and all data exclusions (if any). From previously published studies with similar designs, the current sample size was determined to be sufficient to detect the effects under consideration. No interim analyses were performed.

## Results and discussion

Only RTs for correct responses were analysed. Errors on catch trials (i.e. anticipatory responses) represented 7.9% and errors on target present trials (i.e. no

responses) amounted to 0.1%. Latencies shorter than 150 ms were discarded while latencies longer than 1200 ms were replaced with 1200 ms (proportion of outlier latencies was 0.1%). Mean latencies and standard deviations are shown in Table 1. A 2 (cue type: weapon, neutral)  $\times$  2 (cue validity: valid, invalid) repeated-measures ANOVA revealed a main effect of cue validity,  $F(1, 29) = 109.44, p < .001, \eta_p^2 = 0.79, 90\%^{1}$  CI [0.65, 0.85]. Participants were faster to detect the target after a valid ( $M = 471$  ms,  $SD = 72$ ) than after an invalid cue ( $M = 535$  ms,  $SD = 74$ ). The cue type main effect did not reach significance,  $F(1, 29) = 1.61, p = .21, \eta_p^2 = 0.05, 90\%$  CI [0.00, 0.22]. Crucially, the predicted cue type by cue validity interaction was

**Table 1.** Mean reaction times (ms) and standard deviations as a function of cue type and cue validity in Experiments 1 and 2.

Cue type	Cue validity				ABI <sup>a</sup>
	Valid trials		Invalid trials		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Experiment 1					
Weapon	467	73	545	72	78
Neutral	476	72	525	77	49
Experiment 2					
Modern vs. ancient <sup>b</sup>	541	74	–	–	12
Ancient vs. modern <sup>b</sup>	553	74	–	–	–

<sup>a</sup>Attentional Bias Indices (ABI) were calculated by subtracting RTs on valid trials from RTs on invalid trials.

<sup>b</sup>For Experiment 2, “Valid trials” refers to trials for which the target replaced the stimulus category mentioned first under “Cue type” whereas “Invalid trials” refers to trials for which the target replaced the second stimulus category.

significant,  $F(1, 29) = 27.05$ ,  $p < .001$ ,  $\eta_p^2 = 0.48$ , 90% CI [0.25, 0.62]. As Figure 2 illustrates, this interaction confirms that the cuing effect was larger with a weapon cue than with a neutral one.

As we will mention in the general discussion section, several authors suggest that testing cue type simple effects is informative to investigate whether threatening stimuli attract (i.e. draw) or hold attention (Fox et al., 2001; Stolz, 1996). The former, they argue, translates into valid cue simple effects and the latter into invalid cue simple effects. Tests of these cue type simple effects revealed that on valid trials, RTs following weapon cues ( $M = 467$  ms,  $SD = 73$  ms) were faster than RTs following neutral cues ( $M = 476$  ms,  $SD = 72$  ms),  $t(29) = 3.03$ ,  $p < .005$ ,  $d = 0.55$ , 95% CI [0.16, 0.93]. These tests also revealed that on invalid trials RTs following weapon cues ( $M = 545$  ms,  $SD = 72$  ms) were slower than RTs following neutral cues ( $M = 525$  ms,  $SD = 77$  ms),  $t(29) = 3.6$ ,  $p < .001$ ,  $d = 0.66$ , 95% CI [0.26, 1.05]. Thus, this pattern of results would suggest that weapon cues both hold and attract attention.

In the previous analysis, we used a standard ANOVA that treats participants as the only random variable. This means that the results can only be generalised to other participants, but not to other stimuli (Judd, Westfall, & Kenny, 2012). To test whether we could generalise the predicted interaction on other participants as well as other stimuli, we also tested this interaction using a mixed model treating both participants and stimuli as random variables (Judd

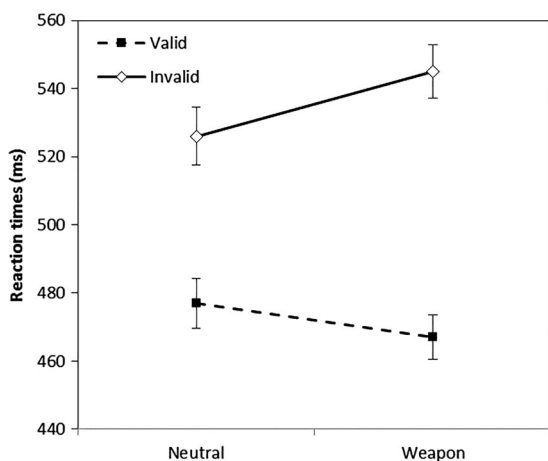
et al., 2012). Importantly, this mixed model revealed a significant interaction,  $t(46) = 3.88$ ,  $p < .001$ ,<sup>2</sup> suggesting that we can generalise this effect not only to different participants, but also to different stimuli.

## Experiment 2

The results of Experiment 1 showed that weapons indeed capture attention. This conclusion is consistent with previous findings suggesting that not only ancient, phylogenetic threats but also ontogenetic, modern threats capture attention (e.g. Blanchette, 2006). Unlike previous research, Experiment 1, however, used a different task, with a carefully controlled set of stimuli, and additionally included a mixed model analysis.

Overall, these findings are coherent with the relevance-detection framework (Pessoa & Adolphs, 2010; Purkis et al., 2011; Sander et al., 2003). In addition, these findings might be reconciled with a “soft” version of the evolutionary perspective with the additional amendment that ontogenetic threat has also access to the fear module.

To further our test, in Experiment 2 our goal was to directly compare the attentional capture of modern and ancient threats. To do so, we used a similar peripheral cuing paradigm with a major modification: a modern and an ancient threatening stimulus were presented simultaneously on each trial (i.e. the dot-probe task, see MacLeod, Mathews, & Tata, 1986). As already mentioned, using a task with a simultaneous cue presentation could be a limitation, because we would not know whether an attentional capture effect is due to one stimuli attracting attention or the other pushing attention away. In this specific situation, however, previous work consistently showed that these two kinds of stimuli do not push attention away (e.g. Blanchette, 2006; Brosch & Sharma, 2005; Fox et al., 2000, 2007; Hansen & Hansen, 1988; Öhman et al., 2001). Therefore, in this context, it is safe to use the two types of stimuli concurrently and to directly pit them against each other in order to tackle the attentional prioritisation issue. With such an adaptation of the paradigm, instead of comparing the difference between valid and invalid trials for different types of cue (and therefore test an interaction), we will compare trials for which modern threats are valid (i.e. modern threats will be on the same side as the to-be-presented target, while ancient threats will be on the opposite side) with



**Figure 2.** Mean reaction times (ms) as a function of cue validity and cue type (Experiment 1). Error bars represent 95% confidence intervals.

trials for which ancient threats are valid (i.e. ancient threats will be on the same side as the to-be-presented target, while modern threats will be on the opposite side). Accordingly, in this last experiment, a strong version of the evolutionary perspective would predict that ancient threats capture attention over modern threats (i.e. RTs will be faster when ancient threats, instead of modern threats, serve as valid cues), while a “soft” version would predict no difference between these two classes of threats. Conversely, a relevance-detection perspective would predict that modern threats capture attention over ancient threats (i.e. RTs will be faster when modern threats, instead of ancient threats, serve as valid cues).

## Method

### Participants and design

Participants were 60 French undergraduate students ( $M_{\text{age}} = 21.5$ ,  $SD = 3.05$ ; 43 females). All participants had normal or corrected-to-normal vision. The experimental design included one within-participants variable: type of valid cue (modern threat vs. ancient threat).

### Materials and procedure

As in Experiment 1, two types of cues were presented. Importantly, for this experiment we used a completely new set of stimuli. There were 15 photos of modern threats (guns, knives, and grenades) and 15 photos of ancient threats (spiders, snakes, and scorpions). All photos of modern threats presented a hand-held object on a white background ( $100 \times 100$  pixels), whereas all photos of ancient threats presented an animal on a tree branch on a white background ( $100 \times 100$  pixels). All photos were transposed to grey-scale to reduce colour variations between stimuli (see Appendix). As in Experiment 1, mean and contrast luminance were computed and compared between the two sets of stimuli. A  $t$ -test revealed that mean luminance did not differ significantly between modern ( $M = 210.8$ ,  $SD = 11.11$ ) and ancient stimuli ( $M = 211.7$ ,  $SD = 8.17$ ),  $t(28) = 0.25$ ,  $p = .80$ ,  $d = 0.09$ , 95% CI  $[-0.63, 0.81]$ . Also, contrast did not differ between modern ( $M = 0.32$ ,  $SD = 0.08$ ) and ancient stimuli ( $M = 0.35$ ,  $SD = 0.05$ ),  $t(28) = 1.29$ ,  $p = .20$ ,  $d = 0.47$ , 95% CI  $[-0.26, 1.20]$ . A pilot study (using a go/no go task) was run on 10 participants to ensure that each kind of stimulus was identified to the same extent. As expected, identification rate did not differ between modern ( $M = 85\%$ ,  $SD = 6\%$ ) and

ancient cues ( $M = 88\%$ ,  $SD = 8\%$ ),  $F(1, 28) = 0.73$ ,  $p = .40$ ,  $d = 0.31$ , 95% CI  $[-0.41, 1.03]$ .

The procedure was identical to Experiment 1 except that the two types of cues were presented simultaneously on each trial. There were 10 practice trials followed by a block of 150 experimental trials. Each of the 30 photos was presented 10 times: 4 times on the same side as the target (i.e. valid; 2 on the left, 2 on the right), 4 times on the opposite side as the target (i.e. invalid; 2 on the left, 2 on the right) and 2 times on catch trials (i.e. targetless trials). Thus, in 40% of the trials, the target was displayed on the same side as the modern cues (modern valid) and in 40% of the trials, the target was displayed on the same side as the ancient cues (ancient valid). The remaining 20% of the trials were catch trials. The pairing of the two types of cues was randomly determined. We report all manipulations, all measures, and all data exclusions (if any). From previously published studies with similar designs, the current sample size was determined to be sufficient to detect effects under consideration. No interim analyses were performed.

## Results and discussion

We only analysed RTs for correct responses. Anticipatory responses (i.e. responses on catch trials) occurred on 10% of the catch trials and error on target present trials (i.e. no responses) did not occur. Latencies shorter than 150 ms were discarded while latencies longer than 1200 ms were replaced with 1200 ms (proportion of outlier latencies was 0.3%). A paired  $t$ -test revealed that RTs for modern valid trials ( $M = 541$  ms,  $SD = 74$  ms) were faster than RTs for ancient valid trials ( $M = 553$  ms,  $SD = 74$  ms),  $t(59) = 4.48$ ,  $p < .001$ ,  $d = 0.57$ , 95% CI  $[0.30, 0.85]$ . Thus, modern threatening stimuli seem to have an attentional advantage over ancient threatening stimuli.

Again, to test whether we could generalise this effect to other participants as well as to other stimuli, we tested it using a mixed model treating both participants and stimuli as random variables. This mixed model revealed a significant difference,  $t(24.03) = 3.62$ ,  $p < .002$ , suggesting that we can generalise this effect not only to different participants, but also to different stimuli.

## General discussion

Being able to pick up threatening stimuli at early stages of information processing is highly functional.

This functionality of stimulus selection might have presumably been shaped by evolutionary constraints. If so, studying an attentional bias by modern threats (e.g. weapons) is informative, because these are less likely to have been selected by evolution than ancient threats (e.g. snakes). Our two experiments suggest that modern threats do capture visual attention (Experiment 1) and, in fact, even more so than ancient threats (Experiment 2). More specifically, in Experiment 1, we used a peripheral cuing paradigm and found a larger cuing effect for weapon cues than for neutral ones, suggesting that modern threats reliably capture visual attention. In Experiment 2, we directly compared attention to modern and ancient threats by displaying them simultaneously. Crucially, our results showed that modern threats capture attention more readily than ancient threats.

Our first contribution concerns the direct test of whether weapons capture attention. As mentioned above, previous work relied on the visual search task that comes with all the limitations discussed in the introduction section. The peripheral cuing task we used overcomes these limitations and enabled us to show that weapons do in fact capture attention.

In addition, scholars in the attention domain also suggest that using this paradigm enables distinguishing whether attention is drawn or held by these threatening cues (Fox et al., 2001; Stolz, 1996). To do so, these authors suggest to test whether the different types of cues differ on valid cues – implying a difference in attention drawing – or on invalid cues – implying a difference in attention holding. Using this framework, previous studies have shown that threatening stimuli are more likely to affect the holding component of attention (e.g. Fox et al., 2001; Fox, Russo, & Dutton, 2002; Koster, Crombez, Verschuere, & De Houwer, 2004). In contrast with these results, in Experiment 1, it seems that weapons both drew and held attention to a larger extent than neutral cues, because both simple effects (i.e. for valid and invalid cues) were significant (see however Alexopoulos, Muller, Ric, & Marendaz, 2012, for a discussion of such analysis relying on simple effects).

Finally, Experiment 1 extends previous work by using carefully controlled stimuli and by performing mixed models analyses enabling to generalise to other stimuli in addition to other participants.

Our second contribution is to provide a direct comparison between attentional capture by modern threats and ancient threats. Indeed, we show in Experiment 2 that visual attention is preferentially oriented

toward modern rather than ancient threatening stimuli when they are presented simultaneously. These findings do not fit well with an evolutionary explanation of the threat superiority effect given that an innate bias could not account for such findings. If the detection of threat is handled by a specific neural circuitry shaped by evolution, this fear module would be only triggered by threats that existed at the time this module was shaped or at least, would be preferentially triggered by these threats than by modern threats. The results of Experiment 2 do not support these predictions and rather indicate that modern threats preferentially attract attention over more ancient threats. Thus, our findings suggest that evolutionary shaping per se is not the definitive key factor regarding whether a threatening stimulus will capture attention. A more parsimonious explanation entails that, for our participants, a gun or a knife is more likely to be a relevant threat than a snake in their current environment. More generally, these findings are coherent with the relevance/significance framework (Broeren & Lester, 2013; Pessoa & Adolphs, 2010; Purkis et al., 2011; Sander et al., 2003). According to this account, attentional resources are rapidly deployed toward any stimulus that is relevant to a person and they are not confined to a specific and narrow class of stimuli. Indeed, relevance is an emergent property shaped by the dynamics between the characteristics of the stimuli, the characteristics of the perceiver (internal state, goals, motivation, or prior knowledge/experiences), and the characteristics of the context (e.g. Pessoa & Adolphs, 2010). In line with this, three experiments recently showed that safety cues receive more attention than threatening cues when the former cues are a means to reach safety, whereas threatening cues receive more attention than safety cues when the former cues were instrumental in reaching safety (Vogt, Koster, & De Houwer, 2016).

### *Limitation and future directions*

There are two reasons to be cautious with rejecting an evolutionary account of threat detection. First, it could be that the attentional deployment to modern threats is handled by a distinct mechanism than the quick subcortical route dedicated to the detection of ancient threats. In that case, the finding of an attentional prioritisation of modern threats does not necessarily invalidate the existence of a fear module. For instance, LoBue (2012) proposed a dual pathway



model in which the detection of ancient threats is an innate bias relying on the evolved fear module, whereas the detection of modern threats is a consequence of general learning mechanisms (e.g. conditional learning), allowing more plasticity regarding the acquisition of new stimuli that trigger fast and automatic detection (see also Blanchette, 2006). In line with this, previous work showed that children displayed an attentional bias for snakes, even if they did not had a first-hand negative experience with them (e.g. LoBue & DeLoache, 2008), whereas they displayed an attentional bias for ontogenetic threat solely if they had previous negative experiences (i.e. three-year-old children displayed an attentional bias for syringes, because a majority of them had negative experiences with them, whereas they did not display an attentional bias for knives for which they did not experience aversive events; LoBue, 2010).

Second, some of the theories based on an evolutionary perspective do not dispute the fact that modern threats also capture attention. For instance, the evolved fear module theory (Öhman & Mineka, 2001) stipulates that modern threatening stimuli can activate the fear module and thus capture attention. This model proposes that modern threatening stimuli could also access this module if a strong relation is learned between a specific stimulus and an aversive outcome or affective state (Koster et al., 2004). Given that a gun is strongly and frequently associated with aversive outcomes, it is possible that this object is tagged as a threatening stimulus by the fear module and thus triggers an attentional capture. Even if such an explanation still holds, we believe the relevance/significance framework to provide a more parsimonious account of our results. Nevertheless, future research should further investigate and identify the mechanisms underlying these attentional biases.

A final comment should be made concerning the automatic nature of attentional capture. Theoretically, it is assumed that this effect takes place in an automatic fashion, because it is not under voluntary control (e.g. Öhman & Mineka, 2001). Empirically, findings of previous research were not totally consistent with the fact that attentional capture is endowed with features of automaticity (e.g. Blanchette, 2006; Fox et al., 2000; Quinlan, 2013). Yet, results of the present research indicate that attentional capture is unintentional. Because unintentionality is only one of the four features of automaticity (the remaining one being unconsciousness, uncontrollability, and

efficiency; e.g. Bargh, 1996; Moors & De Houwer, 2006), future research is needed to assess the other three features. For instance, one could test unconsciousness, using a subliminal cuing, or uncontrollability, using an anti-saccade task, to provide further evidence for the automaticity of this attentional bias (see Alexopoulos et al., 2012, for an illustration).

In conclusion, the present results demonstrate that modern threats capture attention. Moreover, they are the first to show that they preferentially capture attention over ancient threats when presented simultaneously. In doing so, the present research provides cogent evidence for a relevance-detection explanation of the threat superiority effect. It does so by relying on an ecological approach as it considers one's immediate urban environment. Within this perspective, a relevance-detection mechanism attuned to the current environment makes sense from an adaptive viewpoint, in that it is more likely to face a knife attack than a snake attack in a downtown sidewalk.

## Notes

1. We used the 90% confidence intervals for eta-squared, because eta-squared cannot be negative and, therefore, 90% confidence intervals for eta-squared correspond to 95% confidence intervals for other indexes.
2. It is worth mentioning that mixed models often come with approximation of degrees of freedom (in our case Satterthwaite approximations). This explains why these degrees of freedom contain decimals. In addition, there is still no real consensus about which effect size to use with such models. Accordingly, we refrain from presenting such estimates.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## References

- Aarts, H., Dijksterhuis, A., & De Vries, P. (2001). On the psychology of drinking: Being thirsty and perceptually ready. *British Journal of Psychology*, *92*, 631–642.
- Alexopoulos, T., Muller, D., Ric, F., & Marendaz, C. (2012). I, me, mine: Automatic attentional capture by self-related stimuli. *European Journal of Social Psychology*, *42*, 770–779.
- Bargh, J. A. (1996). Principles of automaticity. In E. T. Higgins & A. Kruglanski (Eds.), *Social psychology: Handbook of basic principles* (pp. 169–183). New York: Guilford.
- Bex, P. J., & Makous, W. (2002). Spatial frequency, phase, and the contrast of natural images. *Journal of Optical Society of America*, *19*, 1096–1106.

- Blanchette, I. (2006). Snakes, spiders, guns, and syringes: How specific are evolutionary constraints on the detection of threatening stimuli? *Quarterly Journal of Experimental Psychology*, *59*, 1484–1504.
- Broeren, S., & Lester, K. J. (2013). Relevance is in the eye of the beholder; attentional bias to relevant stimuli in children. *Emotion*, *13*, 262–269.
- Brosch, T., & Sharma, D. (2005). The role of fear-relevant stimuli in visual search: A comparison of phylogenetic and ontogenetic stimuli. *Emotion*, *5*, 360–364.
- Cave, K. R., & Batty, M. J. (2006). From searching for features to searching for threat: Drawing the boundary between preattentive and attentive vision. *Visual Cognition*, *14*, 629–646.
- Crouzet, S. M., Joubert, O. R., Thorpe, S. J., & Fabre-Thorpe, M. (2012). Animal detection precedes access to scene category. *PLoS One*, *7*, e51471.
- DeWall, N. C., Maner, J. K., & Rouby, D. A. (2009). Social exclusion and early-stage interpersonal perception: Selective attention to signs of acceptance. *Journal of Personality and Social Psychology*, *96*, 729–741.
- Fox, E., Griggs, L., & Mouchlianitis, E. (2007). The detection of fear-relevant stimuli: Are guns noticed as quickly as snakes? *Emotion*, *7*, 691–696.
- Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion*, *14*, 61–92.
- Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, *130*, 681–700.
- Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion*, *16*, 355–379.
- Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin*, *134*, 662–676.
- Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, *54*, 917–924.
- Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J. B. Long & A. D. Baddeley (Eds.), *Attention and performance IX* (pp. 187–203). Hillsdale, NJ: Erlbaum.
- Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology*, *103*, 54–69.
- Koster, E. H. W., Crombez, G., Verschuere, B., & De Houwer, J. (2004). Selective attention to threat in the dot probe paradigm: Differentiating vigilance and difficulty to disengage? *Behaviour Research and Therapy*, *42*, 1183–1192.
- LeDoux, J. E. (1996). *The emotional brain*. New York, NY: Simon & Schuster.
- LoBue, V. (2010). What's so scary about needles and knives? Examining the role of experience in threat detection. *Cognition and Emotion*, *24*, 180–187.
- LoBue, V. (2012). Perceptual biases for threat. In G. W. Mills, S. J. Stone (Eds.), *Psychology of bias*, pp. 3752. New York: Nova Science
- LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science*, *19*, 284–289.
- LoBue, V., & DeLoache, J. S. (2011). What so special about slithering serpents? Children and adults rapidly detect snakes based on their simple features. *Visual Cognition*, *19*, 129–143.
- MacLeod, C., Mathews, A. M., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*, 15–20.
- Moors, A., & De Houwer, J. (2006). Automaticity: A conceptual and theoretical analysis. *Psychological Bulletin*, *132*, 297–326.
- Notebaert, L., Crombez, G., Van Damme, S., De Houwer, J., & Theeuwes, J. (2011). Signals of threat do not capture, but prioritize, attention: A conditioning approach. *Emotion*, *11*, 81–89.
- Öhman, A. (1993). Fear and anxiety as emotional phenomena: Clinical phenomenology, evolutionary perspectives, and information processing mechanisms. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 511–536). New York: Guilford Press.
- Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*, *108*, 483–522.
- Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*, 466–478.
- Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: From a 'low road' to 'many roads' of evaluating biological significance. *Nature Reviews Neuroscience*, *11*, 773–783.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*, 3–25.
- Proulx, M. J., & Egeth, H. E. (2008). Biased competition and visual search: The role of luminance and size contrast. *Psychological Research*, *72*, 106113.
- Purkis, H. M., Lester, K. J., & Field, P. (2011). But what about the empress of Racnoss: The allocation of attention to spiders and doctor who in a visual search task is predicted by fear and expertise. *Emotion*, *11*, 1484–1488.
- Quinlan, P. T. (2013). The visual detection of threat: A cautionary tale. *Psychonomic Bulletin & Review*, *20*, 1080–1101.
- Rinck, M., Reinecke, A., Ellwart, T., Heuer, K., & Becker, E. S. (2005). Speeded detection and increased distraction in fear of spiders: Evidence from eye movements. *Journal of Abnormal Psychology*, *114*, 235–248.
- Sander, D., Grafman, J., & Zalla, T. (2003). The human amygdala: An evolved system for relevance detection. *Reviews in the Neurosciences*, *14*, 303–316.
- Schneider, W., Eschman, A., & Zuccolotto, A. (2012). *E-prime user's guide*. Pittsburgh, PA: Psychology Software Tools.
- Seligman, M. E. P. (1971). Phobias and preparedness. *Behavior Therapy*, *2*, 307–320.
- Stolz, J. A. (1996). Exogenous orienting does not reflect an encapsulated set of processes. *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 187–201.
- Töllner, T., Rangelov, D., & Müller, H. J. (2012). How the speed of motor-response decisions, but not focal-attentional selection, differs as a function of task set and target prevalence. *Proceedings of the National Academy of Sciences*, *109*, E1990–E1999.
- Vogt, J., Koster, E. H. W., & De Houwer, J. (2016). Safety first: Instrumentality for reaching safety determines attention

allocation under threat. *Emotion*. Advance online publication. doi:10.1037/emo0000251

Wyble, B., Folk, C., & Potter, M. C. (2013). Contingent attentional capture by conceptually relevant images. *Journal of Experimental Psychology: Human Perception and Performance*, 39, 861–871.

Yantis, S. (1993). Stimulus-driven attentional capture. *Current Directions in Psychological Science*, 2, 156–161.

Young, S. G., Brown, C. M., & Ambady, N. (2012). Priming a natural or human-made environment directs attention to context-congruent threatening stimuli. *Cognition and Emotion*, 26, 927–933.

## Appendix. Examples of stimuli used in the different studies

### Experiment 1



### Experiment 2

