

Northern Michigan University

NMU Commons

Journal Articles

FacWorks

10-2009

Backward Masked Snakes and Guns Modulate Spatial Attention

Joshua M. Carlson
joshcarl@nmu.edu

Andrea L. Lee

Karen S. Reinke

Follow this and additional works at: https://commons.nmu.edu/facwork_journalarticles

Recommended Citation

Carlson, J. M., Lee, A. L. & Reinke, K. S. (2009). Backward Masked Snakes and Guns Modulate Spatial Attention. *Evolutionary Psychology*, 7(4), 534-544. DOI:10.1177/147470490900700404

This Journal Article is brought to you for free and open access by the FacWorks at NMU Commons. It has been accepted for inclusion in Journal Articles by an authorized administrator of NMU Commons. For more information, please contact kmcdonou@nmu.edu, bsarjean@nmu.edu.

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/230753979>

Backward Masked Snakes and Guns Modulate Spatial Attention

Article in *Evolutionary Psychology* · October 2009

DOI: 10.1177/147470490900700404

CITATIONS

20

READS

57

3 authors, including:



[Joshua M Carlson](#)

Northern Michigan University

49 PUBLICATIONS 706 CITATIONS

SEE PROFILE

Original Article

Backward Masked Snakes and Guns Modulate Spatial Attention

Joshua M. Carlson, Biomedical Engineering, State University of New York at Stony Brook, Stony Brook, USA. Email: carlsonjm79@gmail.com (Corresponding Author).

Andrea L. Fee, Department of Psychology, Southern Illinois University-Edwardsville, Edwardsville, USA.

Karen S. Reinke, Department of Psychology, University of Illinois-Springfield, Springfield, USA.

Abstract: Fearful faces are important social cues that alert others of potential threat. Even backward masked fearful faces facilitate spatial attention. However, visual stimuli other than fearful faces can signal potential threat. Indeed, unmasked snakes and spiders modulate spatial attention. Yet, it is unclear if the rapid threat-related facilitation of spatial attention to backward masked stimuli is elicited by non-face threat cues. Evolutionary theories claim that phylogenetic threats (i.e. snakes and spiders) should preferentially elicit an automatic fear response, but it is untested as to whether this response extends to enhancements in spatial attention under restricted processing conditions. Thirty individuals completed a backward masking dot-probe task with both evolutionary relevant and irrelevant threat cues. The results suggest that backward masked visual fear stimuli modulate spatial attention. Both evolutionary relevant (snake) and irrelevant (gun) threat cues facilitated spatial attention.

Keywords: emotion, fear, evolution, backward masking, dot-probe.

Introduction

Threatening stimuli are theorized to elicit an evolutionary-based fear response that increases an individual's likelihood of survival ([LeDoux, 1996](#); [Öhman and Mineka, 2001](#)). This response may be initiated through a subcortical neural system for rapid, relatively non-discriminative, responses or a cortical based system for slow discriminative responses ([LeDoux, 1996](#)). One aspect of this fear response is the automatic direction of visuospatial attention to the location of potential threat. Threatening facial expressions are important biological indicators of danger that enhance spatial attention both in unrestricted ([Pourtois, Grandjean, Sander, and Vuilleumier, 2004](#); [Pourtois, Schwartz, Seghier, Lazeyras, and Vuilleumier, 2006](#)) and restricted ([Carlson and Reinke, 2008](#); [Fox, 2002](#); [Mogg and](#)

Bradley, 1999) processing conditions. However, facial stimuli are not the only significant signals of threat in the environment. For example, poisonous and predatory animals such as snakes, spiders, and sharks can inflict bodily harm and are commonly feared or avoided. Restricted processing of threat images of this nature have been shown to enhance skin conductance (SCR; Öhman and Soares, 1993, 1994) and amygdala (Carlsson et al., 2004) responses. In unrestricted processing conditions these types of threat stimuli modulate spatial attention (Blanchette, 2006; Öhman, Flykt, and Esteves, 2001). Yet, it is unclear if visual threat related stimuli, other than facial expressions, elicit enhancements in spatial attention under restricted processing conditions, such as backward masking.

Backward masking is a method in which the processing of visual threat stimuli can be restricted. Previous research has demonstrated that fearful faces that are presented for 33 ms (or less) and immediately followed by a mask (neutral face) result in increased activity in the amygdala, superior colliculus, and thalamic pulvinar (Liddell et al., 2005; Morris et al., 1996; Morris, Öhman, and Dolan, 1999; Whalen et al., 1998; Williams et al., 2006). Activity in this same pathway has been observed in cortically blind patients (who do not experience “conscious vision”) while viewing unmasked fearful faces (Morris, DeGelder, Weiskrantz, and Dolan, 2001) suggesting this subcortical pathway supports crude visual fear processing. Additionally, research has shown that backward masked snakes and spiders enhance skin conductance responses (Öhman and Soares, 1993, 1994) and elicit amygdala (Carlsson et al., 2004) responses relative to neutral stimuli in snake or spider phobic individuals, respectively. Based on participants’ objective and subjective behavioral measures, some studies have reported that stimuli presented in this manner are not consciously processed (Glascher and Adolphs, 2003; Whalen et al., 1998). However, other findings indicate that the degree of awareness varies across individuals (Pessoa, Japee, and Ungerleider, 2005) and an individual’s level of awareness modulates the amygdala response to fearful faces (Pessoa, Japee, Sturman, and Ungerleider, 2006). Therefore, while the degree to which backward masked stimuli are processed subliminally is still debated, backward masking does restrict the amount of relative visual information compared to unmasked visual stimuli.

Several psychological theories argue for an evolutionarily prepared fear module, which is involved in automatically orienting attention to threat stimuli (LeDoux, 1996; Öhman, Flykt, and Esteves, 2001; Öhman and Mineka, 2001). Evidence for this model comes from conditioning experiments that suggest phylogenetic or evolutionary relevant fear stimuli are more sensitive to fear conditioning and are more robust to extinction effects (Öhman and Mineka, 2001). Several studies that have directly compared the spatial attention grabbing effects of unmasked phylogenetically and ontogenetically fear-relevant stimuli indicate that fear-relevant stimuli in general facilitate spatial attention (Blanchette, 2006; Brosch and Sharma, 2005; Fox, Griggs, and Mouchlianitis, 2007). Additionally, backward masked fear-conditioned snakes and spiders have been shown to grab spatial attention (Beaver, Mogg, and Bradley, 2005). However, these phylogenetically relevant threats were not compared to ontogenetically fear-relevant stimuli and it is unclear what effect evolutionary relevant fear stimuli not presented in a conditioning paradigm would have on spatial attention. While Öhman's (2001) evolutionary based theory allows for fear learning and behavioral studies have shown conditioning-related spatial attention effects to previously neutral stimuli (Koster, Crombez, Van Damme, Verschuere, and De Houwer, 2005) and evolutionary relevant fear stimuli (Armony and Dolan, 2002; Beaver et al.,

2005) it might be expected that under limited and restricted processing conditions that the evolutionary relevancy of a stimulus is more salient. That is, if backward masked fear stimuli are processed through an evolutionarily older subcortical route, one might expect a preference for phylogenetically, compared to ontogenetically, relevant threats under restricted processing conditions. Indeed, this “older” subcortical amygdala, pulvinar, and superior collicular network is hypothesized to specifically have evolved for the rapid processing of and response to venomous snakes (Isbell, 2006). Therefore, it may be expected that crude representations of phylogenetically and ontogenetically fear-relevant stimuli would differentially influence behavior under the restricted processing conditions of backward masking.

While fearful faces have been shown to enhance spatial attention under restricted processing conditions (Carlson and Reinke, 2008; Fox, 2002), it is unclear if this threat related facilitation of spatial attention extends to other types of visually threatening stimuli, such as snakes, spiders, guns, and knives. Furthermore, it is unclear as to whether fear modulated spatial attention in restricted processing conditions is sensitive to the evolutionary relevancy of threatening stimuli. The purpose of the current experiment was to address these issues by using evolutionary relevant and irrelevant threat images in the dot-probe paradigm (see Figure 1). Each trial of the task consisted of two images (one threatening and one neutral) simultaneously presented (33 ms) to the left and right of fixation and immediately masked by neutral images (100 ms). Participants then responded to a target dot appearing either on the left or right side of the screen, which could either be spatially congruent or incongruent with the threat image. It was predicted that threatening compared to neutral images would modulate spatial attention. Specifically, reaction times were predicted to be faster on congruent (target and threat image located at the same spatial location) compared to incongruent (target and threat image located on opposite sides of the screen) trials. Additionally, given the theorized evolutionarily adaptive basis of this attentional response (LeDoux, 1996; Öhman and Mineka, 2001), it was predicted that evolutionary relevant fear stimuli would enhance spatial attention to a greater degree than evolutionary irrelevant fear stimuli. That is, the facilitation of reaction times for congruent compared to incongruent trials should be larger when the threat image is evolutionary relevant rather than evolutionary irrelevant.

Materials and Methods

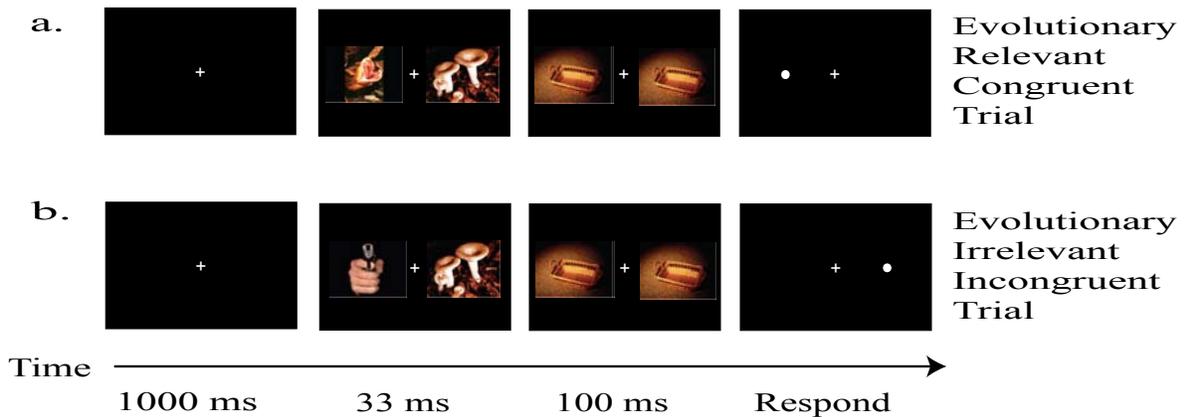
Participants

Thirty-two introductory psychology students from Southern Illinois University at Carbondale with normal or corrected to normal vision completed a dot-probe task for partial course credit. Participants were provided with informed consent and treated according to the guidelines of the Institutional Review Board. Two participants were excluded from data analysis for having poor overall task performance ($\leq 86\%$ correct). Overall accuracy scores for these participants were lower than two standard deviations ($SD = 4\%$) from the group mean accuracy score (96% correct), which suggests that these participants were less compliant with task instructions. As noted in the results section the exclusion of these 2 participants did not influence the results. The final sample included 30 participants (16 female, 14 male). Of these participants, three reported being left handed, while the remaining 27 participants reported that they were right handed.

Stimuli and Material

Six evolutionary relevant threatening (1051, 1200, 1270, 1274, 1930, and 2100), six evolutionary irrelevant threatening (6260, 6350, 6560, 9592, 9630, and 9911), and six neutral from both evolutionary relevant (e.g., mushrooms and trees) and irrelevant (e.g., spoon and hairdryer) categories (2010, 5531, 5593, 5780, 7004, and 7050) color images from the International Affective Picture System (IAPS; Lang, 1999) were used in the current study. Comparisons between the normative valence and arousal ratings of the IAPS images validate our threatening (M valence = 3.18, M arousal = 5.89) vs. neutral (M valence = 5.89, M arousal = 3.25) image categorization ($ps < .05$). Evolutionary relevant and irrelevant fear stimuli did not differ ($ps > .10$) in their overall arousal ratings (M relevant = 5.52, M irrelevant = 6.27) or overall luminosity (M relevant = 73.16, M irrelevant = 76.44). Examples of presumably evolutionary relevant fear stimuli consist of snakes, spiders, and bugs, whereas knives, syringes, and guns are examples of evolutionary irrelevant fear stimuli. Sixteen additional neutral stimuli were chosen as masks from both evolutionary relevant (e.g., birds, bunny, trees, and shells) and irrelevant (e.g., basket, fan, chair, and bus) subcategories (1450, 1603, 1731, 1740, 1750, 5030, 5532, 5535, 5720, 5760, 5800, 7002, 7010, 7020, 7037, 7060, 7140, 7235, 7496, and 7620). The experiment was programmed with E-Prime and displayed on a 60 Hz 16" Dell computer monitor. Responses were made with an Electrical Geodesics Inc (EGI) response pad.

Figure 1. Each trial of the dot-probe task began with a fixation cue in the center of the screen for 1000 ms and was immediately followed by two images presented for 33 ms. These images were masked with a neutral image for 100 ms. The target dot then appeared on the right or left side of the screen. Depicted are examples of a.) evolutionary relevant congruent and b.) evolutionary irrelevant incongruent trial types.



Procedure

As depicted in Figure 1, each trial began with a white fixation cue (+) in the center of a black screen for 1000 ms. Next, two images (subtending 6° x 8° and separated by 11.5° of visual angle) were simultaneously presented (33 ms) to the left and the right of fixation. These initial images always contained one threat and one neutral image with the threat image equally occurring in the left and right visual fields. The initial images were immediately masked by a separate sample of neutral IAPS images for 100 ms (the same neutral image mask was presented on each side of the screen to prevent potential

asymmetrical mask biases). We do not claim that these backward masking procedures rendered the initial image subliminal or nonconscious per se, but did restrict the processing of the initial image (relative to unmasked images). Finally, the target dot appeared either on the left or the right side of the screen and participants indicated as quickly as possible the location of the target dot, which remained on the screen until the participant responded. Participants used their right index finger to indicate when the target appeared on the left side of the screen and right middle finger to indicate the target appeared on the right side of the screen. Half of the initial threat images were spatially congruent with the target dot, while the other half were spatially incongruent (in this instance the neutral image precedes the target). If the initial threat image automatically captures spatial attention (relative to the competing initial neutral image) then threat congruent trials should produce faster reaction times than incongruent trials. During each trial, the fixation cue remained in the center of the screen throughout the entirety of the trial and participants were instructed to always fixate on this cue. The experiment began with a brief (15 trial) practice block followed by five experimental blocks of 64 trials.

Results

Similar to other dot-probe studies ([Carlson and Reinke, 2008](#); [Fox, 2002](#)), only correct responses between 100 and 750 ms were included in the analysis of reaction time data, which therefore excluded incorrect (4%), premature (0.3%), and delayed responses (0.7%), respectively. Reaction time analyses were performed on the remaining 95% of the data. An Evolutionary Relevancy (relevant vs. irrelevant) by Congruency (congruent vs. incongruent) by Visual Field (left vs. right) repeated measures analysis of variance (ANOVA) was conducted on participants' reaction time data. There was a significant effect of congruency ($F(1, 29) = 5.21, p < .05, \eta_p^2 = .15$) where there were faster reaction times for congruent (341.17 ms) relative to incongruent (345.48 ms) trials. The congruency effect remained significant when the reaction time data for facial cues (angry and neutral) were excluded from the analysis, $F(1, 31) = 6.87, p < .05, \eta_p^2 = .19$, congruent: 340.3 ms, incongruent: 345.6 ms. This suggests that threat stimuli other than faces capture spatial attention in restricted processing conditions. When poor performers were included in the analysis the overall congruency effect still remained significant, $F(1, 31) = 4.51, p < .05, \eta_p^2 = .13$. The Evolutionary Relevancy by Congruency interaction failed to reach significance ($F(1, 29) = 1.24, p = .27, \eta_p^2 = .04$). However, given our a priori hypothesis of a stronger congruency effect for evolutionary relevant threats, we performed follow up t-tests to further explore this effect. Evolutionary relevant threats resulted in significantly faster reaction times on congruent compared to incongruent trials ($p < .05$). While a similar pattern was found for evolutionary irrelevant threats, this difference did not reach significance ($p > .05$, see Table 1 for mean reaction times). The Congruency by Visual Field interaction did not reach significance, $F(1, 29) = 1.85, p = .18, \eta_p^2 = .06$, nor did the Evolutionary Relevancy by Visual Field and the Evolutionary Relevancy by Visual Field by Congruency interactions (F 's (1, 29) < 1). These results suggest that backward masked threatening images modulate spatial attention.

Table 1. Mean reaction times and standard errors.

	Trial type	Reaction time (ms)
Evolutionary Relevant*	Congruent	340.33
	Incongruent	346.32
Evolutionary Irrelevant	Congruent	342.20
	Incongruent	344.71
Overall*	Congruent	341.26
	Incongruent	345.52

*congruent vs. incongruent difference is significant at $p < .05$

While an overall congruency effect was found for threatening images, we performed follow up t-tests on each threat image to assess which types of threat stimuli were more effective in capturing spatial attention. As can be seen in Table 2, Bonferroni corrected *t*-tests, which explicitly tested for faster reaction times in congruent compared to incongruent trials (i.e., single-tailed), revealed that certain threat images such as an open mouthed snake ($t(29) = 2.86, p_{corr} < .05$) and a pointed gun ($t(29) = 3.18, p_{corr} < .05$) were more effective in capturing spatial attention than other threats. While there was a difference between individual stimuli on the size of the congruency effect, these differences did not align with evolutionary relevance.

Table 2. Mean differences and standard errors by evolutionary relevancy and stimulus.

IAPS Image Description	Evolutionary Relevant			Evolutionary Irrelevant			
	IAPS Image Number	Congruent - Incongruent Difference	Standard Error	IAPS Image Description	IAPS Image Number	Congruent - Incongruent Difference	Standard Error
	Snake*	1051	-15.07	5.28	Aimed Gun*	6260	-19.02
Spider	1200	1.02	3.82	Knife Attack	6550	-3.24	3.74
Roach	1270	-0.49	5.09	Gun Attack	6560	1.64	6.08
Roaches	1274	-8.48	6.40	Injection	9592	0.63	4.79
Shark	1930	-0.75	5.36	Bomb	9630	-6.95	6.63
Angry (face)	2100	-9.53	5.58	Car Accident	9911	9.55	5.91

**significant at $p < .05$, Bonferroni corrected for 12 single-tailed comparisons*

Discussion

The present findings indicate that visual fear-relevant stimuli such as snakes and guns have the capacity to modulate spatial attention under the restricted processing conditions of backward masking. These results extend previous findings of enhanced spatial attention to masked threatening faces in highly trait anxious (Fox, 2002; Mogg and Bradley, 1999, 2002) and unselected populations (Carlson and Reinke 2008), suggesting this behavior is not solely associated with facial cues of threat, but includes other types of visual threat as well. These attention effects were not influenced by evolutionary relevancy in the current study. That is, both evolutionary relevant (i.e., snake) and irrelevant (i.e., gun) backward masked visual threat stimuli enhanced spatial attention.

Although evolutionary relevancy did not influence spatial attention, certain images such as the striking snake and the aimed gun were more attention grabbing than others (see Table 2). Interestingly, both of these threats were directed towards (as opposed to away from) the observer. Previous research has revealed larger SCRs for backward masked images of snakes and guns directed towards participants (Flykt, Esteves, and Öhman, 2007). Thus, observer directed threats may be more efficient in automatically eliciting spatial attention under restricted processing conditions. This is possibly due to the relatively more immediate nature of directed threats, where a rapid automatic fear response would greatly enhance an organism's likelihood of surviving such a threat. Given that the

present study was not explicitly designed to address this issue, future research should explore the role of crude directed vs. undirected threat on spatial attention.

We provide evidence that in addition to facial expressions other backward masked threat-related visual stimuli are capable of eliciting enhancements in visuospatial attention. Our data provide a behavioral complement to physiological research revealing enhanced SCRs ([Öhman and Soares, 1993, 1994](#)) and amygdala activity ([Carlsson et al., 2004](#)) to these types of visual threat. Backward masked fearful faces appear to be processed through a subcortical superior collicular, thalamic pulvinar, amygdala system ([Liddell et al., 2005; Morris et al., 1996; Morris et al., 1999; Whalen et al., 1998; Williams et al., 2006](#)) and to enhance spatial attention through a neural network consisting of the amygdala, anterior cingulate, and visual cortex ([Carlson, Reinke, and Habib, 2009](#)). It is unclear whether these same systems mediate the processing and facilitation of spatial attention to other types of backward masked threat stimuli. Backward masked snakes and spiders have been found to elicit amygdala responses ([Carlsson et al., 2004](#)) and evolutionary theories claim that the amygdala-pulvinar system specifically evolved in response to our ancestors' interactions with venomous snakes ([Isbell, 2006](#)). It is believed that this system allows for rapid detection and response to visual threats. However, future research is needed to determine the complete neural system involved in mediating the spatial attention response to backward masked non-face threat stimuli.

Emotion processing theories claim rapid fear responses, based on little to no conscious knowledge of the eliciting stimulus, are evolutionarily advantageous, and enhance an organism's likelihood of survival ([LeDoux, 1996; Öhman and Mineka, 2001](#)). However, in the current experiment both evolutionary relevant and irrelevant threats enhanced spatial attention, which suggests that while organisms may have an innate or biological predisposition to direct attention towards crude representations of threatening stimuli, the types of stimuli that elicit this response can be evolutionarily or culturally relevant. A rapid attentional response to culturally learned fear stimuli is consistent with the human amygdala's known role in fear conditioning or learning ([Knight, Nguyen, and Bandettini, 2005](#)). [According to LeDoux \(1996\)](#), it is important to have some evolutionarily determined triggers of the fear response. However, it is also important, in our ever-changing world, to be able to learn or acquire culturally relevant fear triggers. While culturally relevant fear associations appear to be acquired through the amygdala ([Knight et al., 2005](#)), it is unclear whether crude representations of these types of fear stimuli would interact with the spatial attention network. Our research suggests that learned triggers may involve the same spatial attention network given that backward masking, which results in limited visual processing, did not differentially affect behavior for evolutionary or cultural fear stimuli.

However, while in the current experiment there was not an evolutionary relevancy by congruency interaction, it is inappropriate to make strong conclusions from null results. More research is needed in this area to better characterize the role of evolutionary relevancy in automatic threat-elicited spatial attention. Additionally, the size of the threat-elicited attention effect in the current experiment was rather small. The 100 ms gap (mask duration) between the initial threat image and the target could partially account for this relatively small overall congruency effect. That is, after 100ms the initial orienting of attention to the threat image may begin to be released or weakened. However, masked fearful face dot-probe studies with similar threat-to-target onset differences have revealed

larger attention effects (e.g., [Carlson and Reinke, 2008](#)). Future research could use a methodology where the target is included in the mask that immediately follows the cue and thus provide an immediate sampling of threat-elicited spatial attention.

In sum, we found that backward masked threatening visual stimuli such as snakes and guns modulate spatial attention. It appears that the evolutionary relevancy of these threat stimuli did not influence their attention grabbing efficacy. Other potential factors, such as the direction of threat, may play an important role in whether or not degraded non-face threat images elicit enhancements in spatial attention.

Received 02 August 2009; Revision submitted 16 October 2009; Accepted 10 November 2009

References

- Armony, J. L., and Dolan, R. J. (2002). Modulation of spatial attention by fear-conditioned stimuli: an event-related fMRI study. *Neuropsychologia*, *40*, 817-826.
- Beaver, J. D., Mogg, K., and Bradley, B. P. (2005). Emotional conditioning to masked stimuli and modulation of visuospatial attention. *Emotion*, *5*, 67-79.
- Blanchette, I. (2006). Snakes, spiders, guns, and syringes: how specific are evolutionary constraints on the detection of threatening stimuli? *Quarterly Journal of Experimental Psychology (Colchester)*, *59*, 1484-1504.
- Brosch, T., and Sharma, D. (2005). The role of fear-relevant stimuli in visual search: a comparison of phylogenetic and ontogenetic stimuli. *Emotion*, *5*, 360-364.
- Carlson, J. M., and Reinke, K. S. (2008). Masked fearful faces modulate the orienting of covert spatial attention. *Emotion*, *8*, 522-529.
- Carlson, J. M., Reinke, K. S., and Habib, R. (2009). A left amygdala mediated network for rapid orienting to masked fearful faces. *Neuropsychologia*, *47*, 1386-1389.
- Carlsson, K., Petersson, K. M., Lundqvist, D., Karlsson, A., Ingvar, M., and Öhman, A. (2004). Fear and the amygdala: Manipulation of awareness generates differential cerebral responses to phobic and fear-relevant (but nonfeared) stimuli. *Emotion*, *4*, 340-353.
- Flykt, A., Esteves, F., and Öhman, A. (2007). Skin conductance responses to masked conditioned stimuli: Phylogenetic/ontogenetic factors versus direction of threat? *Biological Psychology*, *74*, 328-336.
- Fox, E. (2002). Processing emotional facial expressions: The role of anxiety and awareness. *Cognitive Affective and Behavioral Neuroscience*, *2*, 52-63.
- Fox, E., Griggs, L., and Mouchlianitis, E. (2007). The detection of fear-relevant stimuli: Are guns noticed as quickly as snakes? *Emotion*, *7*, 691-696.
- Glascher, J., and Adolphs, R. (2003). Processing of the arousal of subliminal and supraliminal emotional stimuli by the human amygdala. *Journal of Neuroscience*, *23*, 10274-10282.
- Isbell, L. A. (2006). Snakes as agents of evolutionary change in primate brains. *Journal of Human Evolution*, *51*, 1-35.
- Knight, D. C., Nguyen, H. T., and Bandettini, P. A. (2005). The role of the human amygdala in the production of conditioned fear responses. *Neuroimage*, *26*, 1193-

1200.

- Koster, E. H., Crombez, G., Van Damme, S., Verschuere, B., and De Houwer, J. (2005). Signals for threat modulate attentional capture and holding: Fear-conditioning and extinction during the exogenous cueing task. *Cognition and Emotion, 19*, 771-780.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. (1999). International Affective Picture System (IAPS): Technical manual and affective ratings. The Center for Research in Psychophysiology. University of Florida: Gainesville, FL.
- LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life*. London: Weidenfeld and Nicholson.
- Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A., et al. (2005). A direct brainstem-amygdala-cortical 'alarm' system for subliminal signals of fear. *Neuroimage, 24*, 235-243.
- Mogg, K., and Bradley, B. P. (1999). Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. *Cognition and Emotion, 13*, 713-740.
- Mogg, K., and Bradley, B. P. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behaviour Research and Therapy, 40*, 1403-1414.
- Morris, J. S., DeGelder, B., Weiskrantz, L., and Dolan, R. J. (2001). Differential extrageniculostriate and amygdala responses to presentation of emotional faces in a cortically blind field. *Brain, 124*, 1241-1252.
- Morris, J. S., Frith, C. D., Perrett, D. I., Rowland, D., Young, A. W., Calder, A. J., et al. (1996). A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature, 383*, 812-815.
- Morris, J. S., Öhman, A., and Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating "unseen" fear. *Proceedings of the National Academy of Sciences U S A, 96*, 1680-1685.
- Öhman, A., Flykt, A., and Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology General, 130*, 466-478.
- Öhman, A., and Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*, 483-522.
- Öhman, A., and Soares, J. J. (1993). On the automatic nature of phobic fear: Conditioned electrodermal responses to masked fear-relevant stimuli. *Journal of Abnormal Psychology, 102*, 121-132.
- Öhman, A., and Soares, J. J. (1994). "Unconscious anxiety": Phobic responses to masked stimuli. *Journal of Abnormal Psychology, 103*, 231-240.
- Pessoa, L., Japee, S., Sturman, D., and Ungerleider, L. G. (2006). Target visibility and visual awareness modulate amygdala responses to fearful faces. *Cerebral Cortex, 16*, 366-375.
- Pessoa, L., Japee, S., and Ungerleider, L. G. (2005). Visual awareness and the detection of fearful faces. *Emotion, 5*, 243-247.
- Pourtois, G., Grandjean, D., Sander, D., and Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex, 14*, 619-633.
- Pourtois, G., Schwartz, S., Seghier, M. L., Lazeyras, F., and Vuilleumier, P. (2006). Neural systems for orienting attention to the location of threat signals: an event-related fMRI study. *Neuroimage, 31*, 920-933.

Masked threat modulates spatial attention

- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., and Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, *18*, 411-418.
- Williams, L. M., Liddell, B. J., Kemp, A. H., Bryant, R. A., Meares, R. A., Peduto, A. S., et al. (2006). Amygdala-prefrontal dissociation of subliminal and supraliminal fear. *Human Brain Mapping*, *27*, 652-661.