

AN INVESTIGATION OF THE EVOLUTIONARY CONSTRAINTS AND MALLEABILITY
OF FACILITATED VISUAL ATTENTION TO THREATS

by

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M.S., Kansas State University, 2009

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

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Department of Psychology
College of Arts and Sciences

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Abstract

Öhman and Mineka (2001) proposed the existence of an evolved fear module with four Fodorian characteristics of modularity. They presented evidence that the fear module is selective, automatic, encapsulated, and operates in dedicated subcortical neural circuitry. The consistently rapid physiological and behavioral (attention capture) evidence (e.g., Öhman & Mineka, 2001) provides clear support for its automaticity. However, recent developments (e.g., Blanchette, 2006) cast doubt on the selectivity of the module. Specifically, it is unclear whether or not the fear module automatically responds selectively to evolutionarily ancient fear stimuli or whether modern threats may also elicit automatic responding. Furthermore, previous research using visual search paradigms has produced unclear results regarding the evolutionarily derived selectivity of the fear module. Unfortunately, the visual search method is notoriously sensitive to visual characteristics of stimuli (Duncan & Humphreys, 1989). However, eye movements provide a valid alternative measure of covert attention capture. In order to clarify the issues, Experiment 1 used an oculomotor inhibition paradigm to present ancient and modern threats with one another or neutral stimuli in competition for visual attention. In addition, we collected measures of participants' experience with the stimuli to assess the influence of experience/familiarity/learning on rapid attention to threats. Furthermore, because image inversion maintains low level stimulus characteristics (e.g., spatial frequencies, contrast, and luminance) while disrupting the semantic processing of images, presenting the stimulus pairs upside down was used to determine whether any observed effects were due to low level stimulus characteristics. Experiment 1 produced null results with respect to systematic differences in attentional processes as a function of threat type. Because Experiment 1 was modeled after

Nummenmaa et al., (2009, Exp 3), it was therefore necessary to attempt to replicate their findings. Experiment 2 successfully replicated the findings of Nummenmaa et al. Therefore, it is suggested that the rapid attention processes responsible for systematic deviations in saccade trajectories seen in Experiment 2 (and Nummenmaa et al., 2009, Exp 3) do not translate to the methodology used in Experiment 1. Given the findings from the present study, the question of whether or not there exists an evolved fear module remains open. This study clearly supports the existence of an attentional bias for emotional content as indicated through the use of oculomotor inhibition paradigm. However, like the visual search methodology, the oculomotor inhibition paradigm appears to be very sensitive to visual differences of the stimuli.

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Dedication

This work is dedicated to my loving wife, Ann. Thank you for being my friend when I was not the easiest man to be around. Through your love, patience and support I have been able to achieve my goals.

Chapter 1 - Introduction and Literature Review

In order to evolve and pass on their genetic legacy our ancestors had to persevere in harsh environments rife with threats where their survival depended on eating and not being eaten. Our ancestors had the ability to respond quickly to threats, thereby surviving to pass on their genes. This ability requires rapidly attuned visual attention. The purpose of the present research is to gain a deeper understanding of how visual attention is allocated to threats in the modern environment. We ask to what extent our visual attention to threatening and fear-relevant objects is influenced by our evolutionary history. The answer to this question has implications for theories of fear responding and visual attention. It also carries practical implications for safety and survival in modern times.

The study of fear has a rich history (Cannon, 1929; LeDoux, 1996; LeDoux, 2000; Öhman, Eriksson, & Olofsson, 1975; Öhman, Fredrikson, Hugdahl, & Rimmö, 1978; Öhman & Mineka, 2001) and great strides have been made toward understanding the physiological and cognitive nature of the fear response. The predominant theory of how threatening stimuli evoke physiological fear responses and receive enhanced attention is Öhman and Mineka's (2001) "fear module." Öhman and Mineka's theoretical fear module is proposed to have evolved to detect certain stimuli and evoke physiological and behavioral changes in response. Their theory of an evolved fear module (Öhman & Mineka, 2001) is based on multiple lines of converging evidence and organized around Fodorian principles of modularity (Fodor, 1983). According to Öhman and Mineka, the fear module has developed through evolutionary selection and has four essential characteristics of modularity. Specifically, the fear module is *automatic* in the sense that its response is evoked rapidly and directly by the ancient threat stimuli even in the absence of

conscious perception. The fear module is *encapsulated* in that it is resistant to influences of higher cognition. The fear module is *composed of dedicated neural circuitry* centered on the amygdala which has a known role in emotional responding, especially fear responding (LeDoux, 1996). Lastly, and most importantly for the present research, the fear module is proposed to be *selective* in that evolutionarily-relevant (i.e., ancient) threatening stimuli receive exclusive processing in the module.

The concept of mental modularity as described by Fodor (1983) has received much criticism in past years (Barrett, 2005; Barrett & Kurzban, 2006; Carruthers, 2003; Frankenhuus & Ploeger, 2007; Geary & Huffman, 2002; Over, 2003; Sperber, 1994; Wagner, Pavlicev & Cheverud, 2007) which presents problems for the foundational ideas of Öhman and Mineka's fear module. However, aside from this broader debate on the validity of mental modularity, the present research focuses on a particular aspect of the theorized fear modules' modularity namely, its selectivity. Because recent studies have shown that modern threat stimuli seem to enjoy the same privileged processing as ancient threats, it is uncertain that the fear module is truly selective to phylogenetically relevant fear stimuli (e.g., snakes, spiders, etc.).

Evidence for the Fear Module's Evolutionarily Derived Selectivity

In support of a fear module developed from evolutionary pressures, Öhman and Mineka (2001) argue that the predators and other creatures that threatened the survival of our ancestors have privileged access to processing in the fear module. Barrett (2005) stated that predators presented a steady end to which our minds have adapted to aid survival since the goal of predators has not changed over the course of evolution (e.g., eat other animals). It is for this same reason that researchers believe such animals have such a prominent role in human fears (Arrindell, Pickersgill, Merckelbach, Ardon, & Cornet, 1991).

Empirical evidence for the fear module's selectivity was provided in several experiments (Öhman, Eriksson, & Olofsson, 1975; Öhman, Fredrikson, Hugdahl, & Rimmö, 1978) which demonstrated that snakes and spiders were easier than other types of stimuli to associate with aversive shock. Adding support to this position was the finding that once the associations of ancient threats with aversive shock were established, the associations were more resistant to extinction than associations established with other stimuli. These findings were expanded by Cook, Hodes, and Lang (1986) who showed that images of snakes and spiders made better conditioned stimuli for predicting an electrical shock unconditioned stimulus than images of damaged electrical outlets. Similar advantages for snakes and spiders as conditioned stimuli over neutral stimuli were observed with subliminally conditioned stimulus presentation (Öhman & Soares, 1993; 1998) suggesting that processing of phylogenetically relevant fear stimuli is extremely rapid. Öhman and Mineka (2001) argue that ease of association of snakes and spiders with aversive shock is due to their privileged access to the fear module. This access is said to be granted on the basis of their evolutionary relevance.

Additionally, evidence from visual search paradigms suggests that evolutionarily relevant fear stimuli selectively capture visual attention. This research shows that evolutionarily relevant fear stimuli such as snakes and spiders are detected faster among arrays of flowers and mushrooms than vice versa (Öhman, Flykt, & Esteves, 2001). Also, angry and fearful faces are detected faster among neutral and happy faces than vice versa (Öhman, Lundqvist, & Esteves, 2001). Furthermore, once attention is allocated to evolutionarily relevant threats, these stimuli tend to hold attention (Rinck, et al., 2005). Such evidence suggests that the visual attention system is automatically and selectively activated by threats that have become relevant through evolutionary selection processes.

The idea that evolutionarily relevant threat stimuli capture attention has also received support in other research paradigms. Armony and Dolan (2002) used a variant of Posner's (1980) cueing task using emotional pictures as cues to demonstrate an attentional bias to emotional content such as angry faces. Emotional-neutral picture pairs were presented simultaneously and when the images offset, participants had to respond to a dot that appeared in the location previously occupied by the emotional or neutral picture. The results demonstrated participants were faster to respond to the dot when it was in the location occupied by the angry face picture suggesting that attention had been sent to that location.

Evidence Against the Fear Module's Evolutionarily Derived Selectivity

As reviewed earlier, true Fodorian modular selectivity is thought to be determined by evolutionary processes (Fodor, 1983; Öhman & Mineka, 2001). This implies that a fear module *only* processes evolutionarily relevant fear stimuli. However, Brosch and Sharma (2005) used a visual search task (like that of Öhman and colleagues) to show the fear relevance of a stimulus in general, is more important for its attentional enhancement than is its evolutionary age. Brosch and Sharma found the visual search reaction times (RTs) to phylogenetically relevant threats (e.g., snakes and spiders) were equivalent to ontogenetically relevant threats (e.g., guns and syringes). Search RTs for both sets of stimuli demonstrated characteristics of efficient and parallel search (e.g., flat RT x set size search slopes) whereas search RTs for non-threatening stimuli did not. Images of mobile phones, cups, flowers and mushrooms served as control stimuli. No evidence of efficient search was found for the control stimuli indicating that the threat value of the stimuli, in general, was responsible for the observed effects. Brosch and Sharma (2005) concluded the fear module's selectivity is not limited to evolutionarily relevant threats. This conclusion was supported by Flykt (1999) who showed identical detection results

for both ancient and modern fear stimuli in a backward masking paradigm. Taken together, these findings suggest the fear module may not be highly domain-specific (Sperber, 1994), acting on only ancient threats, but rather it appears to demonstrate less domain-specificity, acting on all types of threats.

Additional evidence for the domain-generality of the fear module was provided by Blanchette (2006). Using the same visual search paradigm used in other studies (Brosch & Sharma, 2005; Fox, Griggs, & Mouchlianitis, 2007; Öhman, Flykt, Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001), she demonstrated that search RTs for modern threats are just as fast, or faster than search RTs for ancient threats indicating that modern threats are just as good at capturing visual attention as ancient threats. Specifically, in Experiment 1, she found that visual search RTs for guns and knives were significantly faster (by ~100 ms in a 2 x 2 grid and ~50 ms faster in a 3 x 3 grid) than for snakes and spiders. Blanchette concluded the phenomenological threat value of a stimulus (i.e., how threatening the stimulus was felt to be) was more important than its evolutionary age for eliciting a rapid behavioral response. In Experiment 2, Blanchette provided an even more convincing demonstration of the flexibility of the fear module when she showed similar RTs for symbolic representations (i.e., cartoon renderings) of the same ancient and modern threats. Furthermore, Van Rullen and Thorpe (2001) present evidence that animals and vehicles can be detected in images in less than 250 ms and that, in central vision, animals and vehicles are detected equally well. Taken together, this evidence suggests an absence of perceptual biases for ancient over modern stimulus categories.

Also using a visual search paradigm, Fox, Griggs and Mouchlianitis (2007) demonstrated modern threats (e.g., guns) were detected just as quickly as ancient threats (e.g., snakes). The unique contribution of their study was that they measured the threat-relevance of their stimuli,

and used this to predict attention capture. This led Fox et al. (2007) to propose that the apparent equivalency between ancient and modern threats was due to the threat *relevance* of the stimuli, a phenomenon they termed the Relevance Superiority Hypothesis (Fox et al., 2007). According to the Relevance Superiority Hypothesis, there is an early relevance evaluation system that proceeds on the basis of the personal goals and motivations of the individual. Objects determined to be highly relevant (such as guns in modern day environments) enhance and modulate the amount of attentional processing dedicated to those particular stimuli thereby causing them to be detected more quickly than less relevant stimuli. The Relevance Superiority Hypothesis predicts no difference in the detection speed of ancient and modern threats. Thus, because both snakes and guns could threaten survival, both have the potential to be evaluated as highly relevant threatening stimuli and thus both can capture attention and receive similar processing.

It is apparent from the reviewed literature that much (although not all) of the evidence demonstrating attentional capture by threatening stimuli has been gained through the use of visual search paradigms. However, visual search paradigms are notoriously sensitive to the visual characteristics of the stimuli (Duncan & Humphreys, 1989; Lipp, Waters, Derakshan, and Logies, 2004). Duncan and Humphreys (1989) outlined a theory of the effect of stimulus similarity on visual search outcomes. According to Duncan and Humphreys, visual search target detection speed is determined by similarity among distractor stimuli, the similarity of the distractor stimuli with the target, and when using multiple targets, the similarity of the targets. Furthermore, similar targets are easier to detect and similar distractors are searched faster than dissimilar distractors. Thus, researchers using visual search paradigms to understand visual

attention to threats should use stimuli that are as perceptually similar as possible in order to limit the contribution of stimulus visual characteristics such as size, shape, color, etc.

Taking the work of Duncan and Humphreys (1989) into consideration, Lipp, et al. (2004) demonstrated that non-dangerous animals (e.g., domestic cats) among a visual array of flowers or mushrooms were detected just as fast as dangerous animals (e.g., tigers) among the same distractors. This suggests that the visual disparity between animal and plant stimuli may be partly responsible for past research results showing speeded detection of threats in visual search arrays (see Öhman and Mineka, 2001). Importantly, Blanchette (2006) examined whether speeded detection of ancient and modern threats in visual search is due to their perceptual dissimilarity from their distractors. Refuting this hypothesis, she showed that even when searching for a threatening target that is perceptually similar to its distractors (e.g., a grenade among balls or syringes among pens) both ancient and modern threats captured attention whereas their similarly shaped non-threatening counterparts did not. Nevertheless, search for modern threats was, in fact, faster and more efficient than the search for ancient threats. Such findings suggest that cognitive mechanisms for attention to threats can be modified by input from environment and are not hardwired to process strictly phylogenetically relevant threats.

An additional issue arises from a conceptual consideration that has implications for fear and threat detection behavior. Given the mixed findings regarding the evolutionary constraints of the fear module and the Relevance Superiority Hypothesis proposed by Fox et al. (2007), it is plausible that the mixed results regarding threat detection are due in part to the personal relevance of both the ancient and modern threat stimuli. How relevant a threat is to an individual could vary as a function of their personal experiences but also as a function of their goals. In fact, one's goals and motivations have been shown to affect attentional selection (Dijksterhuis &

Aarts, 2010; Yarbus, 1967) as have experiences with stimuli (Nodine et al., 1996). Determining whether one's personal experiences with threats factors into their visual processing is an additional aim of the present research. Identifying participants' experience levels with the threat stimuli used allows assessment of the influence of experience and personal relevance on threat detection behavior.

Based on the work of Duncan and Humphreys (1989) which showed that visual search is sensitive to visual characteristics of searched stimuli and the work of Lipp et al. (2004) who showed a detection advantage for animals in general, it is possible past studies that have proposed attentional capture by evolutionarily-relevant threat animals (such as the work of Öhman and colleagues) may have simply demonstrated attentional capture by any category of animal. However, Lipp and Waters (2007) showed that fear-relevant animals (e.g., spiders) seem to hold attention in visual search longer than perceptually similar fear-irrelevant animals (e.g., cockroaches). Additionally, Blanchette (2006) showed that lions were detected faster among cats than vice versa. Thus, the issue of how evolutionary relevance plays into the attentional capture by threatening stimuli is unresolved.

Overcoming the Limits of Visual Search With an Eye Movement Paradigm

Given the mixed findings and the methodological issues of the visual search paradigm (e.g., Blanchette, 2006; Brosch & Sharma, 2005; Lipp et al., 2004; Duncan & Humphreys, 1989) it appeared the research regarding fear and threat detection could benefit from utilizing a new research paradigm. Because eye movements are an ecologically valid and accurate index of covert attention (Henderson, 2003), eye movement paradigms seemed a suitable candidate for such research.

Important questions arise from the reviewed literature concerning the selectivity of the fear module. Do ancient threats, modern threats or both activate the fear module? Is it possible that both ancient and modern threats are equally good at capturing attention? To what degree is the human fear response modified by environmental inputs? To answer these questions, ancient and modern threats need to be put in direct competition for attention. This would allow us to draw conclusions regarding the relative attentional enhancement and processing privileges of each type of threat. Unfortunately, the methodological issues inherent in the visual search method are not well suited to address the problems in this fashion. Therefore the present experiment used an oculomotor inhibition paradigm to assess whether ancient or modern (or both) threats capture attention during a saccade task. In the oculomotor inhibition paradigm two images are laterally presented and the characteristics (e.g., angle, endpoint deviation and latency) of vertical saccades between the images are recorded (Nummenmaa, Hyönä, & Calvo, 2009). Because participants were instructed to ignore the images, the resulting involuntary curvature of the saccades (toward or away from the images) that resulted from inhibiting eye movements to the images served as an indication of which stimulus was capturing attention (Van der Stigchel, Meeter, & Theeuwes, 2006).

The present experiment was conducted to determine whether neutral, ancient, or modern threat stimuli would capture attention when in direct competition for processing resources. It has been shown repeatedly that when presented among non-threatening distractors both ancient and modern threats appear to capture and hold attention (Blanchette, 2006; Brosch & Sharma, 2005; Fox et al., 2007). However, these two types of stimuli have not been put in direct competition within the same task. In this experiment, by using the oculomotor inhibition paradigm described above we measured how attention was covertly captured by the three stimulus categories (non-

threat, ancient threat, and modern threat) when put in competition for processing resources by presenting them simultaneously. The data acquired indicate the relative strength of each type of stimulus for drawing attention and help to inform debates on the evolutionary constraints and malleability of the fear module and visual attention to threats in general.

Research suggests that the emotional content of an image is available outside of foveal vision. Calvo and Nummenmaa (2007) demonstrated that participants could reliably discriminate unpleasant from pleasant images when presented to the parafovea (i.e., 1-5° retinal eccentricity; Larson & Loschky, 2009). This is possible because even when images are presented parafoveally, the magnocellular pathway provides coarse information to the amygdala that is sufficient for a rough analysis of stimulus valence (Mermillod et al., 2010; Vuilleumier, 2005). Furthermore, images presented parafoveally can also capture attention and affect the saccade generation system even when they are irrelevant to the current task (Nummenmaa, Hyönä, & Calvo, 2009).

Nummenmaa et al., (2009) used an oculomotor inhibition paradigm to demonstrate that emotional scenes capture attention when presented parafoveally. Framing their work within Tipper's (1997; 2000) Population Coding Theory, Nummenmaa et al. demonstrated that emotional scenes capture attention by showing saccades deviate away from the emotional scenes. Research has shown that saccades can deviate towards or away from attention capturing stimuli and there are specific stimulus viewing conditions and theories for why one would expect saccades to deviate in one direction or another.

Saccadic Deviations Toward or Away From an Attention Capturing Stimulus

Van der Stigchel, Meeter, and Theeuwes (2006) present evidence and theory explaining why saccades deviate towards or away from an attention capturing stimulus. In particular, they

argue, saccade trajectories are influenced by stimulus factors such as size, luminance and sudden onsets as well as by the demands of particular tasks (Van der Stigchel, et al., 2006). For example, deviations towards a distractor occur when the saccade target and the distractor are presented simultaneously or in close temporal proximity (e.g., 50 ms; Van der Stigchel, et al., 2006). On the other hand when stimulus onset asynchronies are longer (e.g., 200 ms) saccades will deviate away from attention capturing distractors (Van der Stigchel, et al., 2006).

Tipper's (1997, 2000) Population Coding Theory is the dominant theory for explaining saccadic deviations. According to Population Coding Theory, potential saccade targets are represented by a large population of neurons that code saccade target locations as vectors. These neuron populations are located in a motor map in the superior colliculus (Aizawa & Wurtz, 1998; McPeck, Han, & Keller, 2003; McSorley, Haggard, & Walker, 2006; Van der Stigchel et al., 2006). Furthermore, the response strength of the coded vector of the superior colliculus is positively related to the saliency of the target. If two potential targets are in close spatial proximity, competition will arise among the population codes in the superior colliculus, sometimes resulting in a saccade to the "center of gravity" between the two stimuli (Van der Stigchel, 2006; Zelinsky, 2008). In cases where participants are instructed to move their eyes to one location, one of the two potential targets must be inhibited to resolve the competition. Inhibition of one target over the other affects the saccade trajectory.

Tipper (2000) proposes location specific saccadic inhibition is conducted through two exclusive inhibitory mechanisms. One of these mechanisms operates via lateral inhibition of neurons in the motor map. The neurons in the motor map are retinotopically organized such that adjacent neurons in the superior colliculus code for adjacent locations on the retina. Activity in a given location in the superior colliculus corresponds to saccade target locations. Thus, activity in

the given location in the superior colliculus increases until a saccade is made. The superior colliculus integrates the localized activity into a single output that is sent to premotor circuitry in the brainstem where eye movements are programmed (Moschovakis, 1996). The initial saccade direction is determined by the activity in the superior colliculus but the cerebellum adjusts and corrects saccadic trajectory during flight (McSorley, Haggard, & Walker, 2004; Quaia, Lefevre, & Optican, 1999).

The motor map neurons in the superior colliculus share excitatory connections with their neighboring cells and share inhibitory connections with distant cells. Therefore, excitation of a given location in the motor map simultaneously inhibits distant locations. This lateral inhibition is sufficient for inhibiting an eye movement to a distractor whose saliency is equivalent to the target. However, if a distractor is highly salient and activity in the motor map is high for the distractor location then this mechanism is insufficient for resolving the saccade programming conflict. In this case, a second mechanism operating via reactive feedback from the frontal eye fields (Houghton & Tipper, 1994) suppresses the motor map activity caused by the distractor. According to Tipper (2000) this mechanism's inhibition is much stronger and is directly related to the saliency of the to-be-inhibited location. Highly salient distractors cause greater inhibition of the corresponding neuron populations to sub-baseline levels resulting in saccadic trajectories that deviate away from the distractors. Less salient distractors do not elicit reactive feedback and may instead cause deviations toward the distractor via the primary lateral inhibition mechanism.

Projections from the frontal eye fields to the superior colliculi have an important role in the top-down inhibition of saccade target locations (Schlag-Rey, Schlag, & Dassonville, 1992). The top-down inhibition from the frontal eye fields suppresses the distractor-related activity in the superior colliculi below baseline resulting in a negative addition (Tipper, Howard, & Paul,

2001) to the averaged superior colliculus output. This results in an initial saccade deviation away from the distractor location. However, this reactive feedback from the frontal eye fields is only necessary for competing target locations of high salience.

Saccade deviations away from distractors are observed when certain viewing conditions are met. Specifically, deviations away are observed with longer saccade latencies (e.g., 200 ms) whereas shorter saccade latencies produce deviations towards distractors (McSorley et al., 2006). Additionally, predictable saccade target locations seem to produce deviations towards distractors (Van der Stigchel et al., 2006). Population Coding Theory affirms that the onset of a distractor comes with inhibition of saccades to it. The inhibition is a result of instruction not to make an eye movement to that stimulus. According to the Premotor Theory of Attention (Rizzolatti et al., 1987) an eye movement is programmed when attention shifts toward a stimulus, in this case the distractor. But because the viewer knows that the saccade should not be executed, the inhibition affects the subsequent saccade resulting in saccadic trajectories that deviate away from the inhibited distractor location on their way to the target. Thus the saccade starts by heading away from the distractor location but through the corrective influence of the cerebellum, the saccade is pulled back towards the correct saccade target resulting in a saccade trajectory which arcs away from the distractor location. Furthermore, the more a distractor location attracts an eye movement, the more it must be inhibited. Greater inhibition results in more dramatic deviations. Thus, greater deviation away from a given stimulus can indicate greater attention capture by the stimulus.

As mentioned earlier, researchers (Godijn & Theeuwes, 2002; McSorley et al., 2004) have proposed that the frontal eye fields are a possible source of top-down inhibition of distractor locations. The frontal eye fields have inhibitory connections to the superior colliculus

that run through the substantia nigra of the basal ganglia (Basso & Wurtz, 1997; 2002).

Although behavioral data (Godijn & Theeuwes, 2002; McSorley et al., 2004) supports such a model, there is no neurophysiological evidence that the frontal eye fields inhibit areas of the superior colliculus during deviations away from the distractor. This inhibition hypothesis would be supported by neurophysiological data showing that superior colliculus activity at the distractor location is inhibited below baseline during deviations away from the distractor. However, despite the lack of confirming neurophysiological data, behavioral data have shown that longer saccade latencies produce deviations away in line with the idea that top-down inhibitory influences take time to affect the saccade program (Godijn & Theeuwes, 2002).

To summarize, saccadic deviations towards a distractor seem to be caused by unresolved competition between locations in the motor map of the superior colliculus. Furthermore, deviations towards a distractor occur with stimuli of comparable saliency at early stimulus onset asynchronies and short saccade latencies. Deviations away from the distractor arise from the inhibition of highly salient distractors, large stimulus onset asynchronies and long saccade latencies. The long stimulus onset asynchronies and saccade latencies allow top-down influences sufficient time to inhibit motor map neurons coding for to-be-ignored locations below baseline.

Based on what we know about saccade trajectories and oculomotor inhibition, we have developed a methodology to investigate the evolutionary constraints imposed on visual attention to threat. The investigation is reported in the sections that follow.

Chapter 2 - Experiment 1

Stimulus Presentation Parameters

The present experiment adopts the same oculomotor inhibition paradigm used by Nummenmaa, Hyönä, and Calvo (2009) and is designed to meet the conditions under which deviations away from attention capturing stimuli can be expected. Specifically, long stimulus onset asynchronies (e.g., 200 ms) will be used (Van der Stigchel et al., 2006) and by leaving the central fixation dot on the display, saccade latencies will be prolonged (McSorley et al., 2004; Van der Stigchel et al., 2006). This should allow sufficient time for top-down inhibitory processes to take effect (Van der Stigchel et al., 2006). Under these conditions, saccades should deviate away from the more salient of two laterally presented distractors (Van der Stigchel et al., 2006).

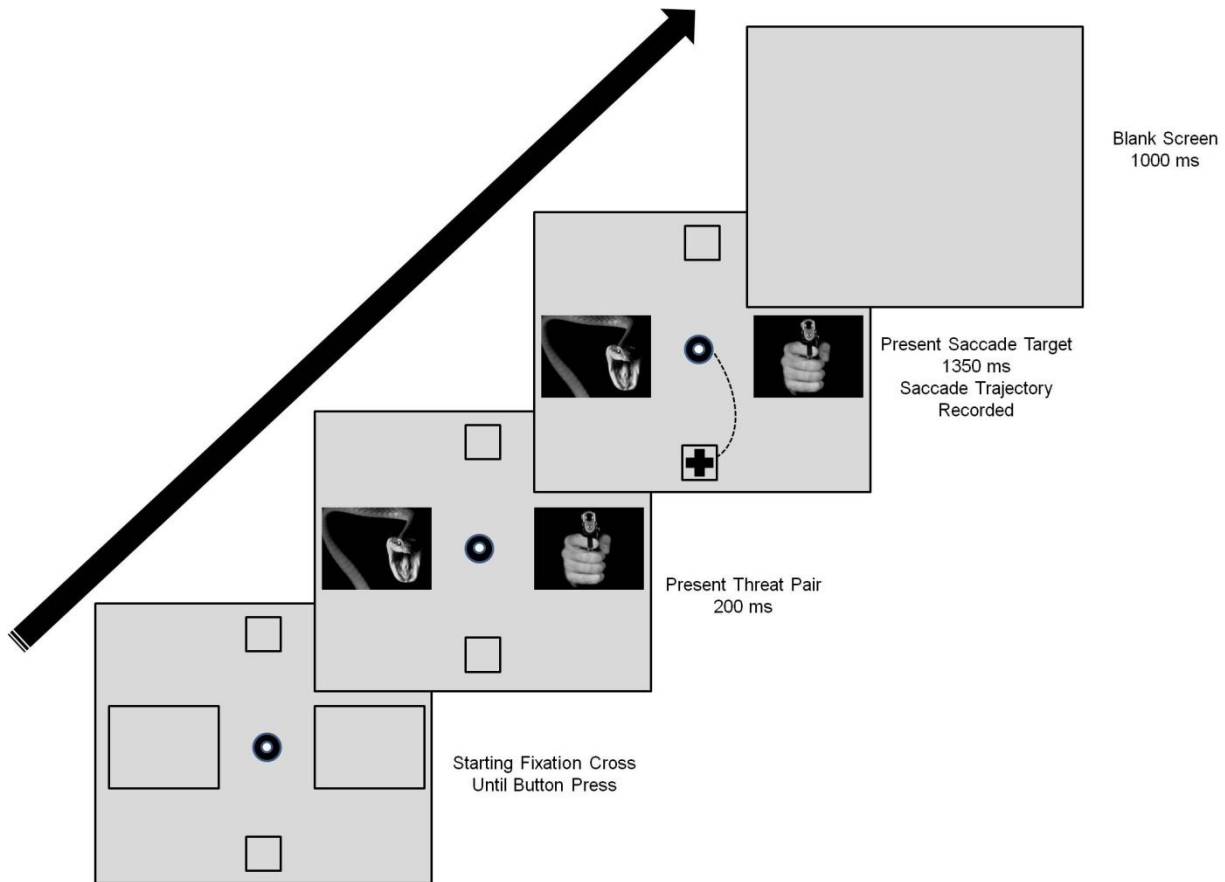
Previous research suggests that emotional stimuli are highly salient (Vuilleumier, 2005) and emotional content has been shown to capture attention (Nummenmaa et al., 2009). Thus, in order to isolate the effect of the emotional content on attention, lower level stimulus salience due to luminance contrast will be controlled for by equating all stimuli for mean luminance and image contrast. In this way, oculomotor capture should derive from the emotional content of the images rather than their luminance and contrast. However, because previous research has not explicitly isolated the effects of emotional salience from salience derived from low-level image characteristics, we cannot be entirely sure that what has been determined “emotional salience” in past research is not confounded with low-level image characteristics. Recall that highly salient images evoke strong reactive feedback inhibitory mechanisms responsible for causing saccade deviations away from an attention capturing stimulus. This suggests the possibility that

equalizing image luminance and contrast may affect image saliency and subsequently, eye movement patterns.

Additionally, in Experiment 1 all images were presented both in the normal upright position and inverted position. Inverting the image disrupts semantic processing (e.g., Kelley, Chun & Chua, 2003) while maintaining the low level properties of the stimuli (e.g., spatial frequencies, orientations, phase, and contrast). Thus, any effect of images' emotional content should be reduced or eliminated during inversion if the effect is due to the emotional content of the stimuli and not due to low level stimulus properties (Gutiérrez, Nummenmaa & Calvo, 2009).

Using the oculomotor inhibition paradigm reported by Nummenmaa, et al. (2009, Exp. 3), participants were presented with image pairs of ancient-, modern-, and non-threats on either side of a central fixation point (see Figure 2.1). Participants were asked to make a saccade from the central fixation point to a saccade target positioned horizontally centered on either the top or bottom edge of the display. By asking participants to make vertical saccades from the central fixation point and recording the eye movements, saccade trajectory served as a measure of whether one threat type reliably captured attention. Because the Premotor Theory of Attention (Rizzolatti, Riggio, Dascola, & Umiltà, 1987) posits that shifts of covert attention involve programming eye movements, and the Population Coding Theory posits that inhibiting an eye movement to an attention capturing stimulus causes saccades to curve away from it under the proposed conditions, in the present experiment attentional capture was indexed by saccadic curvature, saccadic latency and saccade endpoint deviation. We also recorded data indicating when participants erroneously made saccades to a distractor. These error data served as an additional measure of preferential looking and were also used to index attention allocation.

Figure 2.1 Trial schematic. In this hypothetical example the saccade curved away from the snake indicating the ancient snake threat captured attention and a saccade to that stimulus was inhibited.



Hypotheses

The degree of saccadic curvature was calculated to explore whether the independent variables differentially and reliably affected saccades. Specifically, because curving saccades indicate that the population of neurons responsible for programming an eye movement to the threat stimulus was inhibited below baseline (Godijn & Theeuwes, 2004) the degree of saccade deviation indicated the degree of neuronal inhibition with larger deviations indicating greater inhibition. Thus, this measure allowed us to establish a rough picture of how attention is

allocated in the face of ancient and/or modern threats. For example, when ancient and modern threats are put in competition for attention, is one or the other consistently winning out?

If the fear module contains the Fodorian characteristic of evolutionarily derived selectivity (Öhman & Mineka, 2001), we would expect the ancient threat stimuli to successfully compete for attention when paired with both neutral images and modern threats. Such preferential attention capture for ancient threats would be indicated by saccades reliably deviating away from the ancient threat images but not the neutral or modern threat images and would suggest the fear module is constrained by evolutionary parameters. On the other hand, recent research has shown that modern threats also capture attention (e.g., Blanchette, 2006). If modern threats also activate the fear module we would expect saccades to curve reliably away from the modern threat stimuli. Such a result would indicate the fear module's selectivity is not constrained by evolutionary relevance. Of course it is possible no particular threat category will reliably capture attention. In the event of an absence of a statistically significant effect of threat category or threat pair on saccade trajectories it would be important to consider why.

If the lack of the effect is due to consistently straight saccades, then this would suggest that our stimuli are not capturing attention. One potential reason this may occur would be if the images presented were too small or too close together (causing a global effect, see Van der Stigchel et al., 2006). Revisions to the experimental program could fix this issue. However, because the stimulus size and position is based on the work of Nummenmaa et al., (2009, Exp 3) this problem should be successfully avoided.

A more interesting reason to observe a lack of effect of threat category on saccade trajectories is that the saccades curved, but they did not curve reliably away from one threat category or another since both threat types capture attention. Because which specific images will

be paired with each other will be randomized, this could only indicate that the success of a stimulus to successfully compete for attention was dependent upon whether it was competing with a different type of threat or a neutral stimulus and that its effect was larger in that instance. This finding would further suggest that if the fear module exists, it does not exclusively select ancient threats for processing.

Also, if we treat saccade latency as an independent variable, we can test to see if saccadic curvature varies as a function of saccadic latency. According to Van der Stigchel et al., (2006) we may find that shorter saccade latencies result in saccade deviation towards the attention capturing stimulus whereas longer latencies may produce saccades that deviate away from the stimulus. Additionally, we can conduct analyses to determine if a particular type of threat produced more misdirected saccades (e.g., to the image) than the other threat types. This analysis serves as a measure of preferential looking, a known index of overt attention (Nummenmaa, et al., 2009).

We can also make predictions based on participants' experience with our stimuli. Specifically, because experience is positively related to attention to relevant targets (Nodine, Kundel, Lauver, & Toto, 1996) it makes sense that more experience with the stimuli would facilitate attention to it. Thus, we would expect a main effect of experience such that those with more experience with the stimuli will demonstrate greater attentional capture by the stimuli as indicated by increases in saccade deviation. We may also expect faster saccade latencies from more experienced participants. Such results would implicate learning and experience in shaping fear and threat detection behavior.

Lastly, we expect a main effect of image inversion such that there should be less attentional capture with inverted images. When images are inverted there should be a

diminished effect of threat pairing, or experience. However, when the images are upright we expect a stronger effect of threat pairing and experience. Thus, it is plausible that we will observe a three-way interaction between threat pair, experience and image orientation.

Method

Participants

33 undergraduate students with varying experience with the threat categories used herein were recruited from Kansas State University to participate in the experiment in exchange for course credit. Due to ethical considerations, all participants were warned of the potentially phobic and anxiety provoking nature of the stimuli at recruitment. The main reason for measuring participants' experience with the present threat categories is to gain insight into the degree of domain-specificity of some cognitive mechanism that allows experience to influence threat detection behavior.

Materials

A Sloan near-acuity letter chart was used to ensure participants had normal or corrected-to-normal vision. Groups of participants were surveyed after completion of the experiment on their experience with, and anxiety caused by, the stimuli used herein using an adapted form of a specific anxiety questionnaire (SNAQ; Klorman et al., 1974; see Appendix A) that has good psychometric properties. Participants were also tested for state and trait anxiety using the State-Trait Anxiety Inventory (STAI; Spielberger, 1983; see Appendix B). The experiment was conducted on a Dell computer running Experiment Builder ® software. Eye movement data was acquired with an Eyelink 1000 (SR Research, Mississauga, Ontario, Canada) remote eye tracker with a sampling rate of 1000 Hz. The stimuli were displayed on a 17-inch ViewSonic CRT

monitor with a gamma correction of 2.2 that took account of the perceptual compression of brightness.

Stimuli

384 images collected from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005) and the internet that comprise the three threat categories (192 neutral images, 96 images of ancient threats, and 96 images of modern threats) were used to create the neutral-neutral, neutral-modern, neutral-ancient, and modern-ancient threat pair stimuli. Each pairing included 72 trials of upright images and 72 trials of inverted images (72 images x 2 orientations x 4 pairings = 576 trials). Each of the four pairings had one category on the left or right for half of the time (i.e., 36 of 72 trials had category X on the left and category Y on the right. The side of presentation was reversed for the other 36 trials). The images featured readily identifiable objects. The ancient threat stimuli included images of snakes, spider, angry faces and dangerous mammals. The modern threat stimuli included images of guns, knives, syringes and electrical hazards. The neutral stimuli consisted of flowers, mushrooms, office supplies and dishes. The images measured 9.5 cm x 7.1 cm (360 x 270 pixels) subtending 11.83° x 8.92° of visual angle at a fixed viewing distance of 58 cm. All images were converted to grayscale and adjusted for equal mean luminance and RMS contrast. Which image is presented to the left or right visual field was randomized and counter balanced so each threat type appeared equally often to the left and right of fixation. Additionally, 24 images (12 Neutral, 6 Ancient, and 6 Modern) were used for 12 practice trials to familiarize participants with the task. The practice images were not used in the main experiment.

Similar to the methods used in Nummenmaa et al. (2009, Exp 3), the central fixation stimulus was a black dot with a white center with a diameter of 50 pixels (1.4 of visual angle),

and the saccade targets were black crosses measuring 50 x 50 pixels (1.4° of visual angle), centered on either the top or bottom edge of the display (see Figure 2.1). Also similar to the methods of Nummenmaa et al. (2009), the location of all stimuli, including the distractor images and the saccade targets were marked on the initial trial screen with black rectangles that served as place holders. Whether the target would appear on the top or bottom was unknown, making the target location unpredictable. This is one of the display conditions intended to push saccadic deviations away from distractors by allowing top-down processes to take affect the saccade program (Van der Stigchel, et al., 2006). The center of the saccade targets was 11° from the center of the fixation dot. The place holders for the images were the same size as the distractor images. The inner-most edges of the images were located 5° from the center of the fixation dot, while the outermost edges were at 16.6°, thus putting the distractor images within peripheral vision (> 5° eccentricity; Larson & Loschky, 2009). Past research (Gutierrez et al., 2009) has shown that emotional content is available from peripheral vision.

Procedures

Participants were tested individually in a dimly lit room. Prior to starting the experiment, participants received a verbal warning of the potentially phobic and anxiety provoking nature of the stimuli. Participants then completed the Sloan near-acuity letter chart vision test. Participants not scoring 20/30 or better were not allowed to participate. After completing the vision test, participants completed the informed consent process and went through the eye tracker calibration procedure. The calibration procedure required participants to fixate on a series of dots appearing randomly at nine positions on the monitor. Following calibration, participants completed the practice task followed by the 576 experimental trials that took approximately one hour to complete. Drift correction was performed after every trial to maintain calibration. After the

experiment, participants completed the surveys. Participants were debriefed and thanked for their participation.

Tasks

In the practice task, participants completed 12 trials (three trials from each of the four possible threat category pairings: Neutral-Neutral, Neutral-Ancient, Neutral-Modern, and Modern-Ancient) of the saccade task used in the main experiment. Participants were required to make eye movements to the saccade target as quickly as possible after target onset. In the main experiment participants completed 576 trials that started with the presentation of the central fixation dot. To initiate the trial, participants pressed the “NEXT” button on a hand held game pad controller using their right hand. The threat-pair images immediately onset followed 200 ms later by the saccade target. The saccade target onset served as the imperative signal to initiate the saccade. Participants were instructed to ignore the images and make vertical saccades to the target presented on the central vertical axis orthogonal (above or below) to the images and hold fixation until the end of the trial. Consistent with the method of Nummenmaa et al. (2009, Exp. 3) participants had 1,350 ms post-target onset to complete an eye movement to the saccade target after which time the screen went blank for 1,000 ms. After the 1,000 ms blank screen a drift correction screen containing only the central fixation dot appeared. Participants had to fixate the dot and press the “NEXT” button on the handheld gamepad to advance to the next trial. This drift correction ensured proper eye tracker calibration throughout the experiment. After drift correction, the next trial initiated as indicated by the appearance of the first trial screen containing only the central fixation dot and placeholders. The total trial duration was 2,550 ms. An example trial is illustrated in Figure 2.1.

Design

The main independent variables in the experiment were a) the threat category pairing of the target images (4-levels: neutral-neutral, neutral-modern, neutral-ancient and ancient-modern, within-subjects), b) experience with the stimuli (2-levels: high or low, between subjects) c) image inversion (2-levels: upright & inverted (within-subjects), and d) anxiety created by the stimuli (2-levels: high or low, between-subjects (median split)), yielding a 4 x 2 x 2 x 2 mixed design. Saccadic latency (i.e., the time required to initiate an eye movement), saccade angle and saccade deviation (i.e., the degree of saccade curvature in angular degrees) were the dependent variables used to index attention capture. Additionally, misdirected saccades (i.e., saccades to a threat image) were recorded as an additional indicator of preferential looking which has been used to demonstrate attentional capture (Nummenmaa et al., 2009) and were analyzed separately. Based on previous research regarding our stimulus timing parameters (Nummenmaa et al., 2009, Exp. 3; Van der Stigchel et al., 2006), when forced to ignore the threat stimuli, participants' saccades were expected to arc *away* from the attention capturing stimulus.

Results

Precursors to Analysis

Trials were temporally filtered to focus on the period of interest between the onset of the images and termination of the trial upon target fixation. Using this interest period, further data processing ensued in order to provide clean and analyzable datasets. In line with the methods of Nummenmaa et al. (2009, Exp. 3) trials indicating anticipations, (saccade latencies < 80 ms) and retardations (latencies over two standard deviations above the participants' mean) were removed. Saccade starts and ends were identified by Eyelink software utilizing a 22 deg/s velocity and 8,000 deg/s² acceleration criterion (McSorley et al., 2006). Trials indicating saccades to the

wrong target were labeled as errors for separate analysis (Nummenmaa et al., 2009). Saccades with an endpoint deviation greater than 4° from the center of the target were removed. Additionally, saccades with amplitudes less than 10° were labeled undershoots (Nummenmaa et al., 2009) and removed from the analysis. In total, 33.6% of the cases were removed. The majority of the problem cases were undershoots (24.4%) resulting from short saccades around the viewing space during the interest period. Further, 7.3% of the removed cases were from saccades landing more than 4° from the center of the target. The final 1.9% of the removed cases was from saccades to the wrong target. In terms of trials, 19% of the trials were removed. This is substantially more than Nummenmaa et al. (2009, Exp 3) who only removed 8% of their trials. However, given that this experiment had 4.5 times the number of trials used in Nummenmaa et al., there was substantially more room for error.

Further processing of the eye movement data was required to assign values to the saccadic deviations. We recorded the X and Y coordinates for the eye at every millisecond during the interest period. These data were used to calculate and assess the initial deviation angle of a saccade in the first 10 ms post-initiation. Saccade angle deviation was calculated as the initial angle between the saccade sample points in the first 10 ms of the saccade and the straight path from fixation to the endpoint of the saccade (Van der Stigchel, et al., 2006). The angles of the saccades were calculated by creating a straight line from the beginning and end points of a saccade. This line then served as the abscissa. Next, the slope of the line from point 1 (eye location at 1ms) to point 10 (eye location at 10 ms) using the start-to-finish line as the abscissa was determined for each trial. Taking the arc tangent of this slope produced an angular value which served as the dependent variable in the analysis. This angle determination method is illustrated in Figure 2.2. In addition to the statistical analyses of these data, plots of the data

points facilitate visual analysis of the data and clearly show consistent trends in eye movement behavior.

Saccades deviating to the left were assigned negative values and saccades deviating to the right were assigned positive values. The saccade angle values were divided by the values of saccade amplitude to account for potential effects of amplitude on saccade curvature. This resulted in a saccade angle per amplitude ratio value that indicated both the direction and degree of the saccadic deviation (Nummenmaa et al., 2009).

The endpoint deviation of the saccades (i.e., how far the first fixation after saccade initiation falls from the correct saccade target) was also calculated as a measure of saccade deviation (Nummenmaa et al., 2009). This measure was also assigned negative and positive values for left and right deviations, respectively. To account for the potential effect of saccade amplitude on endpoint deviation, the endpoint values were similarly divided by the saccade amplitude to obtain deviation per amplitude ratio value. This resulted in a second value that represented the direction and degree of saccadic deviation (Nummenmaa et al., 2009). These values were then transformed to represent deviation in terms of visual angle¹.

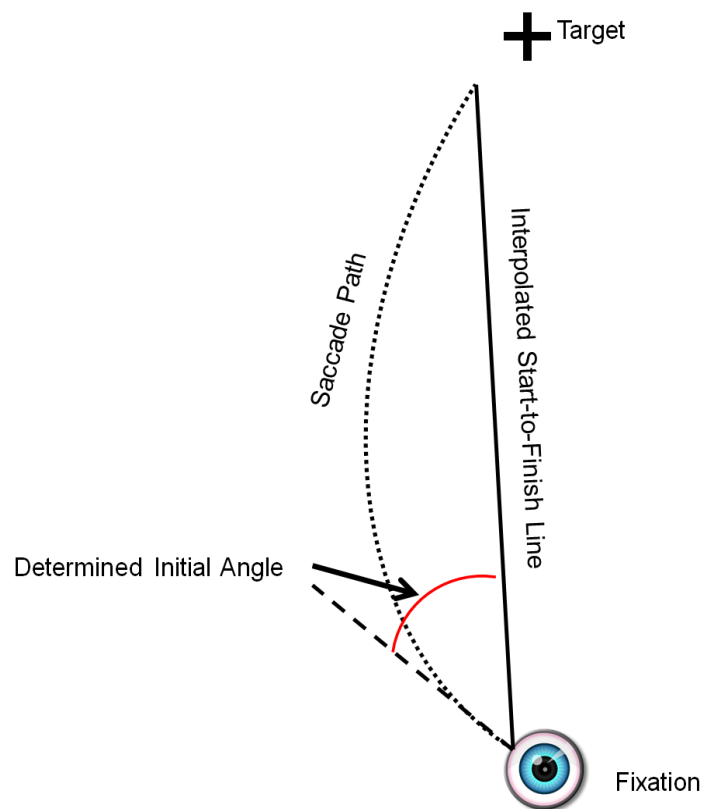
As a third measure, saccade latency (i.e., the lag from target onset to saccade initiation) was recorded. This variable was analyzed to provide information about processing speed.

¹ We completed the transformation of the endpoint ratio values in accordance with the procedures used in Nummenmaa et al. (2009, Exp 3) in the interest of facilitating comparison across the two studies. However, it would be more appropriate to establish the visual angle values of the raw endpoint deviations and saccade amplitudes first, and then calculate the deviation ratio using these transformed variables. This logic is based on the idea that it makes more sense to establish real visual angle values in the two variables and use those to compute the deviation ratios. Transforming a ratio derived from raw data into visual angle seems less appropriate as one is calculating the visual angle of a derived deviation measure, not an actual deviation measure that exists naturally. Although the two methods do not alter the data patterns, the method used here (and in Nummenmaa et al., (2009, Exp 3) does produce smaller values by an order of magnitude.

Specifically, saccade latency tells us whether or not processing speed is systematically related to the independent variables.

The independent variables used in the following analyses were similar to previous analyses of saccade data. Condition pairing (4 levels), stimuli orientation (2 levels), experience with the stimuli (2 levels) and anxiety caused by the stimuli (2 levels) were tested for their effects on the initiation angles of saccades, the endpoint deviations of the saccades, and the saccade latencies to determine if various threats were systematically affecting saccade programming.

Figure 2.2 Determination of the initial saccade angles.



Of note is the fact that there were 13 unique possible pairing combinations of the threat conditions when accounting for side of presentation. Ancient, modern and neutral threats were paired such that each pairing combination occurred with equal frequency when counterbalanced

for orientation (i.e., upright or inverted) and hemifield of presentation (left or right). In the present study, hemifield of presentation is not of theoretical interest and thus, for analytical purposes, threat pairing was collapsed into a six-level variable (i.e., all possible pairs of the three threat conditions). Further, the redundant threat pairings in which ancient threats were paired with other ancient threats (and likewise for modern) were omitted from the analysis to facilitate interpretation of the results. This resulted in a 4-level condition pairing independent variable (i.e., ancient-modern; ancient-neutral; modern-neutral; neutral-neutral). Given the three dependent variables of interest, several mixed ANOVAs were carried out.

Analyses

Overall Analysis

The analysis of saccade initiation angles failed to reveal significant main effects of threat condition pairing, orientation or experience (all $F_s < 1$). Even the Neutral-Neutral pairs did not differ statistically from Neutral-Threat pairs in terms of the degree of deviation they elicited. Although not statistically significant, there was a trend for Modern-Neutral pairs ($M = 9.35$, $SE = 3.493$) to have a greater angular deviation than the Ancient-Neutral pairs ($M = 4.856$, $SE = 3.428$) in terms of the angle per amplitude ratio measure, $p = .12$

Threat pairing was further collapsed into a new, three-level variable for the number of threats shown (zero, one, or two threats present) and analyses were conducted to test for effects of threat presence on our dependent variables. None of these analyses produced significant main effects or interactions (all $F_s < 1$). This is potentially problematic because on the one hand, if there are meaningful trends in the data, the analysis is not sensitive enough to pick them up. On the other hand, if there are no differences between presenting viewers with one-threat versus no-threat categories, and therefore the present images, including the neutral categories, in general

produce equal attentional capture, or the lack thereof, and the threat value of the stimuli plays no meaningful role in shaping the data. This potential problem is the basis for conducting Experiment 2, to gain evidence as to whether or not these results indicate a Type II error.

Moving on, we measured the distance of the final saccade landing position from the center of the target (i.e., saccade endpoint deviation). This deviation value was divided by the saccade amplitude to calculate an endpoint deviation by amplitude ratio. These endpoint deviation ratios served as the dependent measure of attention capture in another 4 x 2 x 2 mixed ANOVA. Neither threat pairing nor orientation showed systematic relationships with endpoint deviation ratios ($F_s < 1$). However, we suspected that the lack of an effect of orientation may have been due to plausible orientation invariance of a number of our stimuli. Specifically, the ancient threats of snakes and spiders and modern threats of knives and syringes do not have a correct upright orientation. To test this hypothesis, trials presenting these stimuli were removed and the data were reanalyzed. This revealed a significant main effect of orientation on endpoint deviation ratios, $F(1, 292) = 5.706, p = .018$, supporting the notion that the observed effects were not due to low-level image characteristics.

Analysis of the Effects of Experience

We also investigated whether or not participants' level of experience with the threatening stimuli would affect the level of attention capture elicited by those stimuli. The global measure of experience with threats used for this analysis is comprised of significantly inter-correlated subscales. The correlations among threat-experience scores can be found in Table 2.1

Table 2.1. Correlations among the experience scores of the different threats.

	Snake	Spider	Dangerous Mammal	Angry Faces	Guns	Knives	Syringes	Electrical Hazards
Snake	1	.563**	.153**	.071**	.181**	.008	.017*	.258**
Spider		1	.151**	.196**	.091**	.174**	.121**	.338**
Dangerous Mammal			1	.129**	.205**	.205**	.054**	.141**
Angry Faces				1	.088**	.275**	.352**	.358**
Guns					1	.367**	.021**	.292**
Knives						1	.058**	.481**
Syringes							1	.227**
Electrical Hazards								1

*significant at the $p = .05$ level

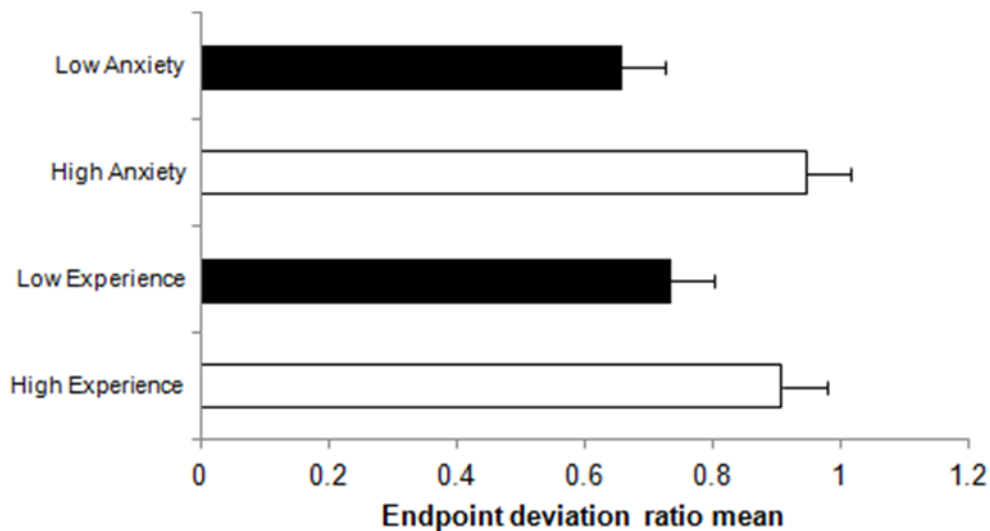
**significant at the $p = .01$ level

Generally speaking, participants who had experience with one type of threat tended to have experience with the other threats. However, this was not the case with knives and snakes which were uncorrelated. This is likely due people's relative inexperience with snakes compared to their likely daily encounters with knives. Interestingly, the strongest correlation was between experience with snakes and experience with spiders, perhaps the two most evolutionarily relevant threats. Given the large number of significant correlations of varying strengths, there is a lot of room for speculation on the underlying reasons for these relationships.

Additionally, utilizing this general experience measure provides clues regarding the domain generality of any cognitive mechanism that allows life experiences to affect attention behavior. Thus, using a global measure of experience we found that participants' experience with the stimuli was significantly related to endpoint deviation ratios, $F(1,474) = 5.767, p = .017$, Cohen's $F = .092$. Planned t -tests showed that those with high experience scores ($M = .909, SD$

= .726) had greater endpoint deviations than those with low experience scores ($M = .734$, $SD = .673$), $t(1, 488) = 2.72$, $p = .007$, $d = .25$. This effect did not interact with condition pairing (i.e., experience affected both ancient and modern threats similarly). This lack of an interaction is expected since the global threat experience variable was collapsed across both ancient and modern threats. These data are presented in Figure 2.3.

Figure 2.3 Endpoint deviation as a function of experience and anxiety with threats. Highly threat-experienced individuals demonstrated significantly more saccade endpoint deviation than those with less threat experience. The same pattern is seen with the anxiety measure. Error bars represent SEM.



Experience led to shorter latencies and larger endpoint deviations and it was therefore important to further examine this pattern. To this end, participants with high and low experience were compared on threat-neutral and neutral-neutral trials. Experienced participants were always faster and exhibited greater endpoint deviations than inexperienced participants regardless of the condition pairing. Importantly however, when only neutral-neutral pairs were selected, experienced participants remained faster and still exhibited larger endpoint deviations. What this means is that the effect of experience on saccade latencies and endpoints is unrelated to the threat

value of the stimuli. This lightly suggests a low level of domain-specificity of some underlying cognitive mechanisms that allow experience with objects to up-regulate attention to them.

Furthermore, it is unclear what the observed effects of the experience variables mean in relation to the present research questions regarding the evolutionary constraints on threat perception.

Nevertheless, one may argue that it is insufficient to utilize a global measure of experience since experience with say, electrical hazards, has little (if any) theoretical relation with experience with say, snakes, in terms of evolutionary principles. This position suggests that it would be more theoretically appropriate to do analyses utilizing more specified measures of experience. Therefore, the global experience measure was broken out in order to examine the effects of specific experiences with the stimuli (e.g., snakes) on the dependent variables of saccade latency, saccade endpoint deviation ratios and saccade angular deviation on trials when that particular stimulus type (e.g., snakes) was presented. Analyses using the subscales of experience speak to the domain specificity of the underlying cognitive mechanisms allowing experience to affect attention processes. It is critical to conduct these analyses for two reasons. First, solely using a global experience measure may be theoretically inappropriate (even though the threat subscales are intercorrelated). Second, and more importantly, analyzing the relationship of specific experience scales to our dependent variables may provide evidence regarding the domain specificity (or lack thereof) of threat detection mechanisms. This is critical as the determination of the magnitude of domain specificity is central to discussions of evolved cognitive mechanisms (Sperber, 1994).

A series of one-way ANOVAs were conducted, selecting specific threats for each analysis. For example, in the first test we selected only those trials in which angry faces were paired with a neutral stimulus. Using a median split for experience with angry faces as the

independent variable, the ANOVA failed to reveal a significant effect of experience on any of the three dependent variables (all $F_s < 1$). Similar tests were carried out for all eight of the threat categories (i.e., angry faces, predators, snakes, spiders, electrical hazards, guns, knives and syringes). Each test yielded similar non-significant results. Thus, in short, when accounting for the specificity of experience, it appears that experience is not meaningfully related to our indices of attention capture (i.e., saccade latency, saccade endpoint deviation ratios, and saccade angles). However, due to a significantly smaller number of cases in these analyses (relative to the omnibus ANOVAs), and the use of median splits for the independent variables, these results could indicate Type II errors.

To test the possibility that the one-way ANOVAs simply lacked the sensitivity necessary to pick up relationships between the dichotomized experience measures and the eye movement parameters to their associated threats, we carried out a series of correlation analyses using continuous measures of specific types of threat experience to see if specific experiences were related to the eye movement variables. As shown in Table 2.2, there were three significant correlations. Experience with snakes demonstrated a relatively strong positive correlation with saccade endpoint deviation ratios, $r = .409$, $p = .016$, as did experience with spiders, $r = .382$, $p = .026$. Lastly, experience with spiders demonstrated a significant negative correlation to saccade latency, $r = -.341$, $p = .049$. This suggests a couple of interpretations of the analyses up to this point.

First, it suggests the possibility that the null effect yielded in the one-way ANOVA testing for effects of snake and spider experience on the eye movement variables (only in cases where snakes and spiders were paired with neutral images) may have been a Type II error based on using a median split. Furthermore, it suggests two things about the significant effect of

general experience on endpoint deviation ratios found in the omnibus ANOVA. It suggests that either a) the omnibus ANOVA indicates a Type I error resulting from the large number of cases considered or b) the effect is driven by the strong relationship between experience with snakes and spiders and endpoint deviation ratios such that the deviations increase with experience.

If the effect of global threat experience on endpoint deviation ratios is driven by experience with snakes and spiders, then removing data from trials in which snake and spiders were presented should remove the effect. That analysis revealed this was the case, $F < 1$, supporting the idea that the effect of experience on endpoint deviation ratios is driven by experience with snakes and spiders.

Table 2.2. Correlations of the specific threat experience measures with the dependent eye movement variables.

Experienced Stimulus	Angle Deviation Ratio	Saccade Latency	Endpoint Deviation Ratio
Snake	.091	-.182	.409*
Spider	.253	-.341*	.382*
Dangerous Mammal	.180	-.210	.122
Angry Faces	.086	-.316	.077
Guns	.042	-.024	.235
Knives	.223	-.085	.070
Syringes	.099	-.080	.172
Electrical Hazards	.011	-.099	.108

* = significant at the $p = .05$ level

** = significant at the $p = .01$ level

This line of reasoning supports the possibility of a domain-specific (i.e., snake-specific and spider-specific) cognitive mechanism whereby experience with snakes and spiders can influence attention to them. This interpretation is in line with the evolutionary notion of preparedness supported by the comparative fear studies showing that monkeys undergoing minimal exposure to snakes will elicit a large fear response to them (Cook & Mineka, 1989), as well as studies showing rapid observational conditioning to snake and spider stimuli (Mineka et

al., 1984). However, these interpretations are offered cautiously in light of the mixed findings from the various analyses.

Analysis of the Effects of Anxiety

In order to analyze any effects of participants' anxiety levels on the dependent variables, we utilized a global measure of anxiety. It is important to note that a global measure of anxiety was justified as not only were there significant correlations amongst the individual anxiety measures, but the global anxiety measure was also correlated with a previously validated and well known measure of global state-trait anxiety (STAI, Spielberger, 1983), $r = .510, p < .001$.

Entering the global anxiety measure into the ANOVA revealed a highly significant effect of anxiety on endpoint deviations, $F(1,474) = 19.30, p < .001$, Cohen's $F = .18$. Those high in anxiety had larger endpoint deviations ($M = .948, SD = .820$) than those low in anxiety ($M = .657, SD = .421$), $t(1, 488) = 4.699, p < .001, d = .45$. This is shown graphically in Figure 2.3. Although participants with less anxiety had longer saccade latencies (i.e., they were slower to react than those with high anxiety), this effect did not reach significance, $F(1, 474) = 3.037, p = .08$. There were no other significant main effects and anxiety did not significantly interact with the other independent variables. The lack of an interaction is contrary to what is expected, as one would expect anxiety to interact with the presence of threat (i.e., no effect of anxiety in neutral-neutral pairs). However, given the high correlation of our anxiety measures with each other and with the STAI (shown in Table 2.3), our specific anxiety scales seem to be capturing an effect of generalized anxiety on eye movements to all stimuli, regardless of their threat value. This suggests that generally anxious individuals exhibit more erratic eye movements. This finding is important so far as it shows that anxiety can affect eye movements. But given that anxiety is unrelated to the present threat manipulation, it is unclear what this means for the larger

research questions regarding the evolutionary constraints on threat perception. Furthermore, adapting the SNAQ for the present purposes seems to have detracted from its construct validity, leading it to become more of a measure of general anxiety than specific anxiety. This may explain the lack of an interaction with the other independent variables.

Table 2.3. Correlations among the specific anxiety measures and with the STAI.

	Snake	Spider	Dangerous Mammal	Angry Faces	Guns	Knives	Syringes	Electrical Hazards	STAI
Snake	1	.074**	.429**	.283**	.381**	.498**	.117**	.222**	.404**
Spider		1	.198**	.491**	.356**	.342**	.082**	.085**	.250**
Dangerous Mammal			1	.281**	.106**	.118**	.065**	.232**	.361**
Angry Faces				1	.289**	.562**	.211**	.359**	.385**
Guns					1	.701**	.106**	.441**	.314**
Knives						1	.270**	.173**	.287**
Syringes							1	.001	.069**
Electrical Hazards								1	.322**

** = correlation significant at the $p = .01$ level

In an attempt to clarify the relationship of anxiety with threats, as was done with the experience measure, the global anxiety measure was broken out and specific analyses were conducted in which threat-specific trials were selected for analysis. A series of one-way ANOVAs using median splits on the specific anxiety sub-scales as the independent variable and the eye movement parameters as the dependent variable showed that the individual anxiety measures were unrelated to the dependent variables with one exception. Anxiety caused by the predatory mammal stimuli was related to saccade latencies $F(1,32) = 4.057, p = .05$, such that those high in predatory mammal anxiety ($M = 528.42, SD = 151.95$) were slower to react than those low in predatory mammal anxiety ($M = 507.34, SD = 95.3$). Given that this is the only threat that produced a difference, it is difficult to interpret this finding. However, the absence of a significant effect of specific anxieties on endpoint deviation ratios suggests that the significant result mentioned above may be due in part to additional analytical power resulting from the inclusion of larger number of cases. Therefore, any ideas drawn from the notion that anxiety affects saccade endpoints should be drawn very carefully in the context of this study. Further research would be required to investigate the effects of both general and specific anxieties on eye movement reaction times in order to posit a more substantive conclusion.

In a larger analysis model including experience and anxiety measures, endpoint deviation ratios were analyzed in a 4 (pairing, within-subjects) x 2 (orientation, within-subjects) x 2 (experience, between-subjects) x 2 (anxiety, between-subjects) mixed ANOVA. The 4-way model failed to show significant effects of threat pairing or orientation on endpoint deviations (all $F_s < 1$). However, both experience, $F(1,348) = 14.04, p < .001$, Cohen's $F = .157$, and anxiety, $F(1,348) = 29.13, p < .001$, Cohen's $F = .296$, remained systematically related to endpoint deviations (though it remains unclear what this means at this time).

There was also a significant relationship between experience and anxiety. Specifically, those with more experience with the stimuli reported less anxiety ($M = 7.95$, $SD = 4.45$) than those with less experience ($M = 11.53$, $SD = 5.80$), $t(1,629) = 8.478$, $p < .001$, $d = .69$. As shown in Figure 2.4, the experience and anxiety factors exhibit a significant negative correlation, $r = -.356$, $p < .001$. This raises the possibility that experience may play a role in shaping overt reactions to threats such as anxiety. However, this experiment was not designed to test such possibilities and additional research would be required to elaborate on this issue.

The data were further analyzed to test for any effects of threat type, experience with the stimuli, anxiety invoked by the stimuli or orientation of the stimuli on saccade latency. Saccade latency was entered as the dependent variable in a 4 (condition pairing, within-subjects) x 2 (orientation, within-subjects) x 2 (experience with the stimuli, between-subjects) mixed ANOVA. The data showed that neither threat pairing nor stimulus orientation was related to saccade latency (all $F_s < 1$). Participants' experience level with the stimuli had a significant effect on saccade latencies, $F(1, 474) = 24.85$, $p < .001$, Cohen's $F = .206$. This relationship seemed to be driven by the fact that those with less experience had consistently longer saccade latencies than those participants with more experience who demonstrated significantly faster saccade latencies, $t(1, 488) = 5.298$, $p < .001$, $d = .453$, see Figure 2.5. As previously noted however, specific measures of experience are unrelated to the dependent variables. Therefore, this effect of experience on saccade latencies should be interpreted cautiously. It is possible that the significant result here is simply due to a larger number of cases being considered in the analysis. Lastly, the participants' experience levels did not interact with the other IVs (all $F_s < 1$).

In a subsequent ANOVA, a median split on the global anxiety measure (e.g., a collapsed measure of all the inter-correlated specific anxiety scales) was used to test for any effects of threat type, anxiety invoked by the stimuli, or orientation of the stimuli on saccade latency. Saccade latency was entered as the dependent variable in a 4 (condition pairing, within-subjects) x 2 (orientation, within-subjects) x 2 (anxiety with the stimuli, between-subjects) mixed ANOVA. This analysis revealed no significant effects.

Figure 2.4 The significant negative relationship between our adapted global anxiety measure and our global experience with threats measure.

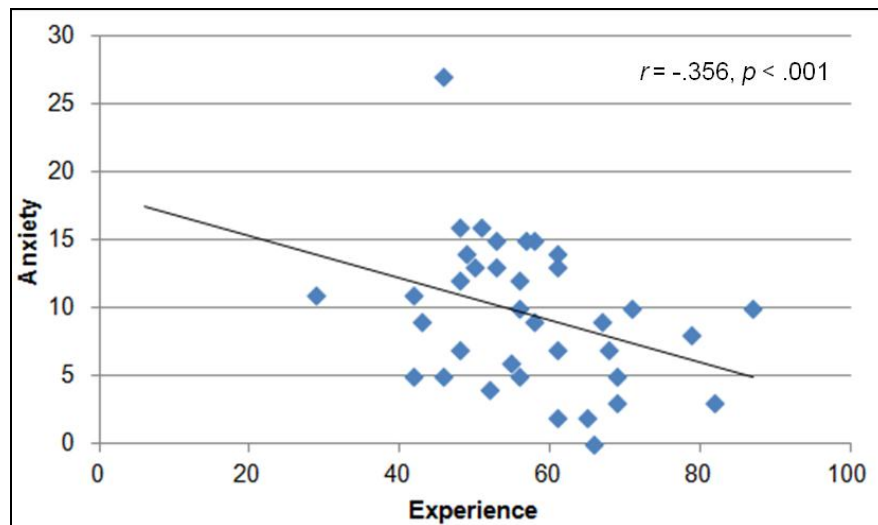
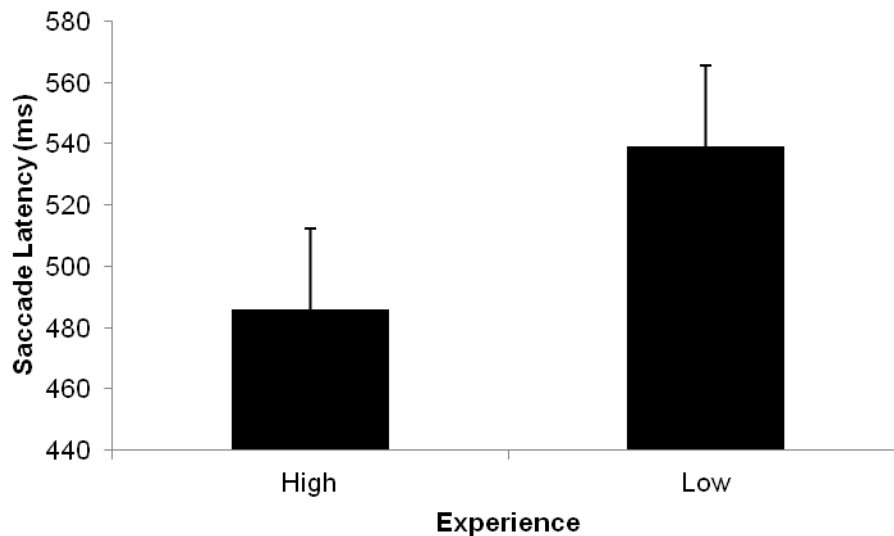


Figure 2.5 Average saccade latency for the high and low experience-with-threat groups. Error bars represent SEM.



Based on the work of Van der Stigchel et al., (2006), we had predicted that if we treated saccade latency as a dependent variable, it would be systematically related to saccade deviation. Specifically, we had predicted longer (i.e., slower) latencies would be related to deviations away from the attention capturing stimulus, whereas shorter (i.e., faster) latencies would be related to deviations toward the attention capturing stimulus. We conducted *t*-tests to examine this predication. First, we selected only conditions where a threat was paired with a neutral stimulus (i.e., ancient-neutral, neutral-ancient, modern-neutral and neutral-modern pairs). The test showed that both the slowest 25% and fastest 25% of saccades in these conditions deviated away from the targets as indicated by saccade angle and endpoint deviations, resulting in no difference in saccade deviation between the two groups of saccade latency, all *ps* > .05.

Subjective Visual Inspection of Eye Movements

When studying eye movements, quantitative statistics do not always tell the whole story. It is both helpful and necessary to plot eye position data in order to visualize eye movement patterns under different conditions of threat pairing. We determined through quantitative analyses that modern threats showed a non-significant trend to cause greater angular deviation of saccades than ancient threats when they were paired with a neutral stimulus. By looking at plots of the eye positions, we can visualize how such a trend in saccade deviation is manifested.

For example, by looking at Figure 2.6 which displays threat-neutral pairs, we can see error saccades were made more often to threatening stimuli. More specifically, in the Ancient-Neutral panel of Figure 2.6, error saccades were made almost exclusively to the ancient threat stimuli. This plot can be compared against the plot of eye positions for neutral-neutral pairings presented in Figure 2.7. It is apparent in Figure 2.7 that there is a much more even distribution of error saccades. Furthermore, Figure 2.7 seems to show overall less deviation than the threat-neutral pair plots in Figure 2.6 in terms of saccade angles and endpoint deviation.

When collapsed across side of presentation, there are 2240 total trials each for Ancient-Neutral and Modern-Neutral pairs. In terms of saccades directly to the images, when looking at the first saccades made in these trials, 3% of the saccades went to the threatening stimuli and 2% went to neutral images. When considering the percentages this difference does not appear meaningful. In terms of raw numbers, when paired with neutral images, ancient threats attracted 70 first saccades whereas neutral images only attracted 45. Looks to modern threats outnumbered looks to neutral images by 58 to 46. Therefore, although the percentages are the same, ancient images actually attracted more direct looks.

Figure 2.6 Eye positions for upright A) Ancient-Neutral, B) Modern-Neutral, C), Neutral-Ancient and, D) Neutral-Modern threat pairings. All saccades portrayed in upward direction starting from the abscissa. The names of the plots indicate in which side each threat category is contained. For example, an Ancient-Neutral plot is comprised of trials where ancient images were on the left and neutral images were on the right. You can see from this figure that error saccades appear to have been made more often to threatening stimuli when paired with neutral stimuli.

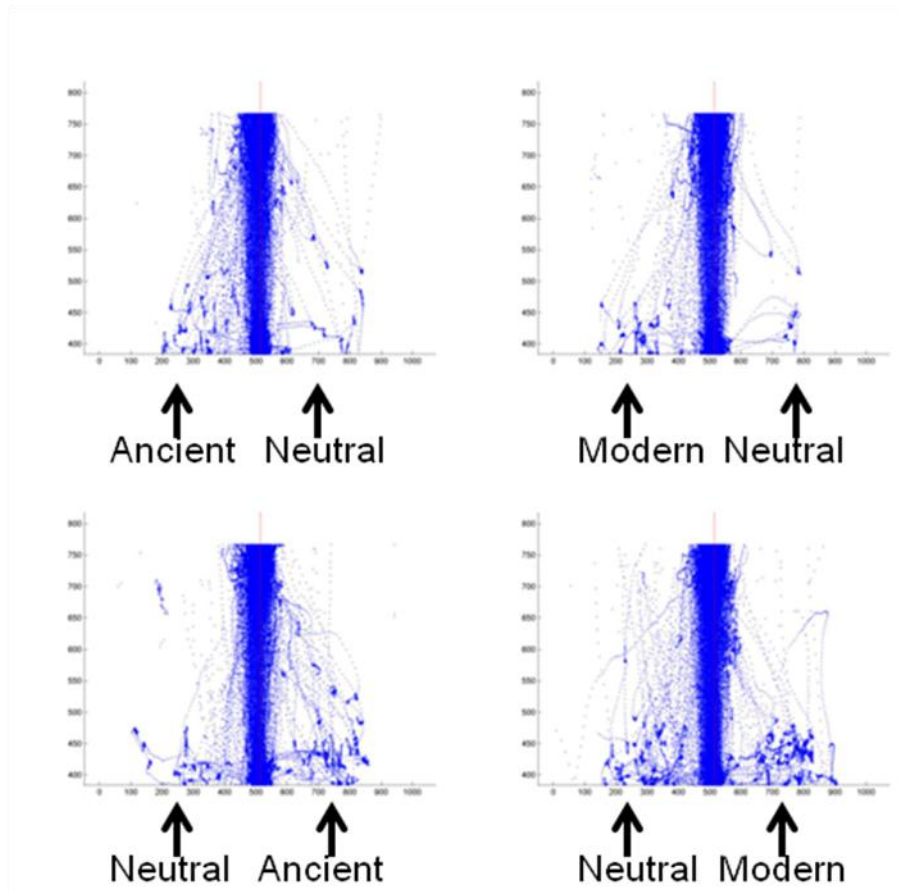
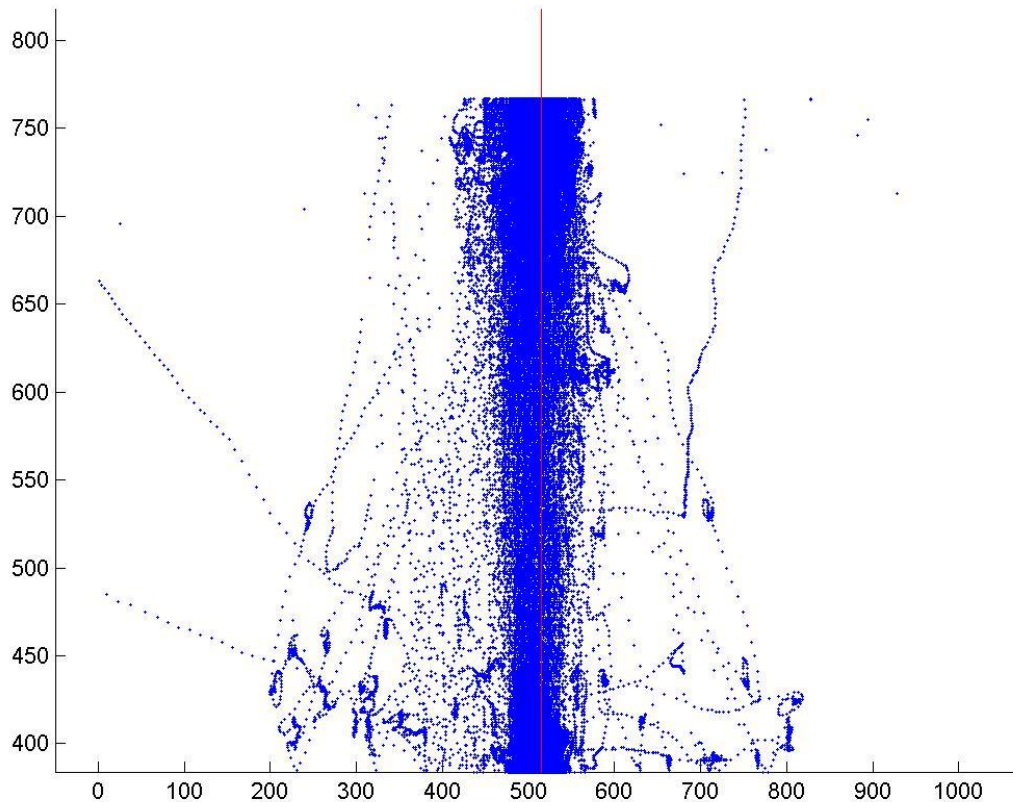


Figure 2.7 Eye position plot for upright Neutral-Neutral pairs. There appears to be relatively equal deviation for angle, endpoint and error saccades measures. However, this interpretation is purely from visual observation and statistical analyses should be regarded as the objective measure.



Eye position plots for every condition pairing are presented in Appendix C. To expand on our visual inspection of the data, we can look at these plots to look for emerging patterns, keeping in mind that the patterns mentioned here result from subjective observations made by one person. They are not intended to be an objective description of the data patterns but rather, food for thought. For example, Neutral-Ancient and Neutral-Modern threat pairings *seem* to show angular deviation away from the threat regardless of its evolutionary age (i.e., the samples seem to deviate more heavily to the left).

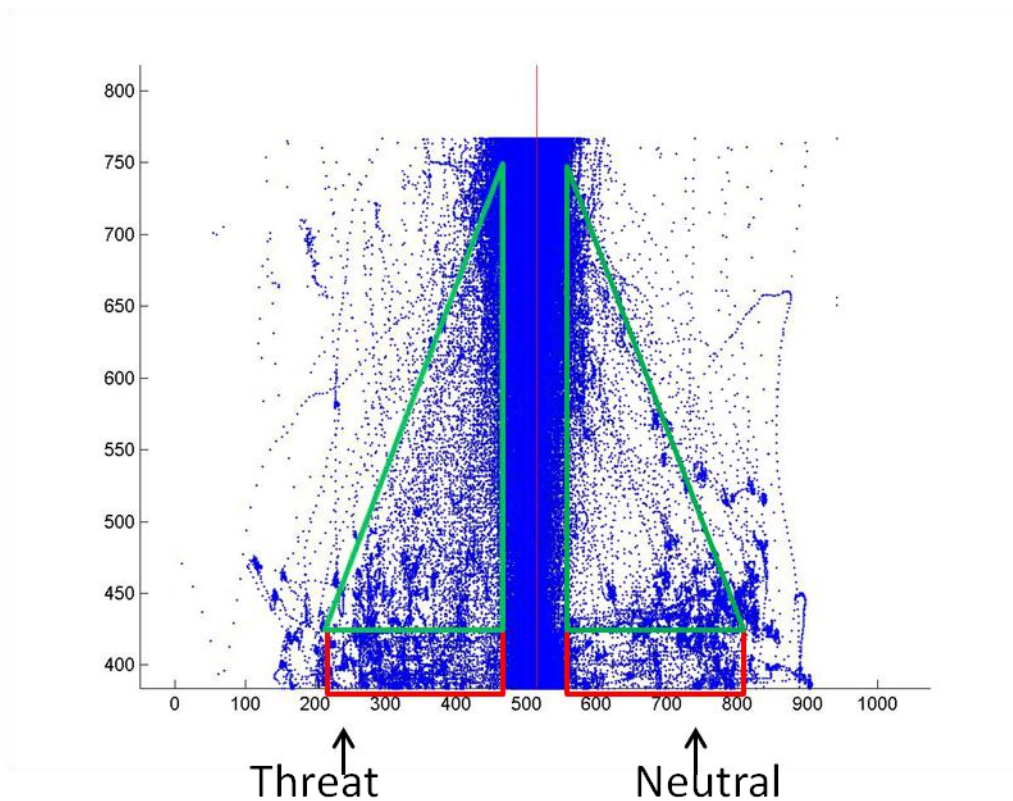
Still more suggestive patterns can be found in the eye position plots that were not identified in quantitative analysis. The analyses above consistently suggest that the orientation of the stimuli was not affecting eye movements. For example, when Ancient-Neutral threat pairings were selected, upright images ($M = 139.1$, $SD = 26.37$) showed a non-significant trend toward a greater angular deviation than inverted images ($M = 138.7$, $SD = 26.3$). Although we expected a stronger effect of orientation with Ancient than with Neutral images, the t -tests did not yield significant differences and therefore we found no significant effect of the orientation IV on saccade deviation measures.

The inverted eye position plots found in Appendix C may suggest something contrary. Subjective inspection of these eye position plots gives a slight impression that for a given condition, saccade deviation was generally less for its inverted counterpart. Error saccades for the inverted counterpart also decreased. For example, considering trials presenting Ancient-Neutral pairs, saccades directly to the threat decreased from 4% of the trials, to 3% of the trials when the images were inverted. Similarly, error saccades to the threat in Neutral-Ancient pairs decreased from 4% to 2% with inversion. For Modern-Neutral pairs inversion brought a decrease from 4% to 2%. The Neutral-Modern pairs showed no appreciable decrease in error saccades between the upright and inverted images. These patterns might suggest that even though the statistical analyses may not have been sensitive enough to detect the effect, rotating images 180 degrees may have detracted from their ability to capture attention. However, it is again worth advising caution in interpreting the raw data plots as subjective interpretations have known limitations. Furthermore, the 2% drop in errors with inversion is not a large decrease.

One last pattern may be emerging by examining the density of points in the overall Threat-Neutral plot shown in Figure 2.8. It appears that threats, in general may have attracted

more error saccades. The areas outlined with red rectangles show where the actual distractor images were located. The areas outlined with green triangles show the saccade paths of when participants moved their eye from the distractor to the target. You can see that the density of the points contained in these interest areas is slightly greater on the “threat” side. This may be an early indication of a threat superiority effect whereby threats capture attention regardless of their evolutionary age. This interpretation is in line with the Relevance Superiority Hypothesis of Fox et al. (2007). Again, this conclusion is offered cautiously given the lack of supporting statistical analyses. Furthermore, this figure shows even neutral images are capable of capturing attention since there is not a total absence of saccades curving away from the neutral side.

Figure 2.8. The overall Threat-Neutral plot. Threats are presented on the left half and neutral images on the right half. All saccades have been rotated to be upward from the abscissa. There is the slight appearance of a higher density of eye samples on the side containing the threats. This may suggest that threats in general, regardless of their evolutionary age, capture more error saccades. However, there are no statistical analyses supporting this conclusion. Furthermore, there is not a total absence of errors on the neutral side. This shows that even neutral images are capable of capturing attention.



Because the side of threat presentation was counterbalanced, there were conditions in which one condition was presented on the left and another was on the right. The counterpart of this condition presented images vice versa. Thus, by transforming one condition, the eye samples have been moved to allow us to collapse across the left-right factor. These new combined plots are presented in Appendix D and display all eye positions for a given pair of threat stimuli, regardless of their side of presentation. For example, data from Neutral-Ancient pairs was mirror-transformed such that the eye position samples on the right half of the vertical

monitor midline are now on the left. Looking at these plots, it becomes harder to discern a pattern of eye movements due to the amount of noise, and the density of the plots resulting from combining the conditions. However, plots of ancient-modern image pairs seem to show that both ancient and modern threats have similar capability to capture attention although this is merely a subjective offering.

Discussion: Experiment 1

Experiment 1 asked two questions. 1) Is the fear module constrained by evolutionary influences and, 2) can the fear module and subsequently observable human behavior relative to threatening stimuli be shaped by experience? Given the data resulting from the present study, a tentative position can be taken in addressing these interesting theoretical and practical issues.

In answer to question one, perhaps one relevant outcome of the present study is the lack of a clear attentional bias when ancient and modern threats were pitted against each other. This null result lightly suggests that modern threats, like ancient threats, are selected for access to the automatic attention system that is an integral part of the fear module. However, due to the lack of a statistically significant difference in saccade trajectories between the threat and no-threat (i.e., neutral-neutral) conditions, this interpretation must be taken as tentative and preliminary at best. Furthermore, due to the large number (576) of trials in Experiment 1 it was necessary to ensure that the failure of our main manipulation to significantly affect eye movements was not simply an order effect as a result of subject fatigue, desensitization, learning or a practice effect. To test these hypotheses, we conducted a multi-level analysis to examine whether there were changes in the dependent variables as a function of trial. The multi-level analysis was chosen because it allows analysis of the data without aggregation as is required in other types of analyses. Analyzing the un-aggregated data allowed the ability to account for within-subjects

variance when assessing effects of independent variables on multiple observations of the dependent variables from different subjects. Although we are primarily interested in data patterns as the experiment progressed, the multi-level model simultaneously assesses the effects of all of the independent variables allowing all of the extraneous variance to be accounted for. Therefore, all independent variables were assessed for interactions with the independent variable of interest. The analysis yielded only one significant main effect of trial on saccade latency, $F(1, 32) = 14.91, p < .001$, Cohen's $F = .229$. Saccade latencies tended to speed up as the experiment progressed. This is inconsistent with the fatigue hypothesis in which we would expect longer saccade latencies as the experiment progressed. However, this result is consistent with a learning hypothesis as well as with a practice effect. Given these findings, it is plausible that the failure of Experiment 1 to demonstrate an attention bias was due, at least in part, to the practice effect that developed during the 576 trials. Based on this analysis, future research must necessarily minimize the number of experimental trials which may require simpler experimental designs.

Nevertheless, if the position that ancient *and* modern threat activates the fear module has some degree of truth (as speculated from subjective visual inspection of the eye position plots), it has theoretical implications. For instance, it would eliminate the possibility of a hardwired, unmodifiable, selective and encapsulated threat attention system such as that proposed in Öhman and Mineka's fear module and would suggest that if the fear module exists, both ancient and modern threats enjoy processing by it. Further, the present data are not completely clear as to whether ancient and modern threats capture attention to a greater extent than neutral imagery. Therefore, more research is undoubtedly needed in order to speak as to whether modern threats receive processing similar to ancient threats at some point along the visual stream.

In answer to the second question of Experiment 1, it was found participants with greater scores on the global experience scale demonstrated greater endpoint deviations and were faster to respond. At first, this result seems counter intuitive, as one may naturally expect experience to breed accuracy (possibly through desensitization). Contrarily, this result suggests that experience with all of the stimuli (recall the subscales were significantly correlated with one another) led to greater attention capture by them. Thus, even if the fear module is automatic and encapsulated in that its behavior is out of conscious cognitive control, the attentional processes supposed to be born from this module *may* be affected by some cognitive mechanism that up-regulates attention to stimuli on the basis of experience. This notion is supported by the strong correlation between experience with snakes and saccade deviation on trials presenting snakes with neutral images. This relationship suggests that such a cognitive mechanism is domain specific such that experience with snakes can influence attention processes in their presence. However, this conclusion is offered cautiously given that the ANOVAs utilizing experience subscales did not systematically affect saccade latencies or endpoint deviation ratios. More research is necessary to clarify the existence or absence of this cognitive mechanism and whether specific experience truly affects attention to threats.

Highlighting caution, it is noteworthy that experience was related to saccade deviation in both the omnibus ANOVA and the correlation analysis showing snake experience was strongly correlated with saccade deviation. These findings are consistent with the findings of Nodine et al. (1996), who showed that experience with stimuli results in facilitated attention to the stimuli. It is possible that the role of experience in fear behavior is to serve to sensitize individuals to the presence of threatening stimuli (perhaps via the aforementioned attention up-regulating cognitive mechanism). This is the idea of biological preparedness outlined by Öhman and Mineka (2001).

Still, it is arguable as to whether or not the present findings are consistent with an evolved fear module. On the one hand you would not expect experience to affect attention capture through a fear module that is supposed to be strictly selective of phylogenetically relevant threats. On the other hand however, studies that demonstrated lab raised monkeys fear response to snakes argued for innate fear mechanisms; but these studies required monkeys to have at least minimal prior exposure to snakes in order to demonstrate the fear response (Cook & Mineka, 1989). This implies that evolutionary influence on threat detection is to inherently prime threats for rapid learning through some cognitive mechanism, in line with the evolutionary notion of preparedness (Öhman & Mineka, 2001). Furthermore, the preparedness argument is in line with the work of Öhman et al., (1975) who demonstrated extremely rapid conditioning of fear responses using snake and spider stimuli. Thus, there is a body of work that supports the idea that the influence of experience is not a separate issue from evolutionarily derived behavior. Indeed, common sense suggests that from an evolutionary standpoint, such biological preparedness would be highly beneficial. Although the present data cannot clearly inform this issue, it is an intriguing possibility.

In addressing question two, namely whether or not experience could shape attention to threats, we also revealed that saccade latency was negatively related to participants' scores on the global experience scale. In other words, individuals with more experience with the range of stimuli were generally faster to react to the onset of the target in the presence of threatening and non-threatening stimuli. The faster latencies of these participants adds a little more support to the notion that experience may lead to sensitization which, in turn, could facilitate registration of the threat (or non-threat) in the motor map of potential saccade targets. Although the limitations of the present data deem this notion speculative at this point, such early registration

would be evolutionarily beneficial in that it would allow more rapid programming of eye movements and expedite saccades to relevant targets. However, at present, these data simply suggest that people who report to have more experience with a wide array of threatening stimuli make faster eye movements in general.

Global anxiety scores were negatively related to saccade latencies. In other words, more generally anxious participants demonstrated faster reaction times. We had originally expected that anxiety would interact with threat pairing since anxiety should only affect attention to anxiety provoking stimuli. However, it appears that our specific anxiety measure seems to be measuring general anxiety. In fact, the specific anxiety measure is highly correlated with the STAI, an established measure of general anxiety. Therefore, this finding suggests that generalized anxiety speeds saccade reaction times. It follows then, that the present data do not allow us to draw conclusions regarding the effect of specific anxieties on attentional processes. It is noteworthy that this data pattern is the same with the global experience measure. This is apparently contradictory since global anxiety and global experience scores are negatively related. Explanations for this paradox are offered below but to allude to that section, it likely stems from limitations of the self-report measures.

Furthermore, global anxiety had a significant effect on endpoint deviations with high anxiety individuals producing greater endpoint deviations. This demonstrates a higher degree of attention capture by those participants considered to be generally anxious. If our measure of specific anxiety demonstrated greater content validity, this result would be in line with past research that showed anxiety is related to attention capture by the anxiety provoking stimulus (Lipp et al., 2004; Öhman et al., 2001). However, the limitations of our anxiety scale only allow us to pose the conclusion that general anxiety may lead to large endpoint deviations.

Chapter 3 - Experiment 2

Although interesting data emerged in Experiment 1, conclusions as to the lack of selectivity of the fear module were made on the basis of null results in the omnibus ANOVA. This is clearly problematic as one could argue that the null findings were not due an equivalent ability of ancient and modern threats to capture attention, but rather, to a failure of the paradigm to elicit and capture differences in the saccade trajectories. Or further, the lack of differences may have been due to a lack of sensitivity of the *analyses* to capture meaningful differences. In order to determine whether the results of Experiment 1 were due to a Type II error or not, it is important to verify that the foundational research upon which Experiment 1 was based is able to demonstrate reliable effects. Therefore, the reliability of the findings of Nummenmaa et al. (2009, Exp 3) must be determined. To this end, Experiment 2 was an exact replication of Nummenmaa et al. (2009, Exp. 3) in every meaningful detail.

If the ability of emotional images to capture attention outlined in Nummenmaa et al. (2009, Exp. 3) was due to a Type I error, it would explain the failure to find differences in Experiment 1 here. Conversely, if the results of Nummenmaa et al. (2009, Exp. 3) are replicable, then the lack of a statistically significant effect of threat category in Experiment 1 could have arisen from various sources. In either case, understanding the reliability of the attention bias to emotional content must be understood if the present data are to be properly interpreted. The goal of Experiment 2 is to achieve this understanding through a careful and exact replication of Nummenmaa et al. (2009, Exp. 3).

The overarching hypothesis tested in Experiment 2 is that emotional imagery captures attention. This attention capture will be indexed by saccade trajectories arcing away from the

visual field that contains the emotional stimuli. Confirming this hypothesis would replicate the findings of Nummenmaa et al., (2009, Exp 3).

A successful replication of Nummenmaa et al., (2009, Exp. 3) would suggest that the oculomotor inhibition paradigm is effective at indexing attention bias (as manifested in saccade curvature) in emotional-neutral picture pairs. Therefore, this would mean that the ability of emotional images to influence saccade trajectories did not generalize to the methodology used in Experiment 1. On the other hand, a failure to replicate the findings of Nummenmaa et al., (2009, Exp. 3) would make interpretation of the lack of an attentional bias in Experiment 1 much simpler. Because a failure to replicate Nummenmaa et al. (2009, Exp. 3) would indicate a Type I error on their part, the simplest explanation for the lack of an attentional bias in Experiment 1 would be that there is no true attention bias for emotional content in oculomotor inhibition paradigms as used in the present research. This would easily explain the failure of Experiment 1 to find any effect of threat pairing.

For ease of comparison, the key methodological details of Nummenmaa et al. (2009, Exp. 3) and Experiments 1 and 2 can be seen in Tables 3.1 and 3.2, respectively. Table 3.2 shows that the method of Nummenmaa et al. (2009, Exp 3) was replicated carefully in every meaningful detail. Table 3.3 shows that the design of Experiment 2 is also a very careful replication of Nummenmaa et al. (2009, Exp 3).

Method

The method used in Experiment 2 was a replication in every meaningful detail of Nummenmaa et al. (2009, Exp. 3) except where impossible (e.g., type of computer monitor) or well-motivated and unlikely to bias the results (e.g., the use of a fixation failsafe for trial initiation). As can be seen in table 3.2, all methodological details of Nummenmaa et al. (2009,

Exp. 3) have been replicated in Experiment 2 in great detail so as to facilitate discussion of differences between Experiments 1 and 2.

Table 3.1 Comparison of the key methodological details of Nummenmaa et al. (2009, Exp. 3) and Experiment 1

	Nummenmaa et al. (2009, Exp. 3)	Experiment 1
Participants	N = 15	N = 33
Stimuli: content	<p>IAPS images: <i>Neutral pictures:</i> 2037, 2102, 2190, 2191, 2191.1, 2200, 2220, 2221, 2270, 2272, 2272.1, 2305, 2312, 2312.1, 2357, 2372, 2383, 2389, 2393, 2393.1, 2394, 2396, 2397, 2397.1, 2410, 2491, 2493, 2512, 2513, 2513.1, 2515, 2560, 2560.1, 2575, 2575.1, 2579, 2593, 2593.1, 2594, 2594.1, 2595, 2595.1, 2598, 2598.1, 2635, 2635.1, 2745.1, 2745.2, 2749, 2749.1, 2840, 2850, 2870, 5410, 7493, 7496, 7496.1, 7550, 7550.1, 7620, 7620.1, 9070, 9210, and 9210.1.</p> <p><i>Unpleasant pictures:</i> 2399, 2399.1, 2683, 2691, 2703, 2716, 2718, 2722, 2799, 2800, 2811, 2900, 3051, 3180, 3181, 3225, 3300, 3350, 6010, 6250, 6313, 6315, 6550, 6560, 8480, 8485, 9250, 9254, 9410, 9415, 9423, and 9435. <i>Pleasant pictures:</i> 2040, 2070, 2160, 2165, 2311, 2332, 2352, 2540, 2550, 4599, 4610, 4624, 4647, 4658, 4660, 4669, 4676, 4680, 4687, 4694, 4700, 5621, 5831, 5836, 7325, 8021, 8080, 8161, 8186, 8200, 8490, and 8499.</p>	Images collected from IAPS and the Internet
Stimuli: image alteration	None, full color	Grayscale, equalized for mean luminance and RMS contrast
Stimuli: image size	10.24° x 7.68 °	11.93° x 8.92 °
Stimuli: viewing distance	Not available	58 cm
Display	Black background, white placeholders, 20" monitor	Grey background, white placeholders, 17" monitor
Procedure: SOA	0 ms, 150 ms	200 ms
Procedure: # of trials	128	576
Procedure: trials blocked?	Yes	No
Random delay at trial start?	Yes	No
Procedure: inversion variable?	No	Yes
Sampling rate	500 Hz	1000 Hz
Trial initiation	Experimenter initiated when felt subject fixated centrally	Fixation failsafe, subject initiated

Table 3.2. Comparison of the key methodological details of Nummenmaa et al. (2009, Exp. 3) and Experiment 2

	Nummenmaa et al. (2009, Exp. 3)	Experiment 2
Participants	N = 15, 10 Female, <i>M</i> age = 23	N = 15, 4 Female, <i>M</i> age = 25.7
Stimuli: content	<p>IAPS images: <i>Neutral pictures:</i> 2037, 2102, 2190, 2191, 2191.1, 2200, 2220, 2221, 2270, 2272, 2272.1, 2305, 2312, 2312.1, 2357, 2372, 2383, 2389, 2393, 2393.1, 2394, 2396, 2397, 2397.1, 2410, 2491, 2493, 2512, 2513, 2513.1, 2515, 2560, 2560.1, 2575, 2575.1, 2579, 2593, 2593.1, 2594, 2594.1, 2595, 2595.1, 2598, 2598.1, 2635, 2635.1, 2745.1, 2745.2, 2749, 2749.1, 2840, 2850, 2870, 5410, 7493, 7496, 7496.1, 7550, 7550.1, 7620, 7620.1, 9070, 9210, and 9210.1.</p> <p><i>Unpleasant pictures:</i> 2399, 2399.1, 2683, 2691, 2703, 2716, 2718, 2722, 2799, 2800, 2811, 2900, 3051, 3180, 3181, 3225, 3300, 3350, 6010, 6250, 6313, 6315, 6550, 6560, 8480, 8485, 9250, 9254, 9410, 9415, 9423, and 9435.</p> <p><i>Pleasant pictures:</i> 2040, 2070, 2160, 2165, 2311, 2332, 2352, 2540, 2550, 4599, 4610, 4624, 4647, 4658, 4660, 4669, 4676, 4680, 4687, 4694, 4700, 5621, 5831, 5836, 7325, 8021, 8080, 8161, 8186, 8200, 8490, and 8499.</p>	<p>IAPS images: <i>Exactly the same as Nummenmaa et al. (2009, Exp. 3)</i></p>
Stimuli: image alteration	None, full color	Resized to match size at 58 cm viewing distance, full color
Stimuli: image size	10.24° x 7.68°	Exactly the same
Stimuli: viewing distance	Not available	58 cm
Display	Black background, white placeholders, 20" monitor	Black background, white placeholders, 17" monitor
Procedure: SOA	0 ms, 150 ms	Exactly the same
Procedure: # of trials	128	Exactly the same
Procedure: trials blocked?	Yes	Exactly the same
Random delay at trial start?	Yes	Exactly the same
Inversion variable?	No	Exactly the same
Sampling rate	500 Hz	Exactly the same
Trial initiation	Experimenter initiated when felt subject fixated centrally	Fixation failsafe, subject initiated

Participants

As in Nummenmaa et al., (2009, Exp. 3), 15 college students (11 male, Mean age = 25.7) volunteered to participate in Experiment 2.

Stimuli, display and apparatus

The same stimulus displays used by Nummenmaa et al., (2009, Exp. 3) were used in Experiment 2. All aspects of the display were identical. The same images used in Nummenmaa et al. (2009, Exp. 3) were taken from the International Affective Picture System (Lang et al., 2005) and measured $10.24^{\circ} \times 7.68^{\circ}$ of visual angle. As in Nummenmaa et al. (2009, Exp. 3) the images were presented with the constraints that each image was used twice. If it was presented on the left in block one, it would be presented on the right in block two. An additional constraint was that each image was never paired with the same image twice.

Just like Nummenmaa et al., (2009, Exp. 3) , the images were marked on the trial screen by a white box measuring $10.54^{\circ} \times 7.98^{\circ}$ of visual angle. The inner edges of the image areas were 2.5° of visual angle from the center of fixation. The central fixation point was a white dot with a black center measuring 1.5° in diameter. The saccade targets were white crosses subtending 1.5° located on the central vertical axis of the screen. The position on the trial start screen was marked with white squares subtending 1.6° of visual angle. The background color of all screens was black. All screen layout parameters were exactly the same as in Nummenmaa et al., (2009, Exp 3).

The recording apparatus was the same as in Experiment 1 with one exception. Instead of a 1000 Hz recording rate, the recording rate in Experiment 2 was 500 Hz in order to be consistent with Nummenmaa et al. (2009, Exp. 3).

Procedure

Because Experiment 2 is intended to be as close to an exact replication of Nummenmaa et al. (2009, Exp. 3) as possible, just as in Nummenmaa et al. (2009, Exp. 3), upon arrival all participants were required to score 20/30 or better on near acuity tested using a Sloan letter chart to qualify to participate in the study. Participants were told they were participating in an experiment to see how fast and accurately they could fixate the target. They were instructed to ignore the images and move their eye to the cross when it appeared.

Each trial started with a drift correction screen to ensure the quality of the eye tracker calibration as was done in Nummenmaa et al., (2009, Exp. 3). One point of departure from Nummenmaa et al. (2009, Exp. 3) is in the trial initiation mechanism. In Nummenmaa et al., (2009, Exp. 3) the experimenter initiated the trial when they felt the subject was fixated in the center. In this experiment, this potential source of experimenter error was removed by implementing a fixation failsafe. With this failsafe, the trial was initiated by the subject pressing a button, but the trial would not initiate if their point of gaze was not contained in a 1 ° bounding box in the center of the screen at the time of the button press. However, there was a random delay of 0-100 ms appended to the beginning of each trial to dissuade anticipatory saccades, just as in Nummenmaa et al., (2009, Exp. 3). After this random delay, images were displayed for 1,350 ms. Then, as in Nummenmaa et al. (2009, Exp. 3) the target crosses appeared either simultaneously with (0 ms SOA) or 150 ms after (150 ms SOA) the images onset, at which point the subject was to move his/her eye directly to the cross and hold it until the screen went black (1000 ms). After an inter-trial interval of 500 ms, the drift correction screen reappeared indicating the start of the next trial, as was done in Nummenmaa et al. (2009, Exp. 3).

As in Nummenmaa et al. (2009, Exp. 3) participants completed 10 practice trials to acclimate them to the task (practice images were not used in the main experiment). After practice, the eye tracker was re-calibrated and participants completed two blocks of 64 trials (128 trials total) with a break between the two blocks. To keep the Experiment 2 method exactly the same as Nummenmaa et al. (2009, Exp. 3), the eye-tracker was recalibrated before starting the second block and on an as-needed basis if the calibration began to slip.

Design

As shown in Tables 3.3 and 3.5, Experiment 2 was nearly an exact replication of Nummenmaa et al. (2009, Exp. 3) both in terms of design and method. Thus, as in Nummenmaa et al., (2009, Exp. 3) the same 3, two-level, independent variables were manipulated in Experiment 2. There were two SOAs of 0 and 150 ms. Valence of the images (positive or negative) was randomly selected on each trial with the constraint that valence was counterbalanced across trials throughout the experiment. Lastly, the visual field of the emotional content (left or right) was also randomly chosen and counterbalanced. The dependent variables of interest were saccade latency, saccade endpoint deviation ratios and saccade curvature ratios.

Table 3.3 Comparison of Key Design Details of Nummenmaa et al. (2009, Exp. 3) and Experiment 2

	Nummenmaa et al. (2009, Exp. 3)	Experiment 2
Independent variables	Valence (2 levels, w/in subjects); Visual field (2 levels, w/in subjects; SOA; 2 levels, w/in subjects)	Exactly the same
Dependent variables	Saccade latency, signed saccadic curvature ratios, signed endpoint deviation ratios	Exactly the same
IVs randomized and counterbalanced	Yes	Yes
Trials blocked?	Yes	Yes

Results

A comparison of the results of Experiment 2 to Nummenmaa et al. (2009, Exp. 3) and Nummenmaa et al. (2009, Exp. 3) to Experiment 1 can be seen in Tables 3.4 and 3.5 respectively. Just as in Nummenmaa et al. (2009, Exp. 3), to adjust for the potential effect of saccade amplitudes, the saccade endpoint deviations and curvature were transformed to represent visual angle and divided by their respective amplitudes to create ratios. These ratios were subjected to a 2 (SOA: 0 ms vs. -150 ms) x 2 (Visual field of emotional content: left or right) x 2 (Valence: pleasant vs. unpleasant) within-subjects factorial ANOVA.

The saccade latencies were influenced only by SOA with the 150ms SOA ($M = 407.2$, $SD = 319.35$) producing shorter latencies than the 0 ms SOA ($M = 523.58$, $SD = 383.6$), $F(1,161) = 6.015$, $p = .015$, Cohen's $F = .204$. As shown in Table 3.3, this result closely replicates that of Nummenmaa et al. (2009, Exp. 3).

As in Nummenmaa et al. (2009, Exp. 3), the analysis of the endpoint deviations yielded a main effect of the visual field of the emotional content $F(1, 161) = 8.25$, $p = .005$, Cohen's $F = .246$. The saccade endpoints deviated away from the visual field in which the emotional picture was contained and the endpoint deviations were similar for both SOAs ($F < 1$) and both types of emotional content ($F < 1$). These data are shown graphically in Figure 3.1 along with the similar results of Nummenmaa et al. (2009, Exp. 3) for comparison.

Analysis of the signed saccade curvatures also yielded results consistent with Nummenmaa et al. (2009, Exp. 3). As in their study, while none of the main effects reached significance, the SOA x visual field interaction was significant $F(1,161) = 6.767$, $p = .01$, Cohen's $F = .219$. As in the Nummenmaa et al. (2009, Exp. 3) study, post-hoc analysis revealed that with 150 ms SOA, the saccades deviated to the right ($M = .004$, $SE = .009$) when the

emotional content was presented in the left visual field. Conversely, when the emotional content was presented in the right visual field, saccades deviated leftward ($M = -.0017$, $SE = .012$).

These results are presented graphically in Figure 3.2 alongside the corresponding and similar results from Nummenmaa et al. (2009, Exp. 3).

Table 3.4 Comparison of Key Results of Nummenmaa et al. (2009, Exp. 3) and Experiment 2

	Nummenmaa et al. (2009, Exp. 3)	Experiment 2
Division of EM parameters by saccadic amplitude	Yes	Yes
Saccadic latencies	Influenced only by SOA, $F = 13.9$, $p < .001$. Shorter latencies for 150 ms SOA than for 0 ms SOA (RTs: 218 ms and 290 ms respectively)	Influenced only by SOA, $F = 6.015$, $p = .005$. Shorter latencies for 150 ms SOA than for 0 ms SOA (RTs: 407 ms and 523 ms respectively)
Endpoint deviation	Main effect of visual field, $F = 8.22$, $p = .01$. Saccade endpoints deviated away from VF containing emotional content. Endpoints were similar for both SOAs and both pleasant and unpleasant images (both $F_s < 1$).	Main effect of visual field, $F = 8.25$, $p = .005$. Saccade endpoints deviated away from VF containing emotional content. Endpoints were similar for both SOAs and both pleasant and unpleasant images (both $F_s < 1$).
Saccadic angle	No main effects. SOA x VF interaction was significant, $F = 5.4$, $p = .03$. Multiple comparisons that saccades curved away from emotional content in the 150 ms but not 0 ms SOA.	No main effects. SOA x VF interaction was significant, $F = 6.76$, $p = .01$. Multiple comparisons that saccades curved away from emotional content in the 150 ms but not 0 ms SOA.

Table 3.5 Comparison of Key Results of Nummenmaa et al. (2009, Exp. 3) and Experiment 1

	Nummenmaa et al. (2009, Exp. 3)	Experiment 1
Division of EM parameters by saccadic amplitude	Yes	Yes
Saccadic latencies	Influenced only by SOA, $F = 139, p < .001$. Shorter latencies for 150 ms SOA than for 0 ms SOA (RTs: 218 ms and 290 ms respectively). <i>There were no main effects or interactions of emotional content with saccade latencies.</i>	Influenced only by Experience, $F = 24.85, p < .001$. Participants with less experience had consistently longer saccade latencies than those with more experience, $t = 5.298, p < .001$. <i>There were no main effects or interactions of emotional content with saccade latencies.</i> SOA was not manipulated (constant 200 ms).
Endpoint deviation	Main effect of emotional content, $F = 8.22, p = .01$. Saccade endpoints deviated away from emotional content. Endpoints were similar for both SOAs and both pleasant and unpleasant emotional images (both $F_s < 1$).	No main effect of emotional content or orientation ($F_s < 1$). Significant effect of Experience $F = 2.916, p = .017$. Participants with high general experience scores had greater endpoint deviations than those with low experience scores, $t = 2.72, p = .007$.
Saccadic angle	No main effects of SOA or emotional content. SOA x emotional content interaction was significant, $F = 5.4, p = .03$. Multiple comparisons that saccades curved away from emotional content in the 150 ms but not 0 ms SOA.	No effect of emotional content, $F < 1$. Threat presence did not produce greater deviation compared to neutral-only conditions ($F < 1$). There was only a 200 ms SOA which differs from the critical 150 ms SOA of Nummenmaa et al., 2009, Exp 3

Figure 3.1 Comparison of endpoint deviations from Experiment 2 (top) and Nummenmaa et al. (2009, Exp. 3) (bottom). Error bars represent 95% confidence intervals.

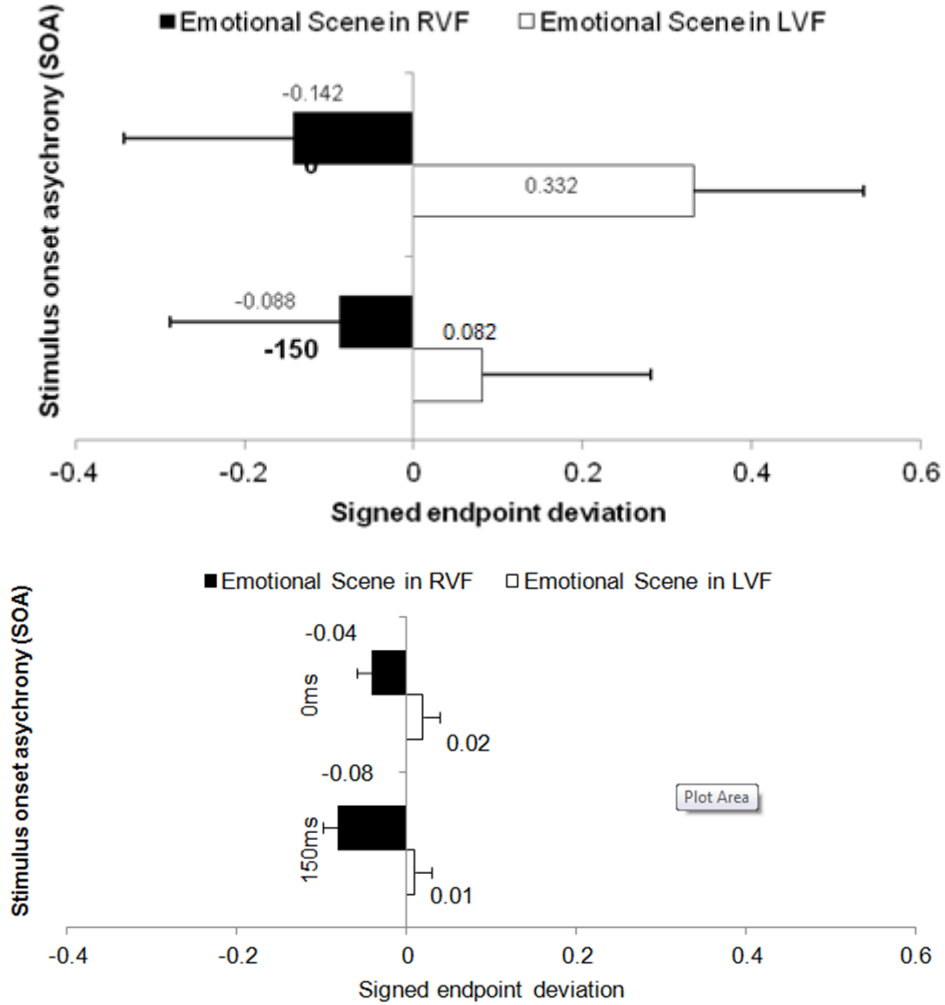
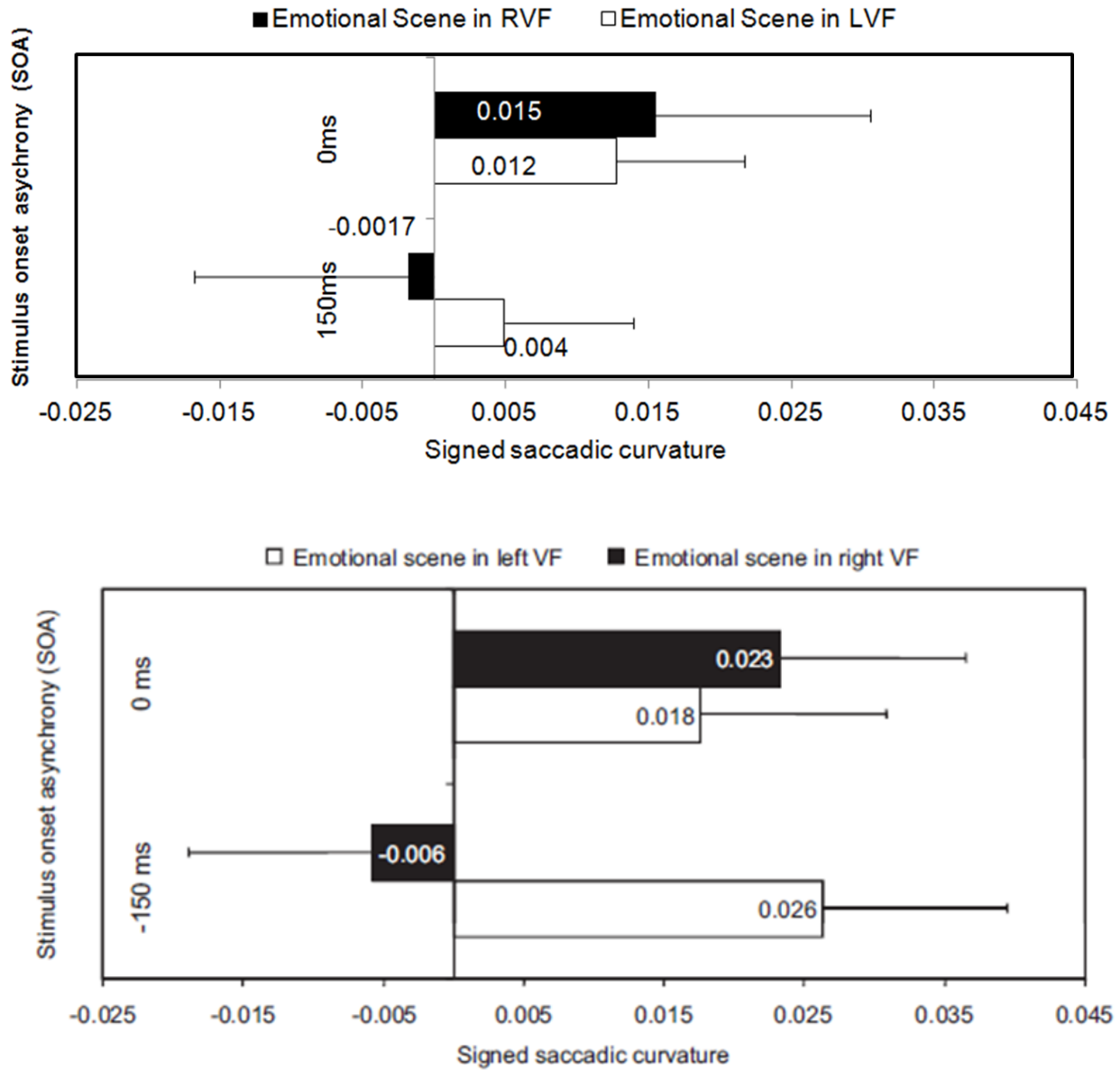


Figure 3.2 Saccade curvature in Experiment 2 (top) compared to curvature from Nummenmaa et al. (2009, Exp. 3) (bottom). Error bars represent 95% confidence intervals.



Discussion: Experiment 2

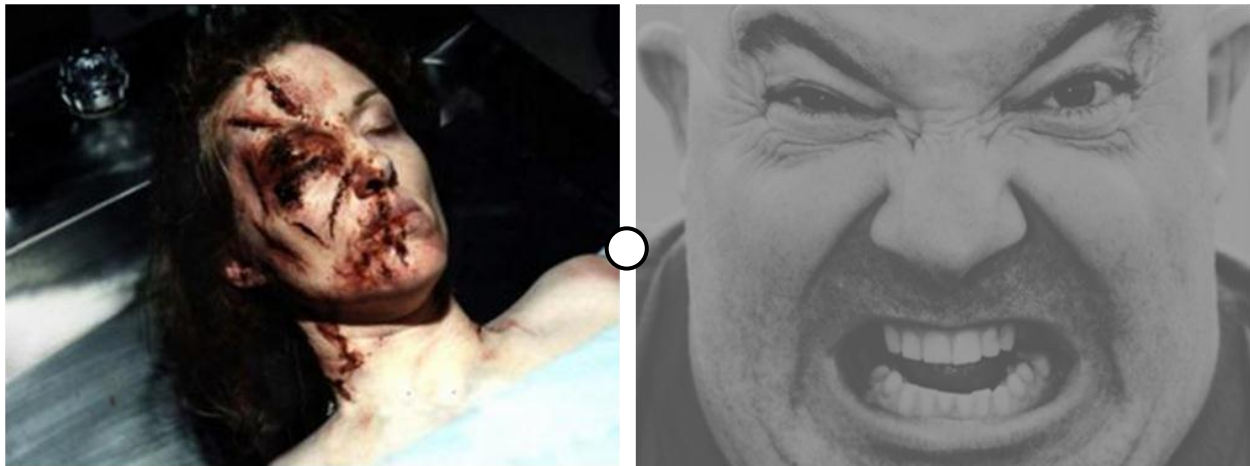
Experiment 2 successfully replicated all of the important findings of Nummenmaa et al. (2009, Exp. 3). The data of Experiment 2 show that in the 150ms SOA conditions, saccades curve away from the emotional images. The implications of this for the findings from Experiment 1 are two-fold. First, the replication of Nummenmaa et al. (2009, Exp. 3) means the oculomotor inhibition paradigm works for indexing attention capture by emotional content. Secondly, it offers a couple of different interpretations of the Experiment 1 results. Which interpretation is favored depends on how one views the null findings from Experiment 1. We discussed that the absence of a statistically significant effect of threat pairing in Experiment 1 could suggest that both ancient and modern threats capture attention. However, the quantitative analyses suggest that neutral images were also capturing attention. The ability of neutral images to successfully compete with threat images for attention strongly suggests that the images used in Experiment 1 lack sufficient salience, whether physical salience, emotional salience, or both. This interpretation is troubling given that, evolutionarily speaking, humans should certainly be more in-tune with the presence of threats than innocuous objects even if they are lacking in color information.

Successfully replicating the findings of Nummenmaa et al. (2009, Exp. 3) demonstrates that the oculomotor paradigm should have allowed the data analysis to detect any meaningful differences in saccade deviation between the threat conditions spawning from attentional biases. The failure to find such effects suggests that either 1) the findings of Nummenmaa et al. (2009, Exp. 3) do not generalize to the methodology used in Experiment 1 or 2) the threat images are not well suited to capturing attention over neutral images in a way that manifests as deviations in saccade trajectories. Given the wealth of research that shows that threats are capable of

capturing attention in other paradigms (e.g., Blanchette, 2006; Brosch & Sharma, 2005; Flykt, 1999; Fox, Griggs, & Mouchlianitis, 2007; Lipp, Waters, Derakshan, & Logies, 2004; Lipp & Waters, 2007; Öhman, Flykt & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001; Rinck, et al., 2005), the most likely explanation of the Experiment 1 data is that the intricacies of the methodology are not well-suited to eliciting systematic differences. Thus, it is important to consider what aspects of the methodology could explain the lack of an effect of threat pairing. The list of important methodological aspects from which we consider is detailed in Table 3.1.

The method used in Experiment 1 differed from the methodology of Nummenmaa et al. (2009, Exp. 3) in at least four meaningful ways. First, the images used in Experiment 1 were changed to grayscale and equalized in terms of mean luminance and RMS contrast. This difference is illustrated in Figure 3.3. Second, the single SOA used in Experiment 1 was 200 ms, 50 ms longer than the 150 ms used in Experiment 2. Third, the pairing conditions used in Experiment 1 included threat-threat (i.e., emotional-emotional) pairings, whereas in Nummenmaa et al. (2009, Exp. 3) and Experiment 2 emotional imagery was only paired with neutral imagery. Fourth, the stimuli in Experiment 2 was selected upon known valence and arousal values and always contained people which are known to capture attention (Fletcher-Watson et al., 2008). The Experiment 1 stimuli were solely selected upon their content (i.e., it depicted one of our stimulus categories).

Figure 3.3 An example of a normal color image used in Experiment 2 (A) and an image equalized for mean luminance and RMS contrast as in Experiment 1(B).



A

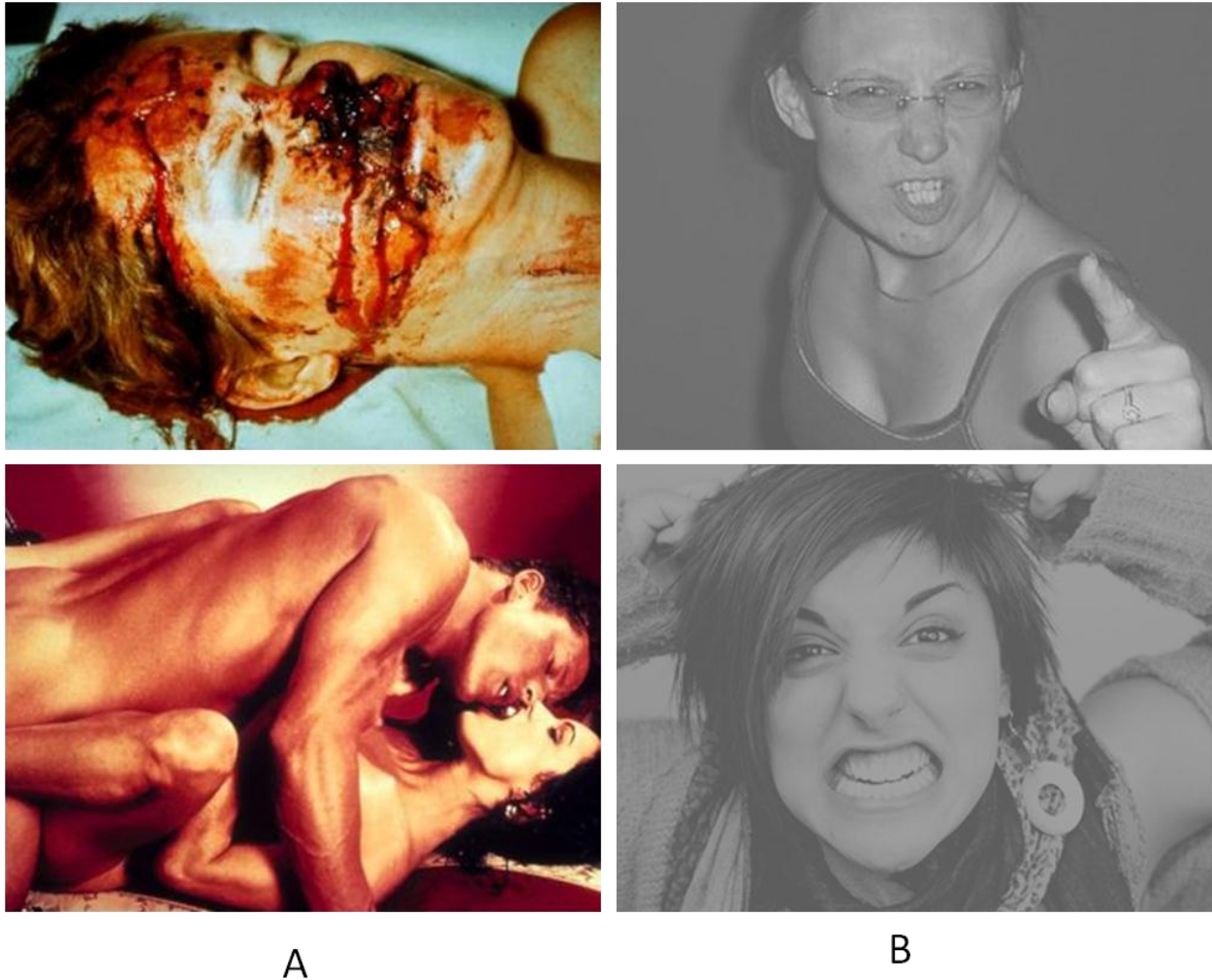
B

The alteration of the images in Experiment 1 could explain the failure to observe an attention bias if color information in images is necessary for attention capture. In fact, all of the past research cited herein that showed facilitated attention to threats used colored stimuli (Blanchette, 2006; Brosch & Sharma, 2005; Flykt, 2005; Lipp et al., 2004; Lipp & Waters, 2007; McGlynn, Wheeler, Wilamoska, & Katz, 2008; New, Cosmides, & Tooby, 2007; Öhman, Flykt, & Esteves, 2001). Considering the grayscale and adjusted images used in Experiments 1 versus the full color images used in Experiment 2, the color-is-necessary explanation is plausible. One reason this may be, for instance, is that many of the images used in Experiment 2 depicted human bodies. The flesh tones and human forms in these images can signal to a viewer that a person is present. Additionally, the negative valence images in Experiment 2 often depicted mutilated bodies. This mutilation introduces organic (e.g., blood red-brown) colors that, when paired with a human form, can also serve as an indication that something extremely emotional is depicted. If you stare at the white dot between images A and B, you may feel as if your eye is drawn to image A. This roughly illustrates the idea that Experiment 2 color images are often

more salient and likely carry weights heavier than grayscale images in terms of neural activation in the saccade motor map. Additionally, the positive valence images in Experiment 2 often depicted nude bodies and pornography. Such strongly emotional and arousing imagery may be what it takes to capture attention to the extent that the saccade program is affected. Such graphic depictions and use of form paired with organic color information were not present in Experiment 1. The differences between the Experiment 1 and Experiment 2 stimuli are illustrated again in Figure 3.4.

The increased salience of the Experiment 2 images could be derived from a *combination* of the color and the forms present in the images. The Experiment 1 images contained the emotionally salient forms but lacked the associated colors. A combination of the color and form image properties may be critical to provide viewers with enough information to then render the images more emotionally salient. Following this logic, a useful question for future research is whether color in emotional imagery is a precursor for it becoming emotionally salient. This could easily be tested by replicating Experiment 2 again using monochrome images. If the emotional bias disappeared under those conditions it would strongly suggest that color is necessary for attention capture by emotional content.

Figure 3.4 Examples of images from Nummenmaa et al. (2009, Exp. 3) and the present Experiment 2 in which flesh tones and blood red provide important information (column A) as to the emotional content of the image. Similar color information was not available in the Experiment 1 stimuli (column B).



A further possible explanation for the difference in results between Experiments 1 and 2 was the fact that Experiment 2 used a 200ms SOA, which was 50ms longer than the longest used in Experiment 1. Given the ultra-rapid nature of visual attention to images (VanRullen & Thorpe, 2001), an extra 50 ms may have been enough time for participants to disengage their attention from the distractor images in order to focus on the main task. Such disengagement (if it were occurring) would explain a lack of saccadic deviation and straighter saccades to the saccade

target. Indeed, Nummenmaa et al. (2009, Exp 3) and Experiment 2 showed significant deviation in the saccades whereas Experiment 1 did not. Because the saccades in Experiment 1 were essentially straight (statistically speaking), this disengagement is plausible.

The third plausibly important difference between the methods used in Experiments 1 and 2 was the condition pairings. Experiment 2 only utilized emotional-neutral pairs whereas Experiment 1 paired emotional content with emotional content. An example of such image pairing can be seen in Figure 3.5. If emotion in general, drives attention biases, pairing two threatening images would have washed out any systematic effects that may have been present. Logically, this leads to the argument that any meaningful differences should have then manifested only in those conditions where a threat was paired with a neutral stimulus. However, analyses yielded no such result. Therefore, it is possible that exposure to multiple threats over the course of the 576 trials in Experiment 1 led to some sort of attentional adaptation, whereby subjects became desensitized to the constant presence of threats and the attention system was not affected to a significant degree between threat conditions. The desensitization hypothesis is plausible given that Bartholow, Bushman and Sestir (2006) showed that repeated exposure to violent and threatening imagery decreased the amplitude of the P300 event related potential “which has been associated with activation of the aversive motivational system (p. 532).” Another important difference between the methodology of Experiments 1 and 2 is that Experiment 1 contained a large number of trials that could have potentially contributed to subject fatigue. In fact, regression analyses support this possibility. This, and other, important methodological differences between Experiments 1 and Nummenmaa et al. (2009, Exp. 3) are detailed in Table 3.1.

The fourth major difference between Experiments 1 and 2 lies in the content of the stimuli. The Experiment 2 stimuli consisted solely of IAPS images selected on the basis of their known valence and arousal value. By using images known to be extremely negative and highly arousing or extremely positive and highly arousing and pairing these with images that displayed none of these characteristics, Experiment 2 has maximized the chances of eliciting an emotional bias. This is contrasted with the Experiment 1 where the stimuli were selected solely on the content. If an image clearly depicted one of our stimulus categories, it was included. Considered with the fact that emotional-emotional pairs were used, this methodology could have minimized the chances of eliciting an attentional bias. Furthermore, all Experiment 2 stimuli depicted people which are known to be very capable of capturing attention (Fletcher-Watson et al., 2008). Experiment 1 stimuli varied in terms of whether or not they depicted people.

Experiment 2 does well to allow us to speculate on the reasons its data differ so greatly from Experiment 1. However, because Experiment 2 was not designed to empirically test these speculative hypotheses, additional research should be conducted to determine the key methodological details that allow the attentional bias for emotional content to manifest. Is it the presence of color? Is it the perfect SOA? Could it be a combination of the two, or something entirely different? These are worthy questions for future research.

Figure 3.5 An example of pairing a neutral image with an emotional image (Top row) versus pairing two emotional images (Bottom row). With the neutral-emotional pair, the emotional image may be a much more emotionally salient image. Such stark differences in emotional content, such as that shown in the top row, may make the competition for attention between the two images, not much of a competition at all. The strong emotional content will consistently beat the neutral content for attention resources. Conversely, with the double threat pair there is intense competition for attention between to imminent threats with equivalent image characteristics (in terms of luminance, contrast and color).



WITH



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Chapter 4 - General Discussion

The combination of Experiments 1 and 2 has led to three broad conclusions. These are 1) attention biases to emotional imagery are a real and replicable finding, 2) the methodology used in Experiment 1 is not well suited for teasing apart differences in attentional processes between ancient and modern threats competing for attention, and 3) slight departures from the oculomotor inhibition methodology used in Nummenmaa et al. (2009, Exp. 3) may be responsible for rendering the Experiment 1 methodology incapable of producing the sort of effect shown in Experiment 2. Nevertheless, Experiment 1 was not completely devoid of meaningful data.

Participants' experience specifically with snakes and spiders was correlated with saccade endpoint deviations. This suggests that there could be a domain *specific* (i.e., snake and/or spider specific) cognitive mechanism that allows experience with snakes and spiders to up-regulate attention to those threats *specifically*. However, because experience levels with snakes and spiders were reportedly lower than experiences with knives (for example) and there was no such correlation observed with knife threats, it is also plausible that the correlations between snake and spider experience and endpoint deviations indicate spurious relationships.

Given past research (Nodine et al., 1996) that shows experience facilitates attention to familiar stimuli, it makes sense that specific experience would lead to larger endpoint deviations in the present paradigm. Speaking from an evolutionary standpoint, it makes sense that learning that something is dangerous would facilitate one's attention to it. However, given the mixed results seen in the analyses regarding the different stimulus categories, it is too early to determine whether experience plays a clear role in shaping attention to threats. No research has yet been done systematically investigating the role of experience in shaping threat-detection. Apart from the present study the most relevant work to date regarding experience was done by Fox et al.

(2007), who showed that threatening stimuli that participants considered *relevant* to themselves more readily attracted attention. Thus, more research is needed to more fully understand the role of experience in shaping attention to threatening stimuli.

A final contribution of the present research is the successful replication of Nummenmaa et al. (2009, Exp. 3). This replication adds support to the reliability of attention biases, as measured by saccadic deviations and curvature, stemming from emotional content presented to parafoveal and peripheral vision.

Limitations and Future Research

Orientation

Recall that the analyses in Experiment 1 failed to yield a significant effect of stimulus orientation. It was predicted that any effect of threat pairing that was observed would disappear when the pair was presented inverted, thus leading to an interaction between threat pairing and orientation. However, no such interaction was revealed. A plausible reason for this, as mentioned in discussion of the eye position plots, is the probable orientation invariance of several of the ancient (snakes and spiders) and modern (knives and syringes) threat stimulus categories used in Experiment 1. Interestingly, when trials with these stimuli are removed from the analysis, orientation had a significant effect on endpoint deviation ratios, lending credence to the orientation invariance hypothesis. Future research should attempt to expand on the present findings using other categories of ancient and modern threats that have a definite “correct” upright orientation, such as the angry human and threatening animal faces in the ancient threat category, and the electrical dangers and guns in the modern threat category. It is likely that such work could reveal an attention bias that relies on correct “upright” orientations. This would indicate that the bias was not caused by low-level image properties. However, any future

research in this vein should stick more closely to the methodology of Experiment 2.

Specifically, color images, 150 ms SOAs, and smaller numbers of trials should be used.

Experience and Domain Specificity

A perplexing pattern of findings in Experiment 1 was the inconsistent effect of experience on endpoint deviations. The omnibus ANOVA revealed significant effects where the one-way ANOVAs using the threat specific subscales failed to. Furthermore, the snake and spider experience subscales demonstrated correlations with saccade endpoint deviation. The results of the ANOVAs suggest that a) the omnibus produced a Type I error, or b) the one-way ANOVAs produced a Type II error. Therefore, a limitation of the present data is that they do not let us make a determination as to which is more likely. At first, the strong correlation of snake experience with endpoint deviations (when only snake-neutral trials were selected) would suggest that the snake-specific one-way ANOVA yielded a Type II error and a domain specific cognitive mechanism was in play. However, given the absence of a similar correlation with the knife subscale (which demonstrated even larger experience scores) it is plausible that the snake and spider experience correlations with endpoint deviations were spurious (i.e., Type I error). These mixed results make it difficult to draw clear conclusions regarding the implications of the experience analyses. For instance, it is impossible to determine from the present data, the degree of domain-specificity of a cognitive mechanism allowing experience to affect attention to threats. Future research should be designed with the express intent of teasing apart those two possibilities. Perhaps a study could manipulate exposure to various threats through a pre-experiment learning task and look to determine whether or not specific exposures primed the participants to either a) respond more quickly or b) be more apt to have their attention captured when the threat was subsequently presented. This would address domain-specificity of any

cognitive mechanism allowing experience to up-regulate attention to specific stimuli. In regard to identifying a less domain-specific mechanism, a different experiment would be needed. Such an experiment would identify two groups of participants. The first group would be experienced with stimulus A and inexperienced with stimulus B and vice versa for the second group. Using some attention-measuring paradigm (such as oculomotor inhibition) researchers would look for attention capture by the stimulus with which the participants were experienced or inexperienced. If facilitated attention was observed, it would support the existence of a less domain-specific mechanism allowing experience to up-regulate attention. However, a failure to observe attention capture would simply mean that particular stimulus combination did not recruit the cognitive mechanism if it existed. Such a result would therefore be inconclusive.

No Manipulation of SOA or Procedures Affecting Saccade Latency

McSorley et al. (2006) showed that faster saccades tend to deviate towards attention capturing stimuli whereas slower saccades deviate away. He attributed this to the fact that reactive feedback to the motor map in the superior colliculus takes time. Based on this work, we had predicted that saccade latency may be systematically related to saccade deviation. However, we found no difference in deviation as a function of saccade latency in Experiment 1. This was likely due to the lack of a direct manipulation of saccade latency through variations in procedures (e.g., voluntary versus reflexive saccades, removing the fixation point as an additional imperative signal to make a saccade).

In Experiment 1 all of the saccades were delayed at least 200 ms post-distractor onset which is a relatively long stimulus onset asynchrony under which we would expect deviations away from the attention capturing stimulus. Indeed, McSorley et al., showed that early on in processing (e.g., 0, 50, and 100 ms SOAs), attention capturing distractors pull saccade deviations

toward them. The switch from saccadic deviations towards distractor stimuli to deviations away from distractor stimuli occurred with the implementation of 200 ms SOAs, the same SOA utilized in Experiment 1. Yet we did not see saccades reliably arcing away from a single distractor. This leads to a couple of arguments for why we did not see a systematic attention bias with the 200 ms SOA in Experiment 1. First, McSorley et al. (2006) used simple shapes in their study. Therefore, it is possible that the timing parameters they outlined for producing saccades away from distractors do not generalize to the complex stimuli used in the present experiments. However, given that our more complex stimuli should take more time process, this explanation seems unlikely. Furthermore, the data from Experiment 2 are roughly consistent with the data of McSorley et al. This adds further doubt to the idea that the 200 ms SOA used in Experiment 1 was incorrect, or was too long. Following this line of reasoning, it also casts doubt on the speculation that the 200 ms SOA was too long and thus allowed attentional disengagement. These arguments together, make the nature of the stimuli used in Experiment 1 the most logical cause of the null findings.

Unidirectional Effects of Negatively Related Anxiety and Experience

Both the general experience and general anxiety (although non-significant) measures (and by extension their respective inter-correlated subscales) were negatively correlated with saccade latencies (i.e., general threat experience and general anxiety were both positively related to faster reaction times); however experience and anxiety were negatively related. Thus, there is a need to explain this apparent contradiction in the present data. How can we explain unidirectional effects by two variables with a negative correlation? The most parsimonious explanation of this contradiction is to attribute it to self-report biases. By asking people if they are experienced with threats or not and then asking them whether or not things make them anxious, common sense

would drive someone to report being more comfortable with a stimulus than they truly are.

However, a stepwise regression showed that both experience and anxiety scores only accounted for about 5% of the variance in saccade latency. While this analysis yielded a significant result ($p < .001$), there is likely another variable (unobserved here) that can account for the substantial amount of unexplained variance and apparent contradictory effects of experience and anxiety on saccade latency. The failure to isolate this variable is a limitation of the present study. Future research interested in how personality characteristics affect fear responding should investigate this issue.

Insensitive Measures

Another possible shortcoming of Experiment 1 was that the angle deviation measure may not have been sensitive enough to capture any meaningful deviations in saccade trajectories resulting from threat conditions (although it was with the Experiment 2 methodology). This hypothesis leads to an obvious direction for future research. Direct saccades to the stimuli in Experiment 1 seemed to suggest that threats, particularly ancient threats, attracted more error saccades. Therefore, a logical follow up to Experiment 1 is to utilize a preferential looking paradigm to assess the relative ability of ancient and modern threats to capture attention. In a preferential looking paradigm, ancient and modern threat images would be presented simultaneously as they were in the present study. But rather than measuring the minute variations in the trajectories of saccades, we would simply measure which images were looked at first. This is a very simple measure of attention allocation since eye movements tend to follow attention in space. However, if the goal is to speak to attention *capture* this study would need to be combined with the oculomotor inhibition paradigm. Attention “capture” is an involuntary response. Because preferential looking is by definition voluntary (people can look at images

they like) such a follow-up study seeking to investigate attention capture would need an index of involuntary direction of attention as is possible with an oculomotor inhibition paradigm.

Did Image Equalization Dampen Attentional Effects?

It is also important to consider why the saccade deviation measures were not sensitive enough to capture meaningful differences in saccade trajectories as a function of threat-pairing. What is interesting is that if you view the eye movement plots on a trial by trial basis, there is clear deviation. This deviation however, does not manifest systematically according to the type of threat present. There is a possible explanation for this seeming failure of our stimuli to capture attention. This study most closely resembles the work of Nummenmaa, et al. (2009, Exp 3) who used a similar oculomotor inhibition paradigm to index attention capture by color image emotional distractors. However, in the interest of keeping all other things equal, we equalized our images in terms of mean RMS contrast and luminance. Recall that Tipper's Population Coding Theory (Tipper, 2000) holds that deviations in saccade trajectories are directly related to the salience of the distractor stimuli (here, threat images). It is possible that by equalizing our images we reduced their bottom-up stimulus salience, thereby adding noise to any systematic deviation we may have seen. Thus, a logical follow up study would be to compare RMS equalized grayscale images, un-equalized grayscale images, RMS equalized color images and un-equalized color images in terms of their ability to capture attention. This would tell us whether having a normal RMS or color are critical to producing the attentional bias for emotional content originally shown by Nummenmaa et al., (2009, Exp 3) and replicated here in Experiment 2.

Recall that one motivation for using the oculomotor inhibition paradigm to assess evolutionary constraints placed on threat detection was that a lot of previous work used visual

search methodology (e.g., Blanchette, 2006; Brosch & Sharma, 2005; Flykt, 2005; Fox et al., 2007; Lipp et al., 2004; Lipp et al., 2007) which is sensitive to the visual characteristics of stimuli (Duncan & Humphreys, 1989). However, based on the findings of this study showing that an attention bias did not manifest with monochrome and RMS equalized stimuli, it also appears that the oculomotor inhibition paradigm is sensitive to the visual characteristics of stimuli. This is an important conclusion in terms of informing methodology of future studies using oculomotor inhibition to index attention biases.

Implications

This research has both theoretical and practical implications. Together, the experiments conducted here addressed the theoretical issues surrounding how visual fear-relevant stimuli capture attention as indexed by eye movements. For example, Experiment 1 began to address the issue of whether one's personal experiences can shape attention.

Experiment 1 explored attention capture by ancient versus modern threats when the two were competing for attentional resources with each other or some neutral stimulus. To date, some research has shown that emotional scenes can capture attention when competing with emotionally neutral scenes (Nummenmaa et al., 2009, Exp. 3). However, this research was not conducted to examine the existence of evolutionary constraints on the processing of fear-relevant threatening stimuli. The results from the Experiment 1 therefore provide fuel for new thinking about the extent to which visual attention to threats is based in evolution. We did not show that a particular type of threat was better at capturing attention than another. In fact, even neutral images were capable of capturing attention on a fair amount of trials. Therefore, at the present time not much can be concluded (from this study) regarding the evolutionary constraints on threat detection.

We do know from Experiment 2 however, that the attention bias to emotion is real, yet it may be fickle, requiring specific viewing parameters in order to manifest. In this regard, a clear theoretical implication our findings carry is that low-level image characteristics may be more responsible for attention capture than the semantic content of the stimuli. We did not observe an attention bias in Experiment 1 which utilized RMS equalized and grayscale stimuli but, we did in Experiment 2 which used unaltered color stimuli. Thus, as previously suggested, future research should attempt to tease apart what specific aspects of emotional imagery are responsible for attention capture by systematically manipulating image properties such as RMS contrast and color.

The present experiment has added to the debate regarding whether or not automatic attention to fear-relevant threatening stimuli is constrained by evolutionary influence. While the present experiments cannot provide a definitive answer as to the evolutionary underpinnings of attention to threats, it is suggested that physical characteristics of the images (e.g., luminance, contrast, and color) are at least partly responsible for determining attention capture. But it does not suffice to say that color and contrast are the only critical components responsible for the manifestation of the attention bias. Perhaps it is the combination of color and form cues which merge through some cognitive mechanism to provide us cues of biological salience which up-regulates stimuli to receive rapid attention. In addition, a hypothesis concerning image color, contrast and/or forms is limited in its strictly bottom-up approach. There are likely top-down influences on attention biases as well. For example, based on the findings of the present study, the role of experiences in shaping attention processes deserves further attention.

In regard to top-down influences on attention, we know from previous work that semantics can influence attention. Most relevantly, the stimuli used in Nummenmaa et al. (2009,

Exp 3) were analyzed using Itti and Koch's (2000) saliency algorithm. This computer program accounts for image characteristics such as orientation, intensity and color. Using this algorithm provided Nummenmaa et al. with quantitative data regarding the overall saliency of their images from a purely stimulus-driven standpoint. This data was subjected to analyses that revealed no significant differences in saliency among the stimuli. Therefore, we can say with confidence that the factors contributing to attention capture in the Experiment 2 replication of Nummenmaa et al. (2009, Exp 3) are most likely due to the semantic differences between the stimuli.

However, in lieu of a direct comparison between color images and monochrome/equalized images we cannot rule out the possibility that color information is necessary for attention biases to manifest. As noted earlier, the past studies demonstrating attention biases that have used complex image stimuli have presented those stimuli in full color. It is important though, to integrate this fact with the fact that McSorley et al. (2006) showed attention capture with monochrome simple shapes. Does this mean that color is only required for attention biases to manifest when using complex stimuli? Not necessarily. A new study from Schmidt, Belopolsky and Theeuwes (2012) uses oculomotor inhibition to show that monochrome angry faces capture attention to a greater extent than neutral faces when paired with innocuous objects. So how then do we explain the failure to demonstrate significant differences between condition pairings in Experiment 1? In light of existing research, the wash-out effect from pairing two emotional stimuli at first appears a likely explanation. But, that means there should have been systematic deviation with only the threat-neutral pairs. There was not. This leaves us to suppose that there may be inherent aspects of the Experiment 1 stimuli that render them weak in terms of their ability to capture attention. Unfortunately, the present study is inconclusive in that regard.

Given the present data, it is much too early to pin down if and how experience affects attention, but the mixed findings here merit additional research. The present data do not allow us to offer clear conclusions regarding domain specificity (or even the existence) of such an experience integrating cognitive mechanism at this time. If a cognitive mechanism exists that allows experience to influence attention to threats in the environment, future research aimed at understanding this mechanism should be designed to explore the domain specificity of it. This is important as degree of domain-specificity is a central issue surrounding the extent to which the mechanism is a result of evolution.

This study is inconclusive in terms of the evolutionary constraints imposed (or not imposed) on visual attention to threatening objects. For this information, it remains necessary to rest on the foundation laid by the research of the past three decades. The studies preceding this provide multiple converging lines of evidence from visual search (e.g., Blanchette, 2006; Brosch & Sharma, 2005), observational condition (e.g., Mineka et al., 1984), and change detection (McGlynn et al., 2008; New, Cosmides, & Tooby, 2006) that attention biases for complex stimuli are real phenomena. It will simply take additional work to more fully understand the evolutionary constraints on those biases. The current results do not allow us to say how this bias manifests and what information it selects, particularly with regard to evolutionarily relevant versus modern threats. Going forward, it will be important to further understand how the malleability of visual attention to threat is affected by stimulus characteristics in addition to gaining a more clear understanding of its evolutionary underpinnings.

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Appendix A - Experimental Questionnaires

1. What is your sex?

Male Female

2. What is your race?

Caucasian/White African-American/Black Asian Hispanic Native American Other

3. What is your age?

4. What is your year in school?

Freshman Sophomore Junior Senior Other/None of the above

7. How many times have you been on military deployment? [If never in the military choose "1 - Never"]

1 Never

2 Currently preparing for first deployment

3 One deployment

4 Two deployments

5 Three or more deployments

Please answer the following questions honestly by placing an “X” in the appropriate answer box. If you do not understand a survey item, please ask the experimenter for clarification. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

		TRUE	FALSE
1	I would feel some anxiety holding a toy spider in my hand.		
2	If a picture of a spider appears on the screen during as motion picture, I turn my head away.		
3	I dislike looking at pictures of spiders in a magazine.		
4	I don't mind being near a harmless spider if there is someone there in whom I have confidence.		
5	When I see a spider, I feel tense and restless.		
6	I would feel some anxiety holding a toy snake in my hand.		
7	If a picture of a snake appears on the screen during as motion picture, I turn my head away.		
8	I dislike looking at pictures of snakes in a magazine.		
9	I don't mind being near a harmless snake if there is someone there in whom I have confidence.		
10	When I see a snake I feel tense and restless.		
11	I would feel some anxiety holding a toy lion, tiger, wolf or bear in my hand.		
12	If a picture of a predatory mammal appears on the screen during as motion picture, I turn my head away.		
13	I dislike looking at pictures of predatory mammals in a magazine.		
14	I don't mind being near a predatory mammal if there is someone there in whom I have confidence.		
15	When I see a predatory mammal I feel tense and restless.		
16	I would feel some anxiety touching an angry person.		
17	If a picture of an angry person appears on the screen during as motion picture, I turn my head away.		
18	I dislike looking at pictures of angry faces in magazines.		
19	I don't mind being near an angry person if there is someone there in whom I have confidence.		

20	When I see an angry face I feel tense and restless.		
21	I would feel some anxiety holding a toy gun in my hand.		
22	If a picture of a gun appears on the screen during as motion picture, I turn my head away.		
23	I dislike looking at pictures of guns in a magazine.		
24	I don't mind being near a gun if there is someone there in whom I have confidence.		
25	When I see a gun I feel tense and restless.		
26	I would feel some anxiety holding a toy knife in my hand.		
27	If a picture of a knife appears on the screen during as motion picture, I turn my head away.		
28	I dislike looking at pictures of knives in a magazine.		
29	I don't mind being near a knife if there is someone there in whom I have confidence.		
30	When I see a knife I feel tense and restless.		
31	I would feel some anxiety holding a toy syringe in my hand.		
32	If a picture of a syringe appears on the screen during as motion picture, I turn my head away.		
33	I dislike looking at pictures of syringes in a magazine.		
34	I don't mind being near a syringe if there is someone there in whom I have confidence.		
35	When I see a syringe I feel tense and restless.		
36	I would feel some anxiety touching an electrical hazard.		
37	If a picture of an electrical hazard appears on the screen during as motion picture, I turn my head away.		
38	I dislike looking at pictures of electrical hazards in a magazine.		
39	I don't mind being near an electrical hazard if there is someone there in whom I have confidence.		
40	When I see an electrical hazard I feel tense and restless.		

Please answer the following questions as honestly as possible by circling the appropriate response. If you do not understand an item, please ask the experimenter for clarification. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

		Never	Occasionally	Sometimes	Frequently	Very Frequently
1	How often do you use firearms (for work or recreation)?	1	2	3	4	5
2	How often were you exposed to firearms growing up (until age 18)?	1	2	3	4	5
3	How often were you exposed to firearms in the last 6 months?	1	2	3	4	5
4	How often do you use knives (for work or recreation)?	1	2	3	4	5
5	How often were you exposed to knives growing up (until age 18)?	1	2	3	4	5
6	How often were you exposed to knives in the last 6 months?	1	2	3	4	5
7	How often do you encounter electrical hazards (for work or recreation)?	1	2	3	4	5
8	How often were you exposed to electrical hazards growing up (until age 18)?	1	2	3	4	5
9	How often were you exposed to electrical hazards in the last 6 months?	1	2	3	4	5
10	How often do you use syringes (for work or recreation)?	1	2	3	4	5

11	How often were you exposed to syringes growing up (until age 18)?	1	2	3	4	5
12	How often were you exposed to syringes in the last 6 months?	1	2	3	4	5
13	How often do you encounter snakes (for work or recreation)?	1	2	3	4	5
14	How often were you exposed to snakes growing up (until age 18)?	1	2	3	4	5
15	How often were you exposed to snakes in the last 6 months?	1	2	3	4	5
16	How often do you encounter spiders (for work or recreation)?	1	2	3	4	5
17	How often were you exposed to spiders growing up (until age 18)?	1	2	3	4	5
18	How often were you exposed to spiders in the last 6 months?	1	2	3	4	5
19	How often do you encounter predatory mammals (for work or recreation)?	1	2	3	4	5
20	How often were you exposed to predatory mammals growing up (until age 18)?	1	2	3	4	5
21	How often were you exposed to predatory mammals in the	1	2	3	4	5

	last 6 months?					
22	How often do you see angry people (for work or recreation)?	1	2	3	4	5
23	How often were you exposed to angry people growing up (until age 18)?	1	2	3	4	5
24	How often were you exposed to angry people in the last 6 months?	1	2	3	4	5

Appendix B - State-Trait Anxiety Inventory

Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	1	2	3	4
	Not at all	A little	Somewhat	Very Much So
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I feel tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel uncomfortable	1	2	3	4
11. I feel self confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I feel jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

STAI Score Sheet

- ❖ 1, 2, 5, 8, 11, 15, 16, 19, 20 are reverse scored.
- ❖ Create a sum total for all of the items.

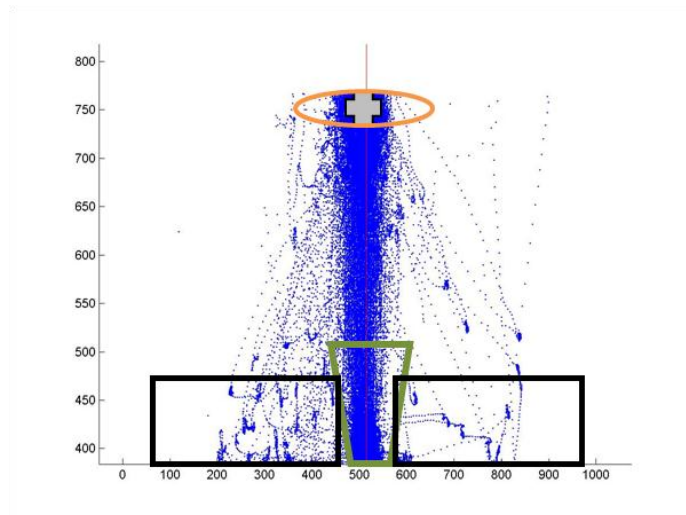
Participant #	Sum Score		Participant #	Sum Score

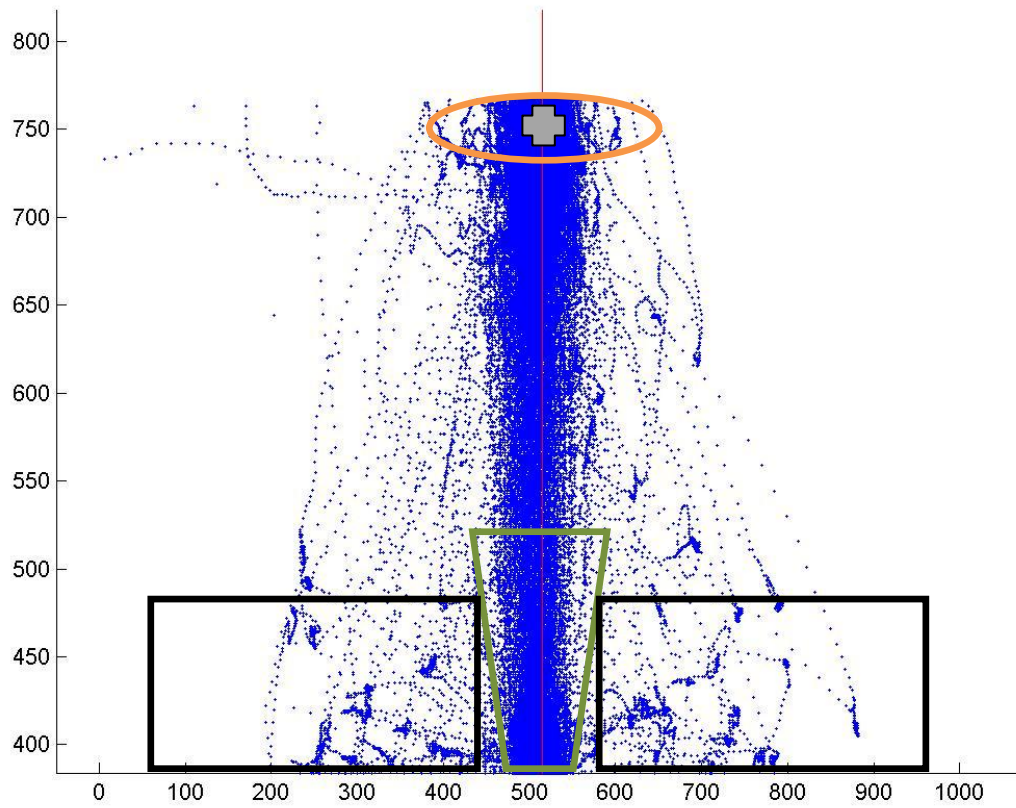
Appendix C - Eye Sample Plots

These are the cumulative plots of saccade patterns by condition. All saccades have been rotated such that they are all upward in direction. Thus, 512 on the abscissa can be thought of as the fixation point. The thin red line in the center represents the central axis of the viewing space. An example figure below shows the different interest areas in these plots to facilitate interpretation.

EXAMPLE

In this example, grey boxes indicate where the images were presented. The grey cross indicates the saccade target. Shapes have been included to note interest regions in the plots. The rectangles highlight areas of the plots that indicate saccades to a particular image. In this example, there are more saccades directly to the left of fixation than to the right. The trapezoid indicates the region of the saccade that shows the initial deviation angle of the saccade. In this example, there were more deviations to the left than the right. The ellipse represents the area of the saccade where we look for saccade endpoint deviations. In this example, there is more endpoint deviation to the left of the saccade target than to the right.



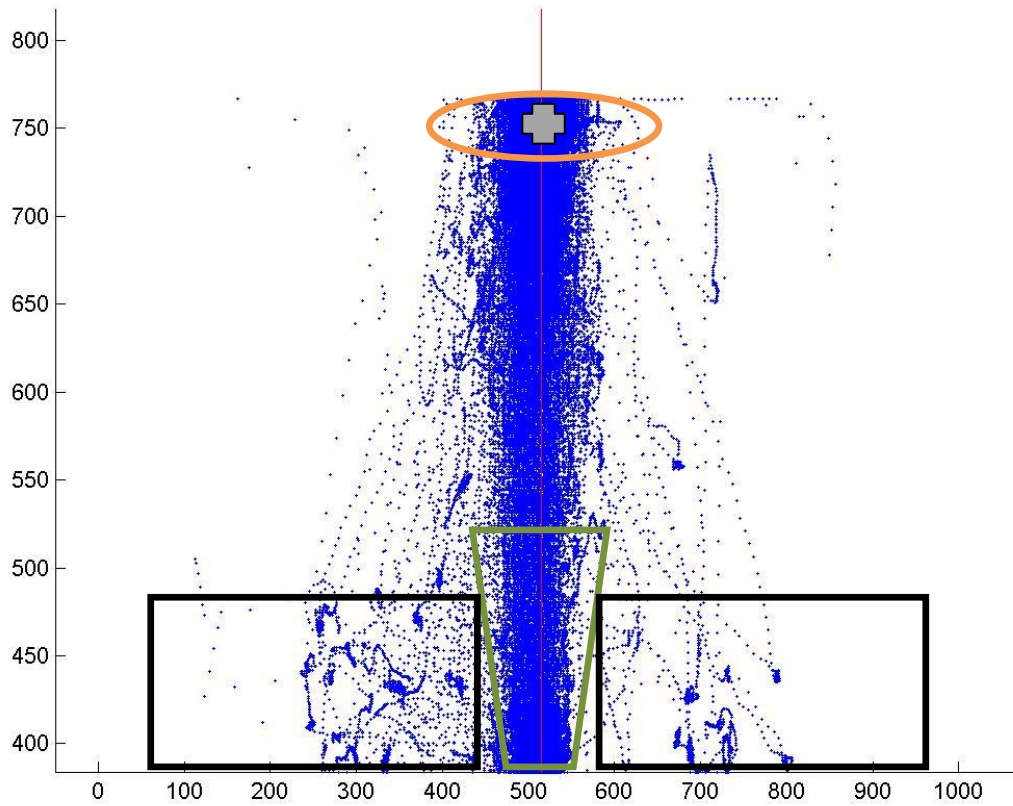


Left: Ancient

Right: Ancient

Orientation: Upright

There is a relatively even distribution of eye movements across the midline. One side does not seem to capturing attention a great deal more than another.

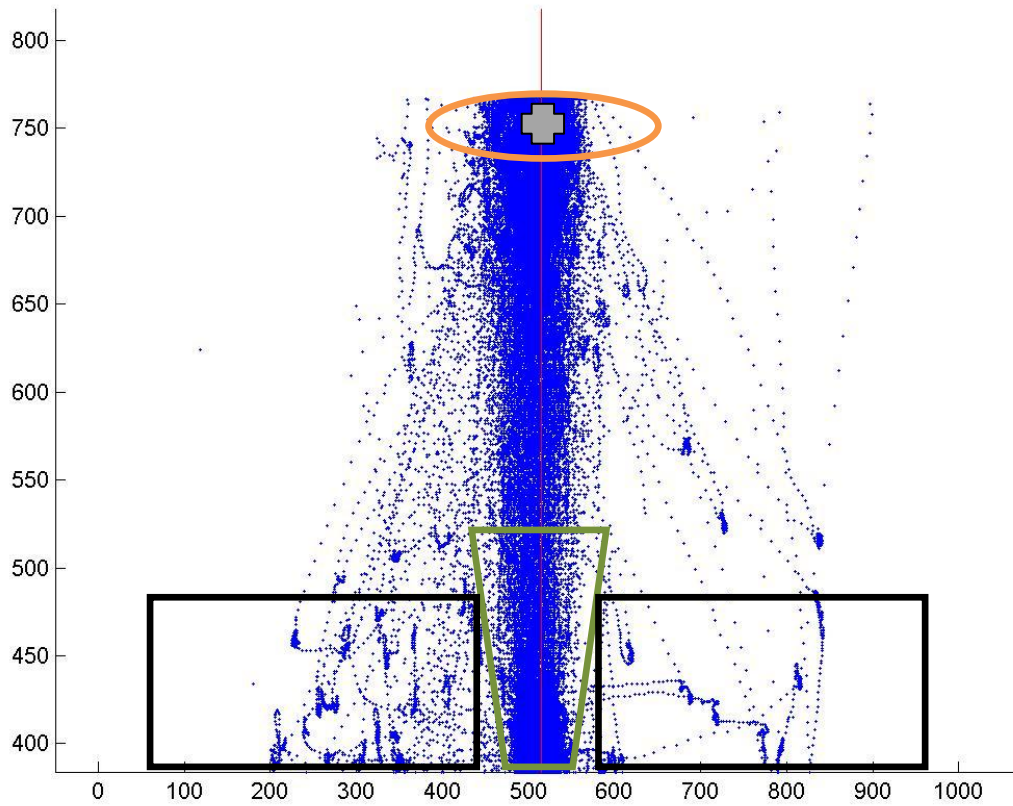


Left: Ancient

Right: Modern

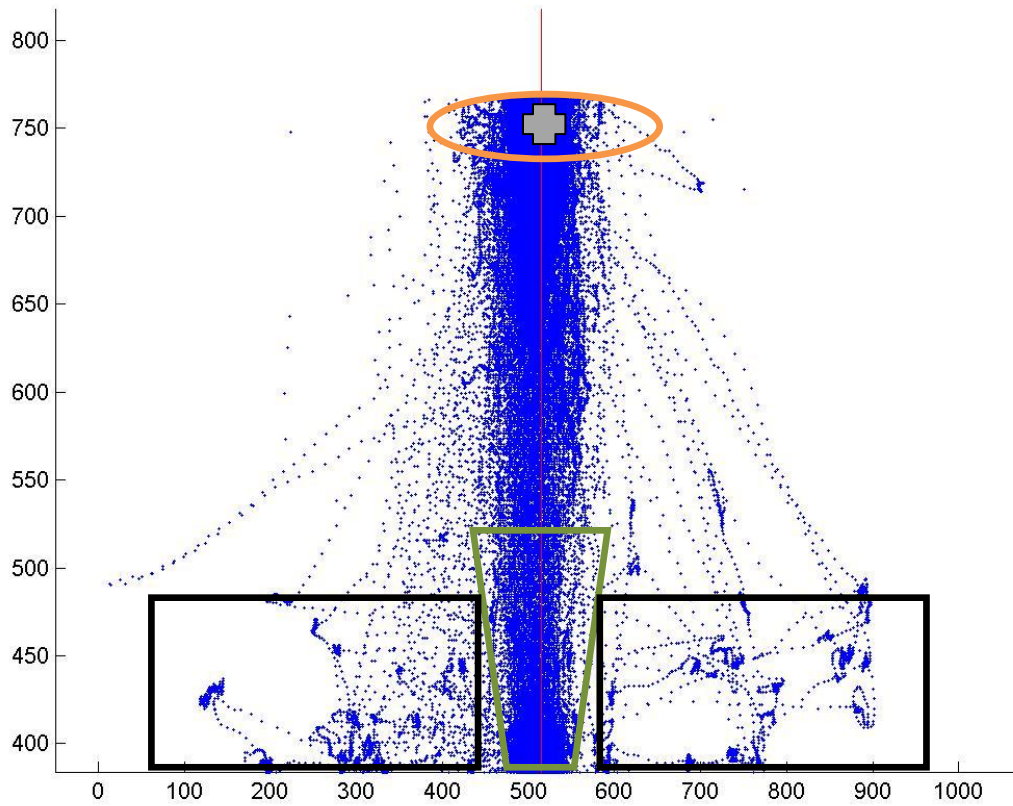
Orientation: Upright

There is a relatively even distribution in terms of endpoint deviations. However, initial saccade angles deviate away from the modern threats and toward the ancient threats. Furthermore, the left (ancient) side appears to be capturing more error saccades where participants looked toward the image.



Left: Ancient
Right: Neutral
Orientation: Upright

There is a clear pattern here. Both endpoint deviations and saccade angle deviations are predominately deviating toward the left (ancient) side of the display. Additionally, the ancient threat images captured more erroneous saccades to the image.

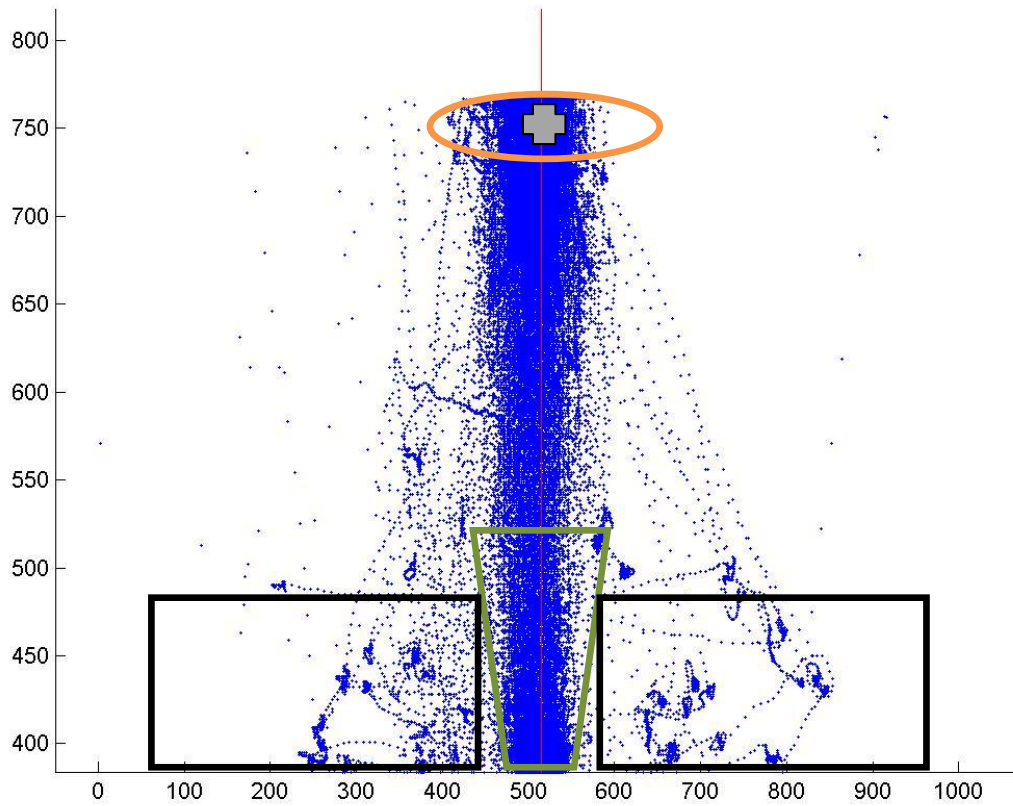


Left: Modern

Right: Ancient

Orientation: Upright

Here, both angles and endpoints deviate toward the left (modern) and away from the right (ancient). However, there is a relatively even distribution of error saccades.

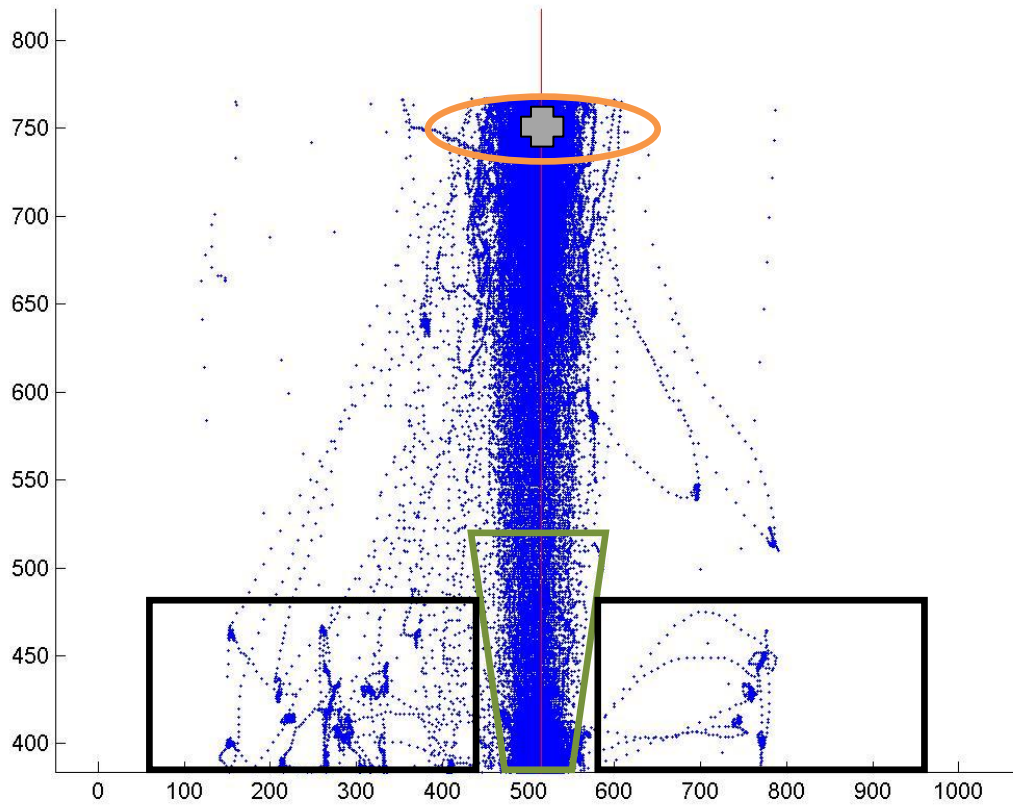


Left: Modern

Right: Modern

Orientation: Upright

Here there is a relatively even distribution of angular deviations and error saccades. However, the endpoint deviations are predominately on the left.

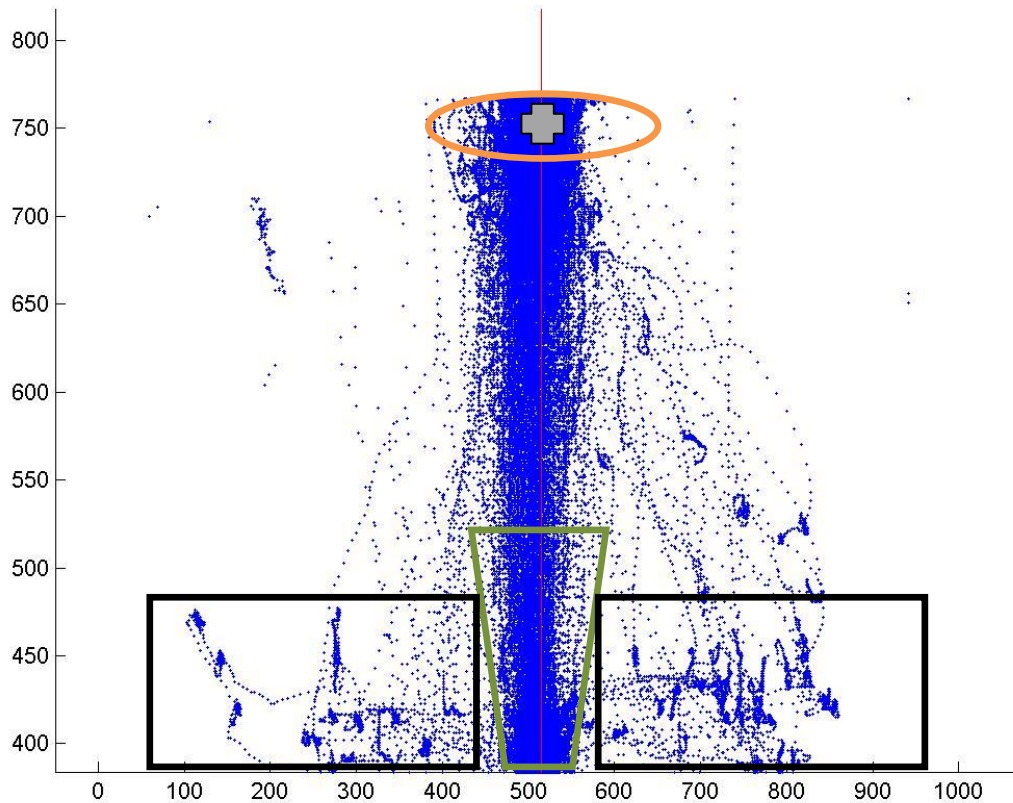


Left: Modern

Right: Neutral

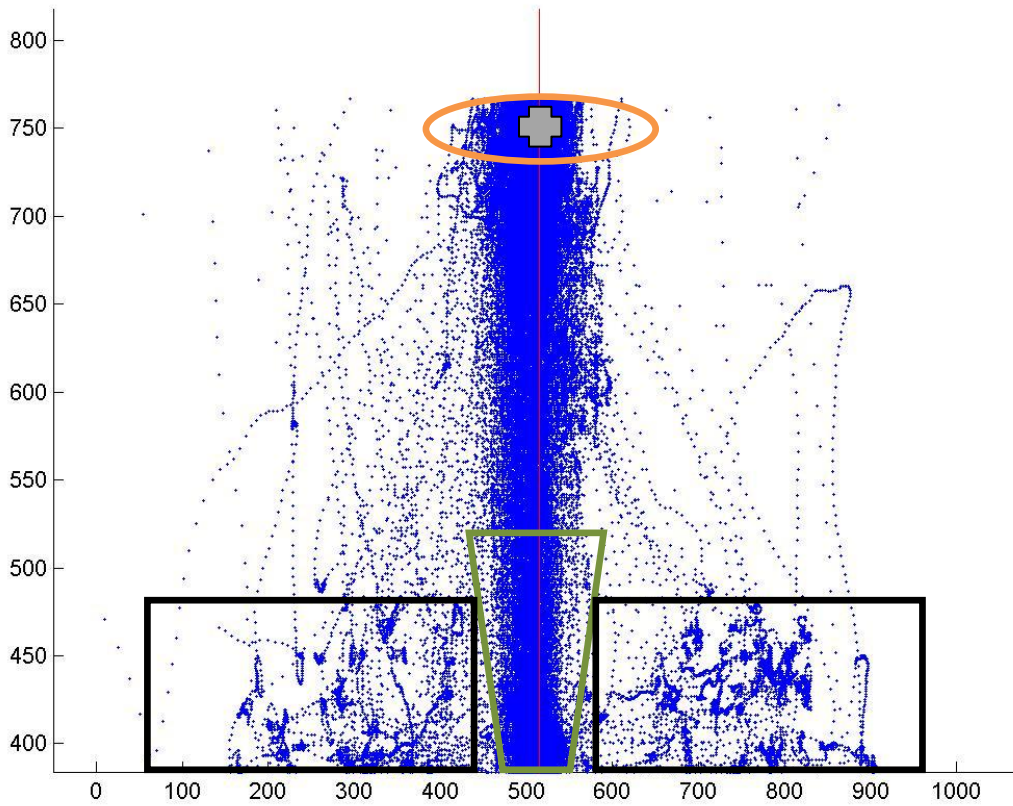
Orientation: Upright

This condition clearly shows more error saccades to the left (modern threat) image. Initial angle deviations seem to veer slightly more toward the left (modern). However, the endpoint deviations are relatively evenly distributed.



Left: Neutral
 Right: Ancient
 Orientation: Upright

This plot shows clear attention capture of the right (ancient) images over the left (neutral) images. The error saccades are directed predominately to the right where the ancient images are. Furthermore, the initial angles consistently deviate away from the ancient images. This plot shows additionally that the endpoint deviations are predominately stacking up on the left, away from the ancient threat images on the right.

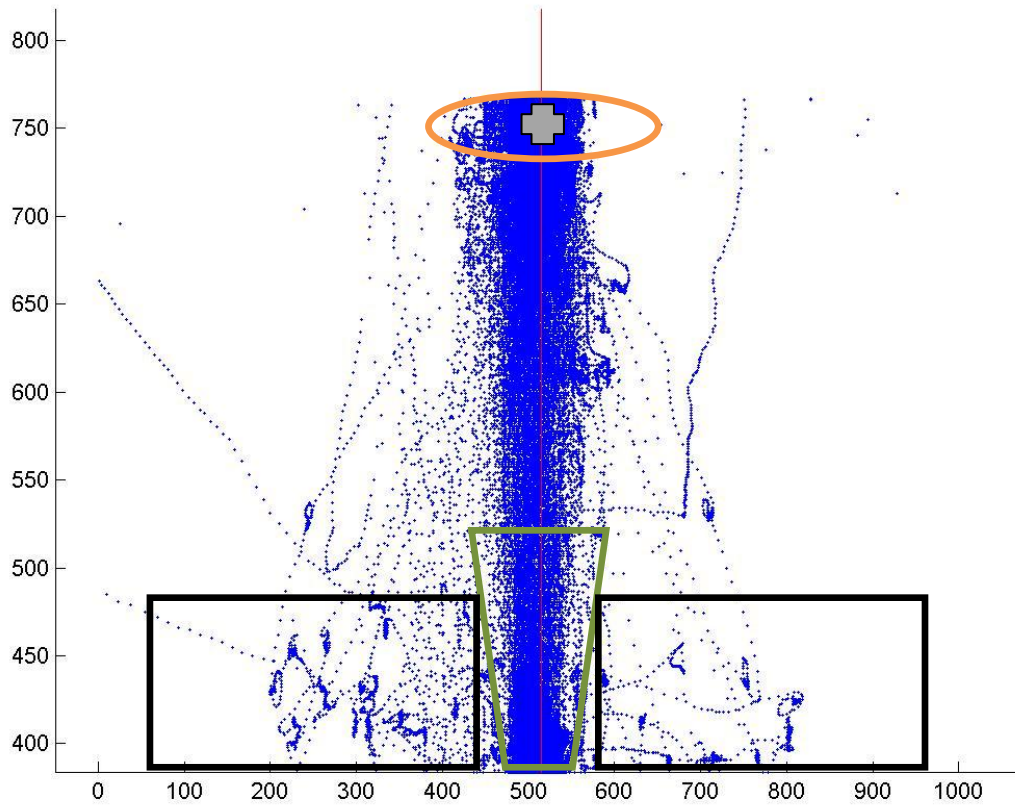


Left: Neutral

Right: Modern

Orientation: Upright

This plot also demonstrates a clear pattern. Although there is not much difference in the error saccades, the initial angles predominately deviate away from the modern threat images on the right. The endpoint deviations show a similar pattern, stacking up on the side opposite from the modern threats.

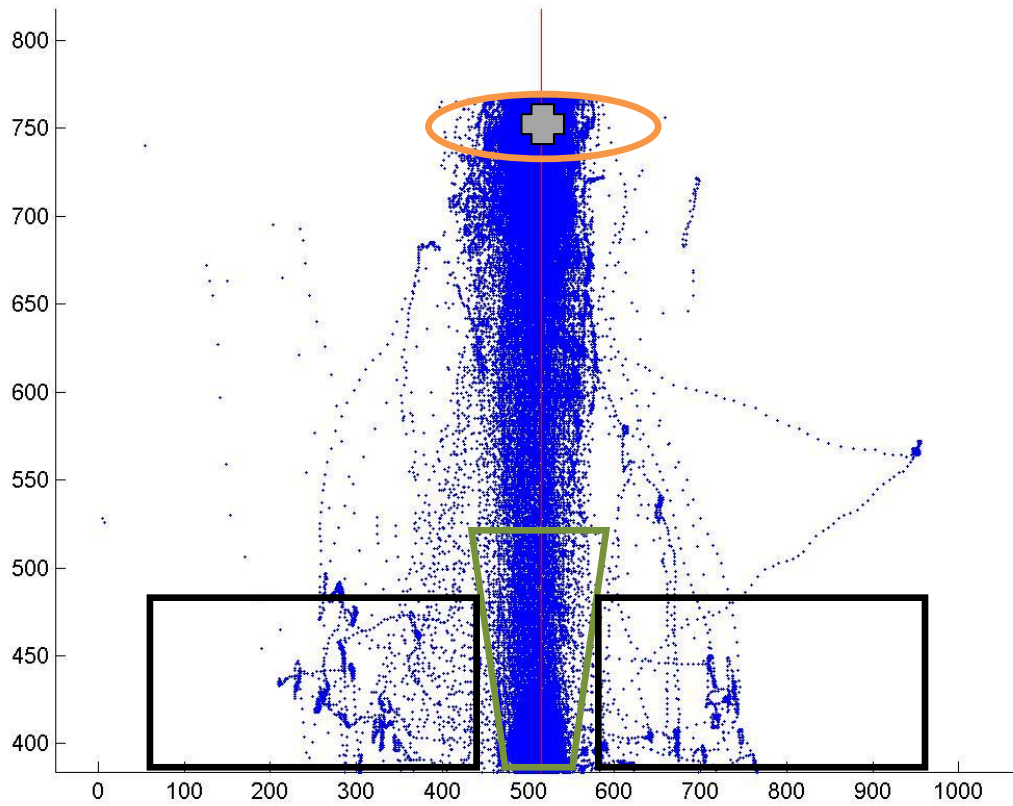


Left: Neutral

Right: Neutral

Orientation: Upright

This plot shows a relatively even distribution of eye locations. One side is not reliably capturing attention over the other.

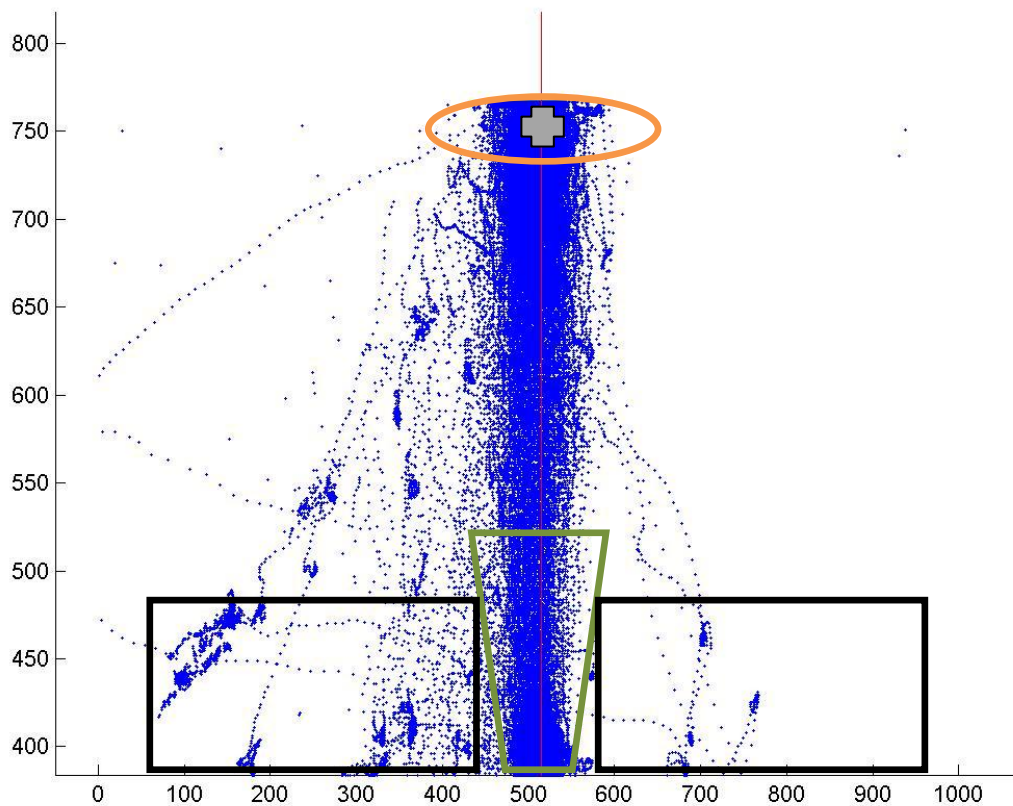


Left: Ancient

Right: Ancient

Orientation: Inverted

There is a fairly even distribution of eye locations in this plot. However, it appears that there be a tendency for the participants to have saccades with leftward angles.

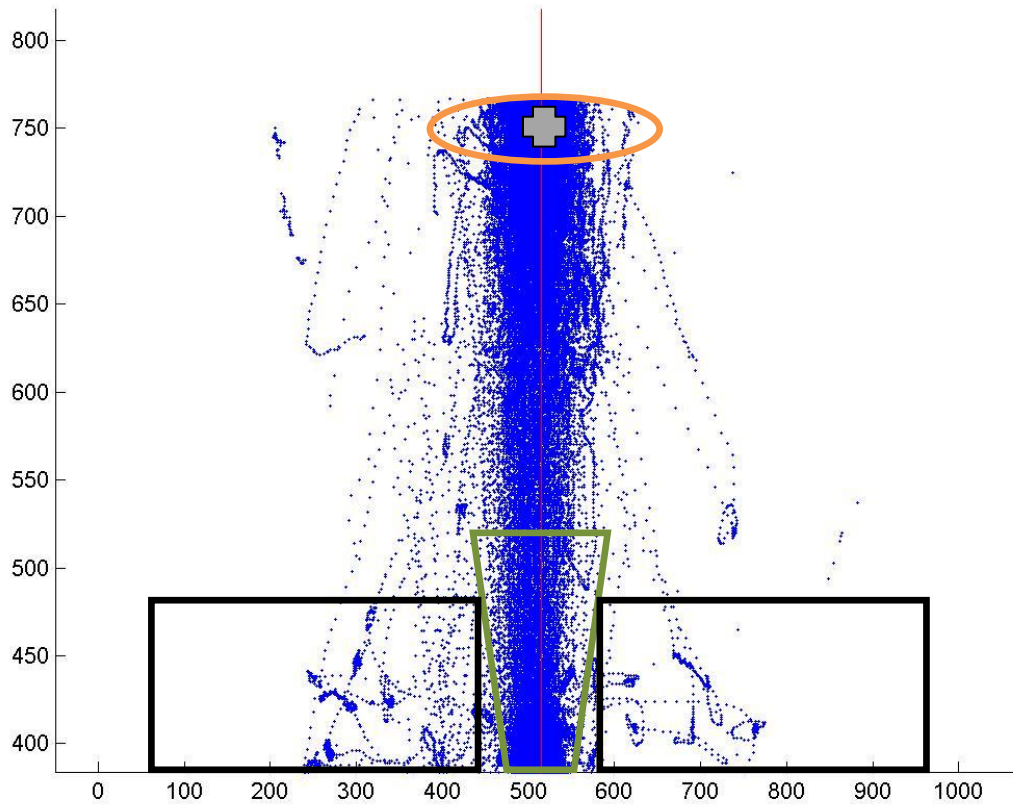


Left: Ancient

Right: Modern

Orientation: Inverted

This plot shows an interesting pattern that elucidates an important difference between the ancient and modern stimuli. There is not a large difference in error saccades, although it appears that the ancient threats captured a few error saccades. The important pattern here is that even when inverted, modern threats seemed to capture attention as indicated by the leftward initial saccade angles. This is likely due to the orientation invariance of the modern stimuli chosen. A syringe or a knife is still a syringe or a knife no matter which way it is oriented.

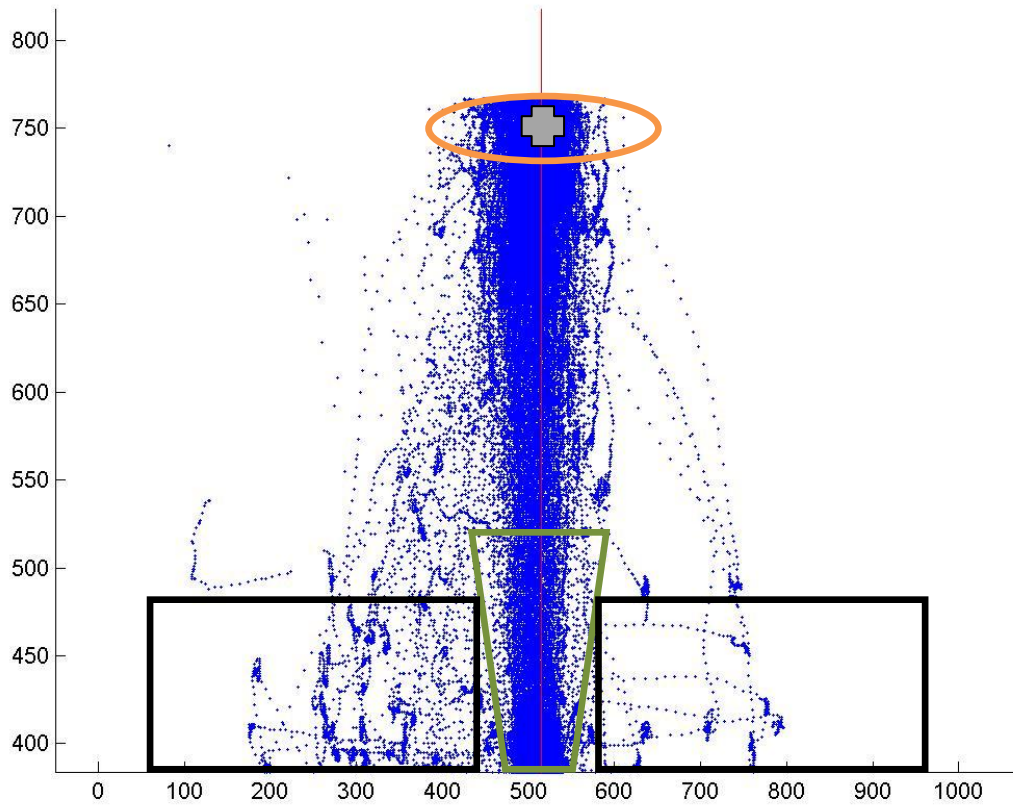


Left: Ancient

Right: Neutral

Orientation: Inverted

There is a relatively even distribution of eye positions in this plot. One side does not seem to capture attention a great deal more than the other. When you compare this plot to its upright counterpart, there are significantly less error saccades to the ancient images.

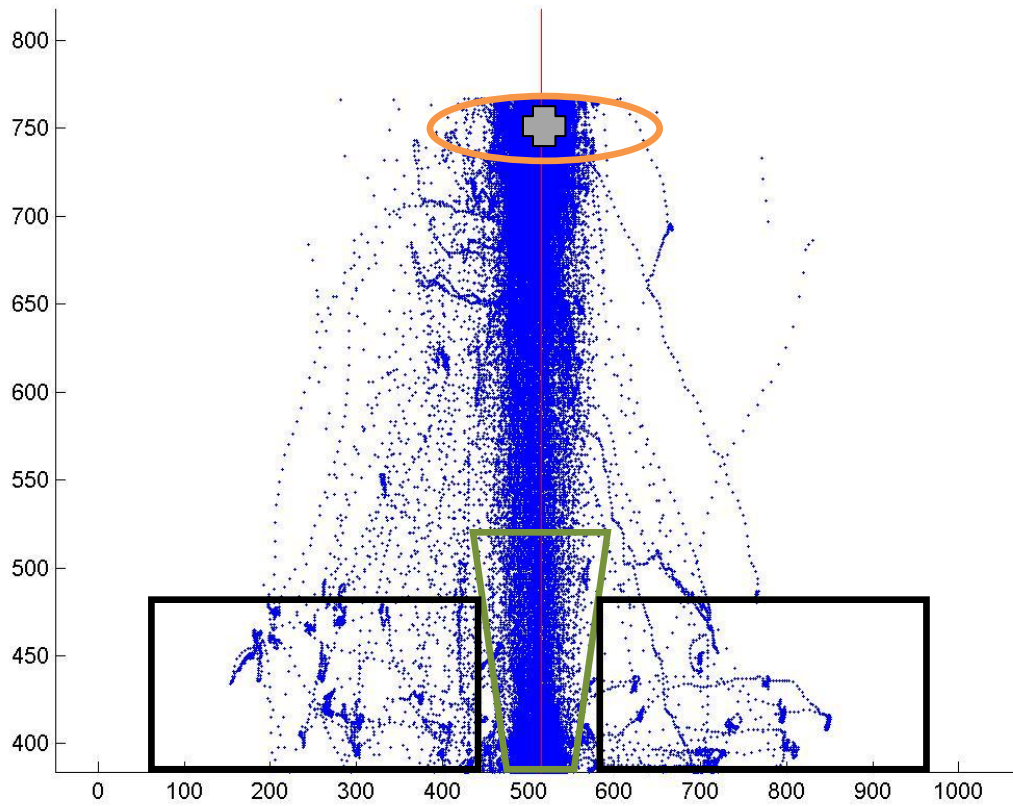


Left: Modern

Right: Ancient

Orientation: Inverted

This plot clearly shows that the inverted modern threat images captured more error saccades. This is likely due to their orientation invariance. However, judging by the angles and endpoints, it seems as though the ancient images were also capturing attention.

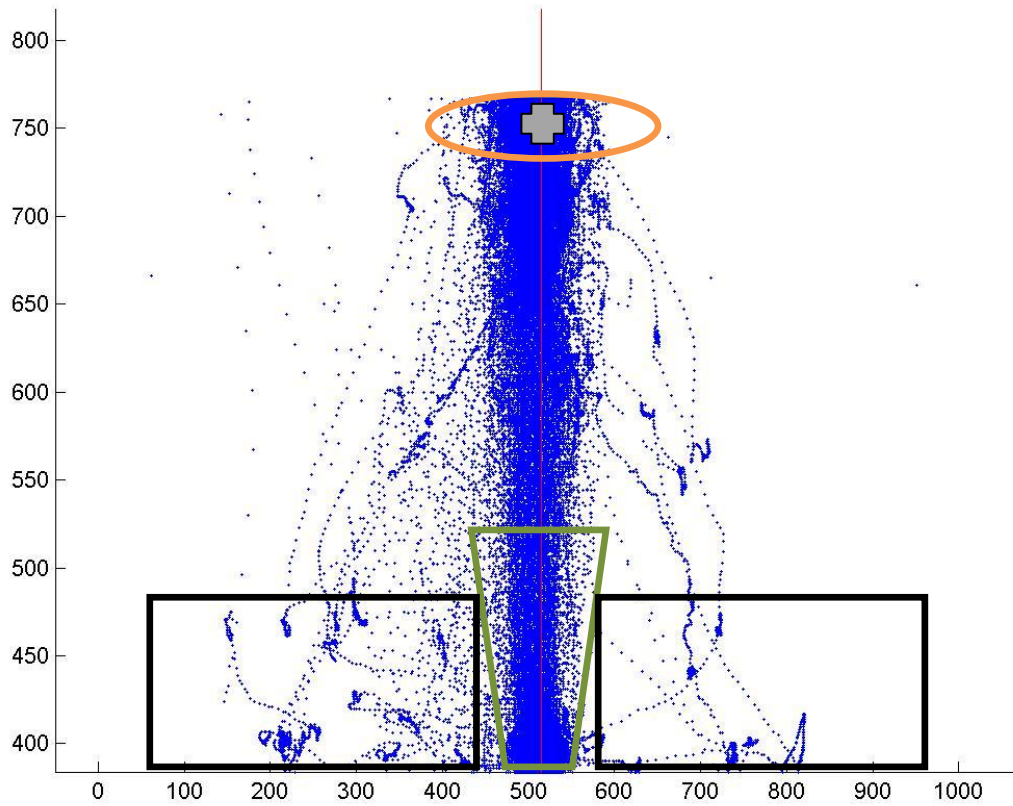


Left: Modern

Right: Modern

Orientation: Inverted

This plot shows a relatively even distribution of all measures although it seems as though the angles may predominately fall on the left.

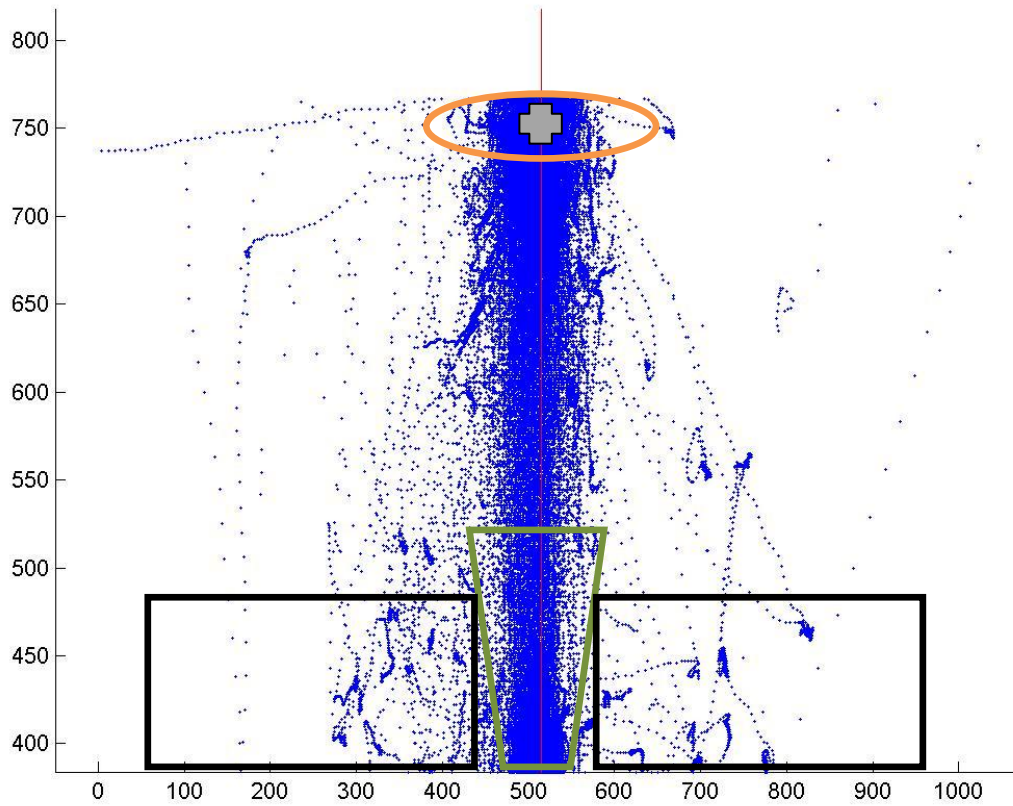


Left: Modern

Right: Neutral

Orientation: Inverted

This plot shows that the majority of saccades endpoints deviated toward the left (modern) and away from the right (neutral). However, there is not a big difference in initial angles. Also, the modern threats seemed to capture more error saccades than did the neutral threats.

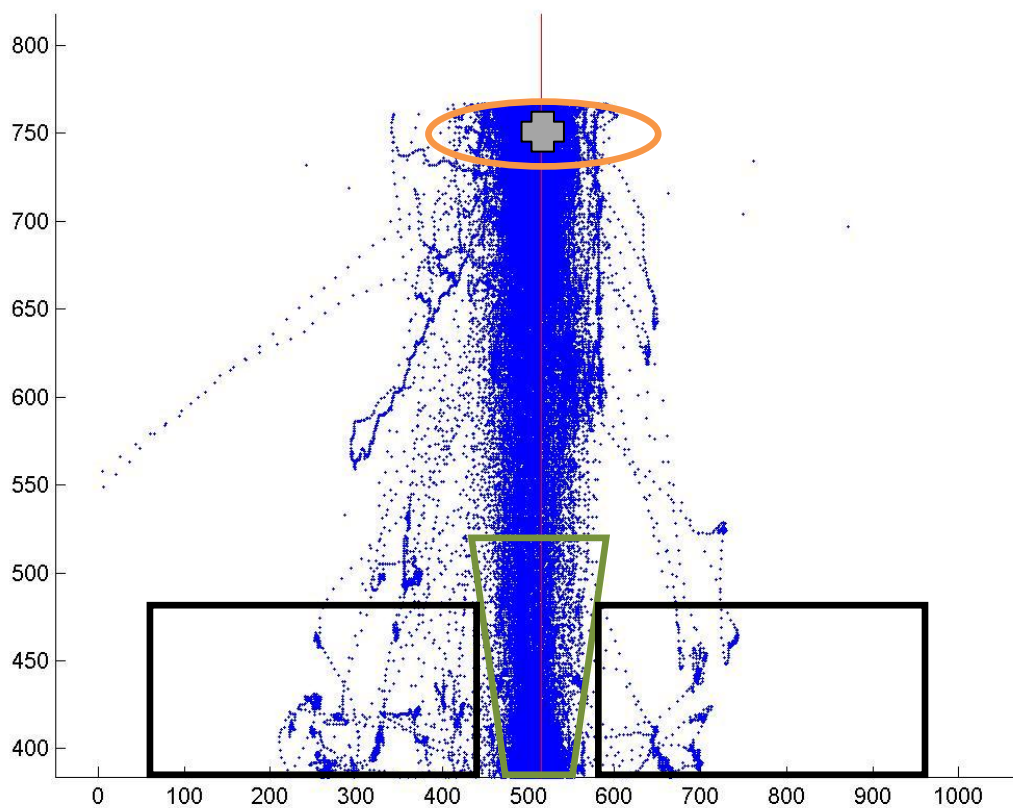


Left: Neutral

Right: Ancient

Orientation: Inverted

There is a relatively even distribution of eye positions in this plot. However, the initial angles seem to deviate slightly more often to the left, away from the ancient threat images.

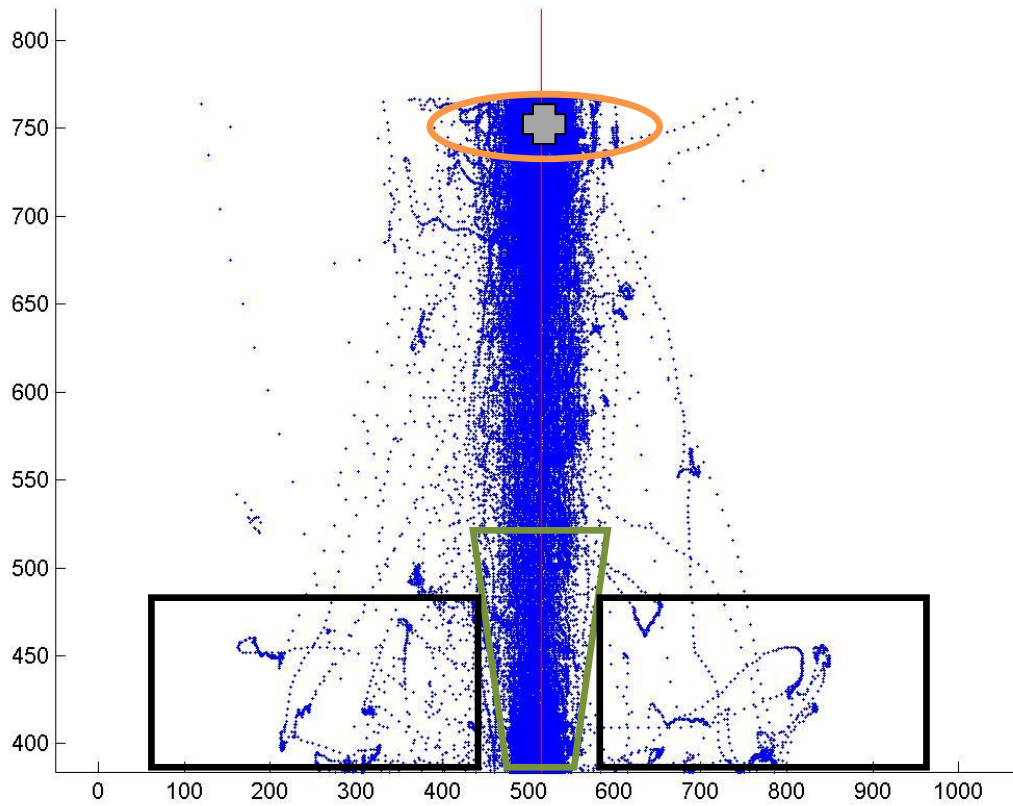


Left: Neutral

Right: Modern

Orientation: Inverted

This plot shows a clear tendency for the saccades to deviate away from the modern threats when they are paired with neutral images. Again, the orientation invariance of these two stimuli likely plays a role in determining this data pattern.



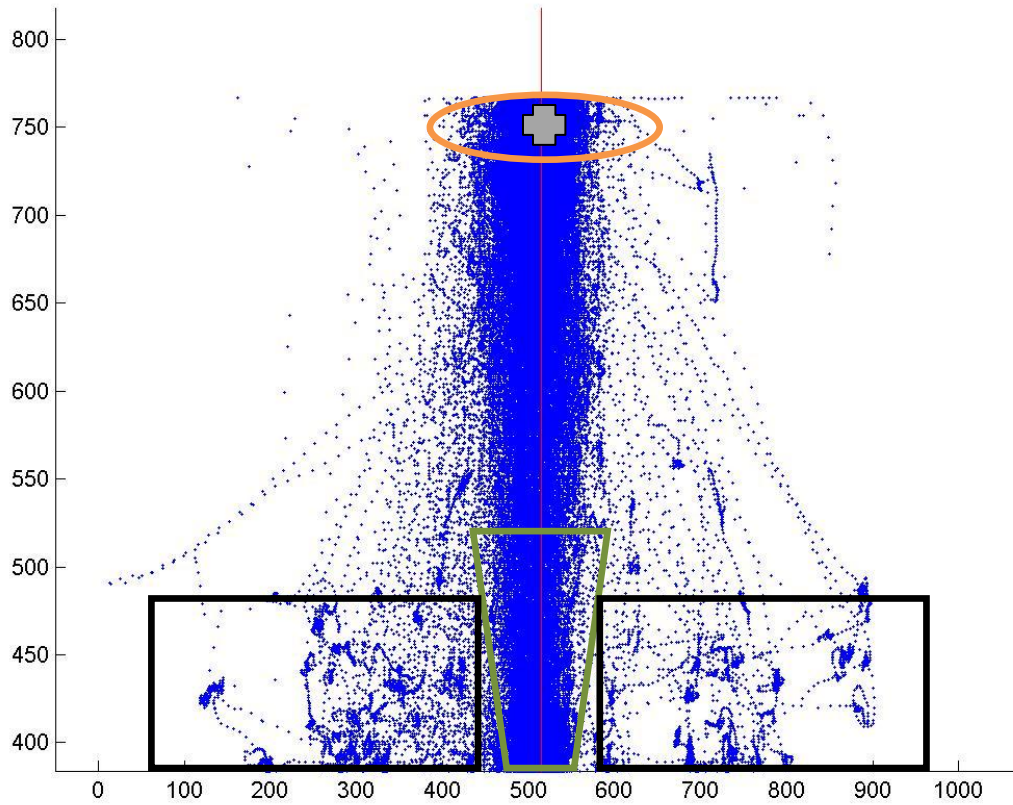
Left: Neutral

Right: Neutral

Orientation: Inverted

There is an even distribution of eye positions in the plot. This plot is perhaps the most evenly distributed of all of the plots, which is what we would expect with two inverted neutral images.

Appendix D

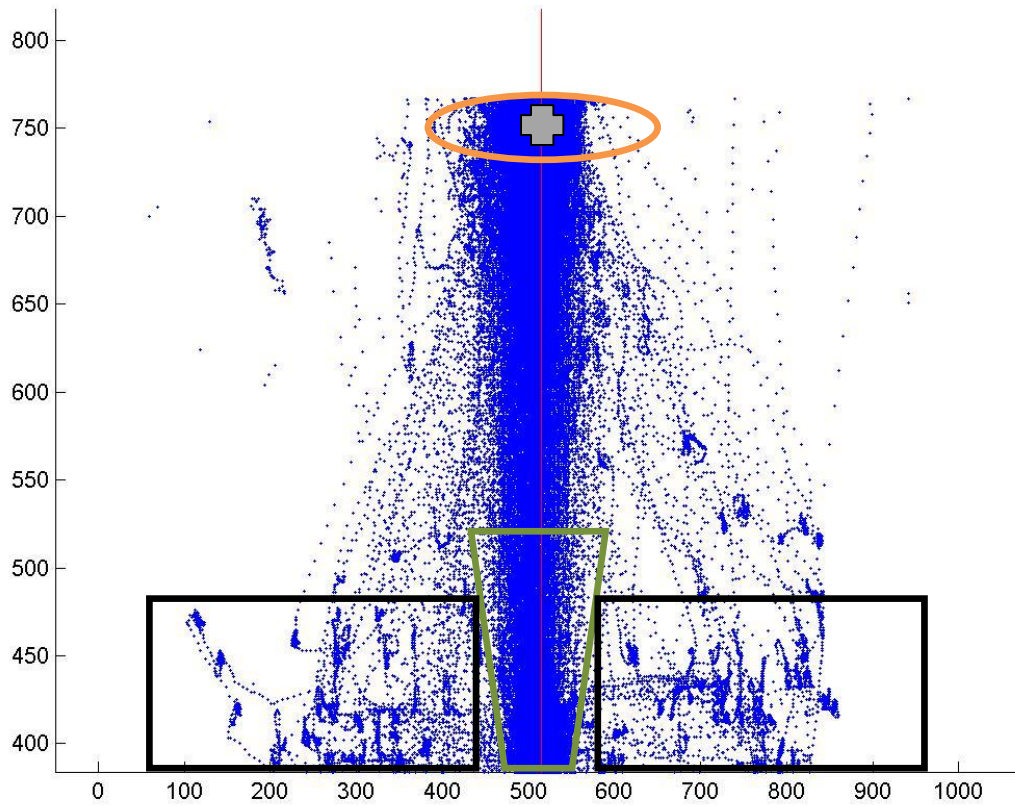


Left: Ancient

Right: Modern

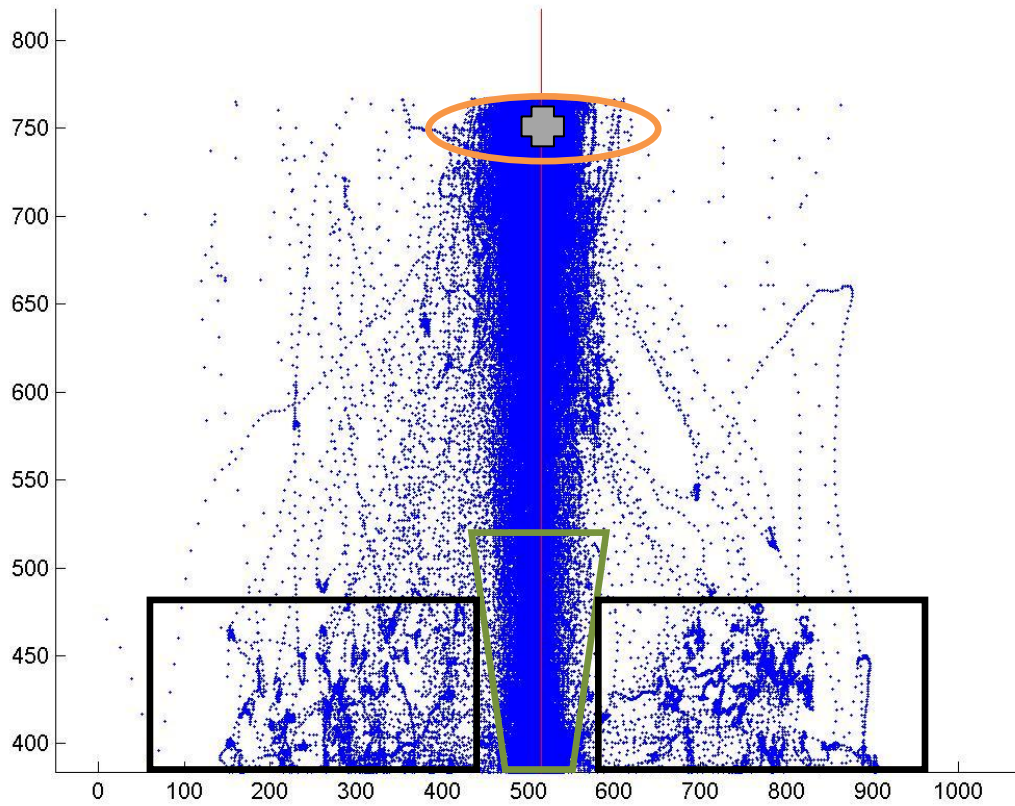
Orientation: Upright

Ancient threats appear to capture a few more error saccades than do the modern threats. However, the deviation of saccade angles is more leftward, away from the modern threats. Judging from this plot, it seems that both ancient and modern threats capture attention.



Left: Ancient
Right: Neutral
Orientation: Upright

This plot does not provide a clear indication of attention capture of one threat type over another.

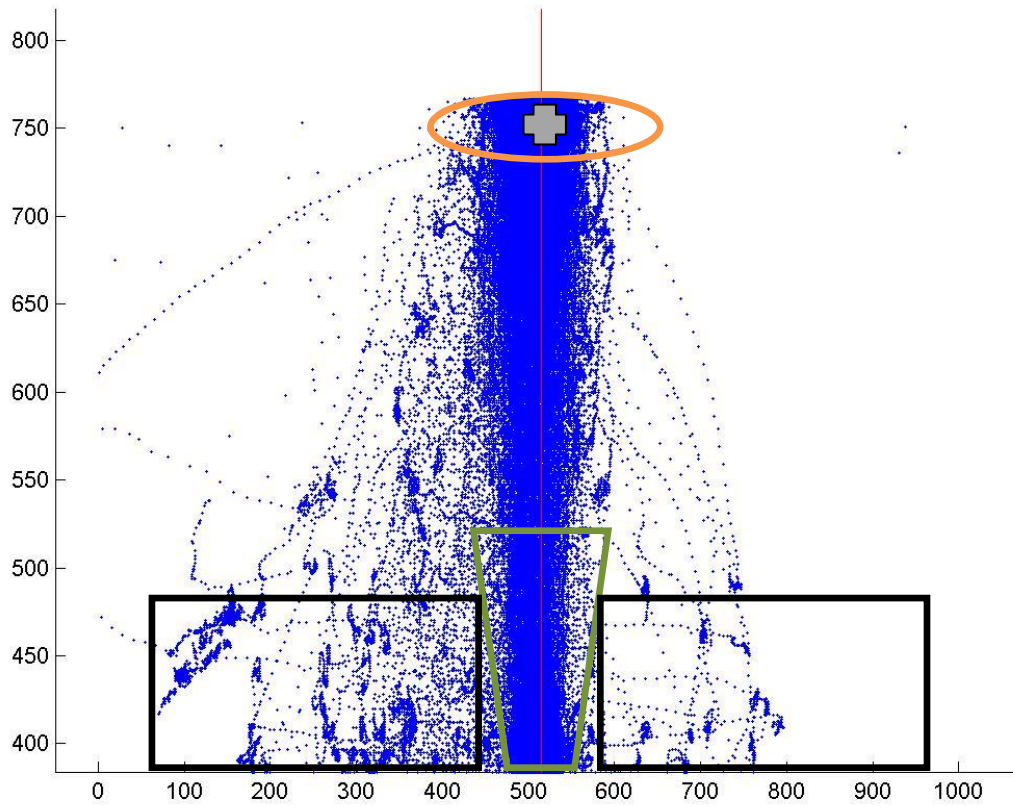


Left: Modern

Right: Neutral

Orientation: Upright

This plot does not provide a clear indication of attention capture of one threat type over another.

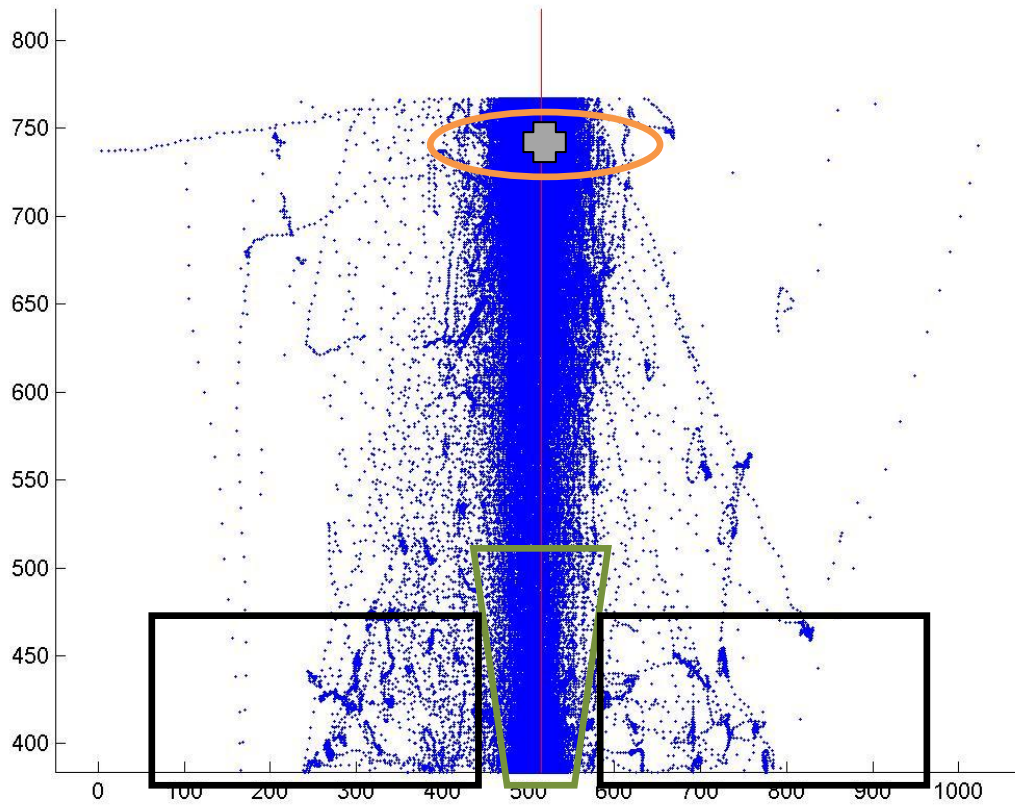


Left: Ancient

Right: Modern

Orientation: Inverted

This plot clearly shows that when inverted, ancient threats seem to capture more error saccades. However, the saccades tend to deviate away from the modern threats.

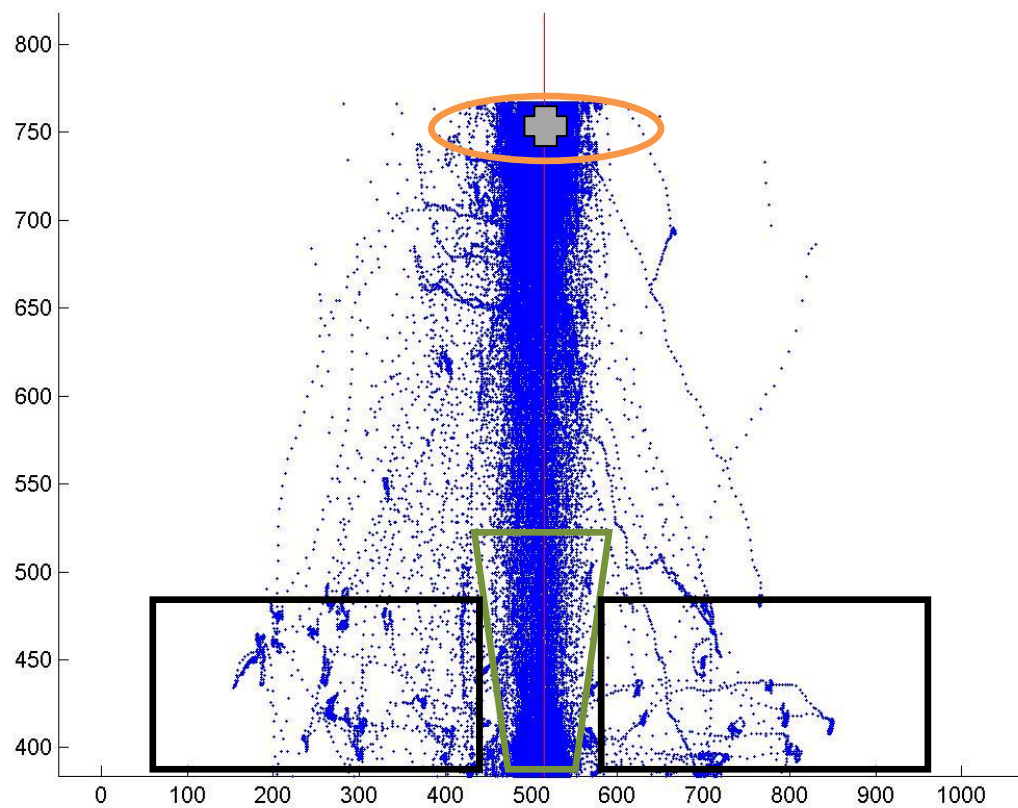


Left: Ancient

Right: Neutral

Orientation: Inverted

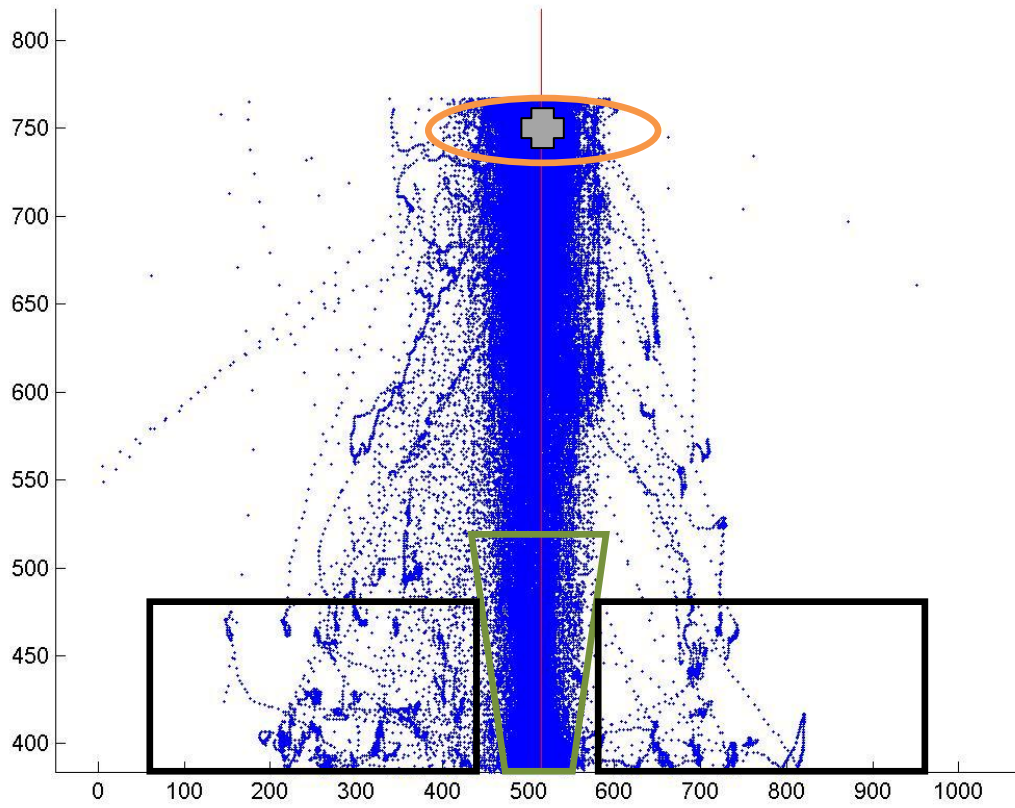
The ancient threats are capturing more error saccades than the neutral images.



Left: Modern

Right: Modern

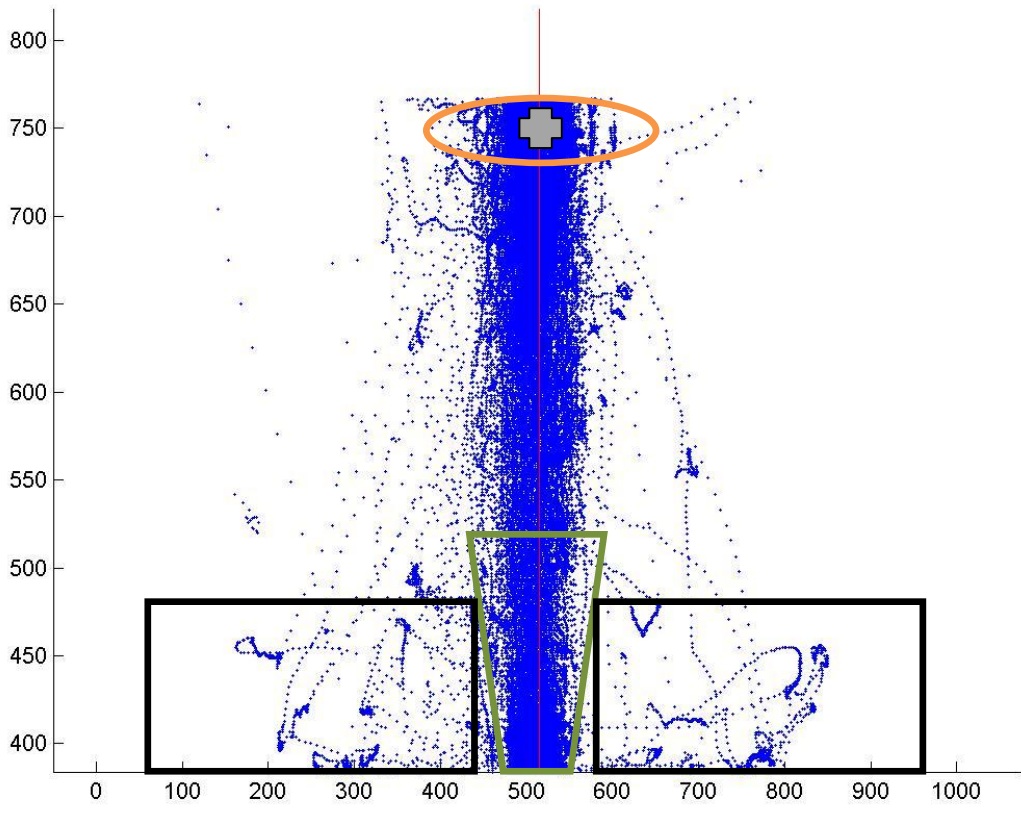
Orientation: Inverted



Left: Modern

Right: Neutral

Orientation: Inverted



Left: Neutral

Right: Neutral

Orientation: Inverted