Correspondences

Threat modulates perception of looming visual stimuli

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Among the most critical of visual functions is the detection of potentially hazardous or threatening aspects of the environment. For example, objects on a collision course with an observer must be quickly identified to allow sufficient time to prepare appropriate defensive or avoidant responses. Directly approaching objects produce a specific accelerating pattern of optical expansion, known as 'looming, which in theory exactly specifies time-to-collision independent of object size or distance. Such looming stimuli have been shown to trigger stereotyped defensive responses in both monkeys [1] and human infants [2]. Psychophysical results in adult participants have similarly suggested sensitivity to looming at early stages of visual processing [3]. Such findings indicate specialization of the visual system to detect and react to such 'looming' stimuli, and have contributed to the traditional view of looming as a purely optical cue to imminent collision [1]. Here, we investigated whether the semantic content of a looming visual stimulus affects perceived time-to-collision by manipulating its threat value. We show that time-to-collision is underestimated for threatening (snakes and spiders) compared to non-threatening (butterflies and rabbits) stimuli. Further, the magnitude of this effect is correlated with self-reported fear. Our results demonstrate affective modulation of the perception of looming stimuli, and suggest that emotion shapes basic aspects of visual perception.

Participants made time-to-collision judgments of looming visual stimuli that expanded in size over one second before disappearing (see Supplemental Experimental Procedures for details). The rate of image expansion was consistent with one of five time-to-collisions between three and five seconds. Stimuli were photographs of animals, commonly perceived as threatening (snakes and spiders) or non-threatening (butterflies and rabbits). Participants were instructed to imagine each stimulus continuing to approach after it disappeared and to judge when it would have collided with them by pressing a button with their right hand at that exact moment.

Judged time-to-collision increased monotonically with actual time-to-collision (Figure 1, left panel), though the rate of this increase was substantially less than would be predicted of an ideal observer, consistent with previous findings [4]. Critically, threatening stimuli were judged as colliding sooner than non-threatening stimuli. Though the pattern of optical expansion was exactly constant across conditions, the content of the looming stimuli nevertheless modulated perceived time-to-collision. Our data are consistent with previous results showing that humans are sensitive to looming as a cue to collision [4], but, critically, that these judgments are also affected by the semantic content of approaching stimuli.

We further investigated whether the magnitude of this effect relates to individual differences in fear of snakes and spiders. We used a self-report questionnaire commonly used for clinical assessment of spider phobia (see Supplemental Experimental Procedures), and adapted the items by substituting each category name for the word 'spider'. To isolate individual differences in fear, we regressed fear ratings for threatening stimuli on ratings for non-threatening stimuli, and calculated the residuals. Similarly, we regressed time-to-collision judgments for threatening on those for non-threatening stimuli, and calculated the residuals. These residuals were negatively correlated (Figure 1, right panel), indicating that fear of snakes and spiders was associated with larger underestimation of time-to-collision of these stimuli.

Experiment 2 controlled for potential low-level confounds in the images by comparing time-to-collision judgments for the images used in Experiment 1 with scrambled versions of these images. Time-to-collision judgments were again reduced for threatening compared to non-threatening stimuli. Critically, this effect disappeared for the scrambled

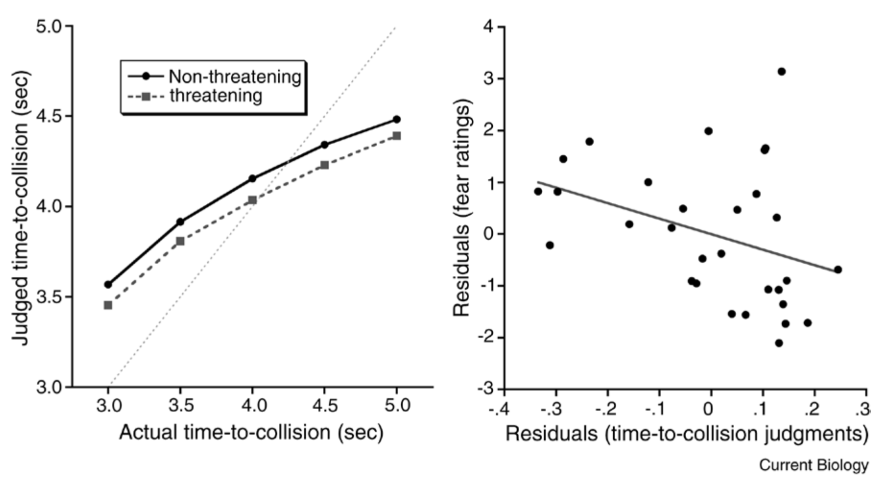

Figure 1. Experimental results.
Left panel: judged time-to-collision increased monotonically as a function of actual time-to-collision for non-threatening (butterflies and rabbits) and threatening (snakes and spiders) stimuli, $F(4, 112) = 47.09$, $p < 0.0001$. The light grey dotted line indicates veridical judgments. There was a clear bias to underestimate time-to-collision for threatening compared to non-threatening stimuli, $F(1, 29) = 12.35$, $p < 0.005$. Right panel: scatterplot showing relation of time-to-collision judgments and fear. For both time-to-collision judgments and fear ratings, variance specifically related to the threatening stimuli was isolated by calculating the residuals regressing scores for threatening on those for non-threatening stimuli. These residuals were significantly negatively correlated, $r(29) = -0.367$, $p < 0.05$, indicating that greater fear was associated with increased underestimation of time-to-collision.

images, demonstrating that the effect is not driven by incidental stimulus-related characteristics. Further, threatening — but not non-threatening — stimuli were judged as arriving earlier than scrambled versions of the same images, suggesting that the effect is driven specifically by responses to threatening stimuli.

Experiment 3 investigated whether reduced time-to-collision judgments could reflect a non-specific effect of seeing threatening stimuli, such as heightened arousal. Participants saw threatening or non-threatening stimuli for one second, immediately followed by a looming blue disc. If the effect we report is a non-specific effect of seeing threatening stimuli, time-to-collision judgments of the blue disc should be faster when preceded by images of threatening stimuli. Contrary to this prediction, priming images had no apparent effect on time-to-collision judgments of a semantically-neutral disc.

Threatening stimuli are perceived as approaching more rapidly than non-threatening stimuli, especially for those who are fearful of those objects. These results show, in contrast to the traditional view of looming as a purely optical cue to object approach [1], that perceiving the time of imminent collision is not entirely driven by purely optical cues, but is also subject to emotional modulation. Gibson and colleagues [1] pointed out that as an optical cue to imminent collision, visual looming is a direct perceptual indicator of threat. Our results suggest that the affective content of looming stimuli also affects perceived time-to-collision. Underestimating arrival time of threatening stimuli may thus serve an adaptive role in leading responses to err on the side of additional time for either fight or flight. Some perceptual biases appear only for explicit perceptual judgments, but not for visually-guided actions [5]. Thus, it is possible that the present effect reflects a purely perceptual distortion that might not affect actions, such as catching.

Recent findings have demonstrated that emotion modulates some basic aspects of perception, such as visual contrast sensitivity [6], but not others, such as auditory directional attention [7]. The selectivity of emotional effects on perception is consistent with anecdotal reports that specific phobias may induce category-specific distortions of perception [8]. Though we investigated variability in fear in an unselected sample (i.e. generally non-phobic), our results provide experimental evidence consistent with this proposal. Other recent results have also suggested that individual differences in fear, even in the non-clinical range, alter space perception. For example, fear of heights is associated with distorted perception of vertical distance [9], whereas claustrophobic fear is associated with increased size of the near space immediately surrounding the body [10]. The present results fit with and extend these by showing that emotion not only alters the perception of space as a static entity, but it also affects the perception of dynamically moving objects, such as those on a collision course with the observer.

Supplemental Information

Supplemental Information includes experimental procedures and two figures and can be found with this article online at http://dx.doi.org/10.1016/j.cub.2012.07.053.

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Groups have a larger cognitive capacity than individuals

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Increasing the number of options can paradoxically lead to worse decisions, a phenomenon known as cognitive overload [1]. This happens when an individual decision-maker attempts to digest information exceeding its processing capacity. Highly integrated groups, such as social insect colonies, make consensus decisions that combine the efforts of many members, suggesting that these groups can overcome individual limitations [2–4]. Here we report that an ant colony choosing a new nest site is less vulnerable to cognitive overload than an isolated ant making this decision on her own. We traced this improvement to differences in individual behavior. In whole colonies, each ant assesses only a small subset of available sites, and the colony combines their efforts to thoroughly explore all options. An isolated ant, on the other hand, must personally assess a larger number of sites to approach the same level of option coverage. By sharing the burden of assessment, the colony avoids overtaxing the abilities of its members.

Nest site selection by *Temnothorax* ants exemplifies collective decision-making without well-informed leaders [5]. When a colony must find a new home, it can choose the better of two new sites even when no single ant assesses both. Instead, comparison emerges from a competition between recruitment efforts. Upon finding a site, an ant recruits nestmates to it with a probability that depends on the site’s quality, as determined by entrance diameter, cavity size, light level, and other features [6]. Her recruits make their own quality-dependent recruitment decisions, creating positive feedback that directs the colony towards the better nest. Consensus is further enhanced by a quorum rule that accelerates recruitment once a site’s population has surpassed a threshold [5].