Do infants find snakes aversive? Infants' physiological responses to "fear-relevant" stimuli

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ABSTRACT

In the current research, we sought to measure infants' physiological responses to snakes—one of the world's most widely feared stimuli—to examine whether they find snakes aversive or merely attention grabbing. Using a similar method to DeLoache and LoBue (*Developmental Science*, 2009, Vol. 12, pp. 201–207), 6- to 9-month-olds watched a series of multimodal (both auditory and visual) stimuli: a video of a snake (fear-relevant) or an elephant (non-fear-relevant) paired with either a fearful or happy auditory track. We measured physiological responses to the pairs of stimuli, including startle magnitude, latency to startle, and heart rate. Results suggest that snakes capture infants' attention; infants showed the fastest startle responses and lowest average heart rate to the snakes, especially when paired with a fearful voice. Unexpectedly, they also showed significantly *reduced* startle magnitude during this same snake video plus fearful voice combination. The results are discussed with respect to theoretical perspectives on fear acquisition.

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Introduction

Fear of snakes is one of the most common fears among human adults (Agras, Sylvester, & Oliveau, 1969; Curtis, Magee, Eaton, Wittchen, & Kessler, 1998; Depla, ten Have, van Balkom, & de Graaf, 2008).

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Because of its overrepresentation in clinical studies of common fears and phobias, researchers have speculated widely about the origins of snake fear. Many have proposed that snakes are part of a special class of evolutionary threats for humans and non-human primates and that snake fear is either innate and does not require specific learning (Poulton & Menzies, 2002) or it is privileged and is learned especially quickly (Öhman & Mineka, 2001; Seligman, 1971).

A large body of research with both human adults and non-human primates confirms that snakes are indeed a special class of stimuli. Rhesus monkeys, for example, quickly learn to fear snakes after watching a conspecific display snake fear. Crucially, this fear learning is selective, and monkeys do not learn to fear flowers or rabbits after watching a similar display (Mineka, Keir, & Price, 1980; Mineka, Davidson, Cook, & Keir, 1984). Likewise, adults more strongly associate photographs of snakes and spiders than flowers and mushrooms with an aversive electric shock, as evidenced by slower extinction to this pairing (Öhman, Fredrikson, Hugdahl, & Rimmo, 1976; for a review, see Öhman & Mineka, 2001). There is also evidence that snakes are privileged in visual attention; adults more quickly detect photographs of snakes and spiders than flowers and mushrooms (Öhman, Flykt, & Esteves, 2001).

More recent work lends further support for the idea that snakes are a special category of stimuli for humans, demonstrating that even infants and young children respond differentially to snakes than to other stimuli. First, preschool children, infants, and even monkeys show the same attentional bias for snakes that adults show and detect them more quickly than flowers, frogs, and caterpillars (LoBue & DeLoache, 2008, 2009; Shibasaki & Kawai, 2009). Second, infants more readily match the image of a snake with something fearful. For example, DeLoache and LoBue (2009) presented 7- to 16-month-olds with two videos side by side on a large screen—one snake and one non-snake (e.g., elephant, giraffe)—paired with an auditory track of either a happy or fearful voice. Infants looked longer at the snakes when listening to a fearful voice than when listening to a happy voice, suggesting that they found something natural about the combination of a snake with a fearful voice. They did not show differential responding to non-snakes as a function of the auditory stimuli. Similarly, Rakison (2009) reported that 11-month-old female infants—but not male infants—learned to associate images of snakes and spiders with fearful faces but not with happy faces. In contrast, when tested with images of nonthreatening stimuli such as flowers and mushrooms, infants did not make any associations between the stimuli and happy or fearful faces, suggesting that female 11-month-olds readily associate snakes and spiders with a fearful face.

Together, this developmental work has been interpreted as evidence in support of evolutionary perspectives about the origins of snake fear. But do the findings described above necessarily indicate that infants are *afraid* of snakes or that they find snakes aversive? A closer look at these data suggests that they do not. DeLoache and LoBue (2009) examined 9-month-olds' baseline responses to snake and non-snake animal videos and reported no differences in behavior; that is, infants showed equal looking time to both and made equal attempts to grasp for them. In fact, the 9-month-olds attempted to *pick up* moving snakes from the screen and showed no behavioral evidence of fear. Moreover, in a recent examination of 18- to 36-month-old children's approach and avoidance responses to live animals, researchers again reported no evidence that young children avoid a live snake and spider (LoBue, Bloom Pickard, Sherman, Axford, & DeLoache, 2013). In contrast, children demonstrated an avid interest in all of the live animals, an interest that was equal for nonthreatening animals (e.g., hamster, fish) and for threatening animals (e.g., snake, spider). This work suggests that snakes might be a special class of stimuli for infants and children but that this special status is related to heightened attention and is not necessarily indicative of fear or aversion (LoBue, 2013; LoBue & Rakison, 2013).

The current experiment was designed to further examine this issue by studying the physiological correlates of infants' behavioral responses to snakes, specifically by measuring heart rate and startle responses. Heart rate deceleration has been used as a measure of orienting or attention (Graham & Clifton, 1966), whereas heart rate acceleration has been used as an index of fear (Campos, Emde, Gaensbauer, & Henderson, 1975). Similarly, a facilitated startle response has been used to measure heightened attention called *attention-modulated startle* (Anthony & Graham, 1983, 1985), whereas others have interpreted facilitated startle responses as vigilance or "freezing"—a category of physiological reactions undergone by humans when confronted with threat—called *emotion-modulated startle* (Lang, Bradley, & Cuthbert, 1997).

Indeed, adults and infants as young as 5 months have a facilitated startle response when presented with negatively valenced stimuli as opposed to positively valenced stimuli (Balaban, 1995), and 9-month-old infants demonstrate a larger startle eye-blink response in response to evolutionarily fear-relevant sounds (e.g., snake hiss) when compared with pleasant sounds (e.g., baby laughing) or even modern fear-relevant sounds (e.g., bomb exploding) (Erlich, Lipp, & Slaughter, 2013).

Here, we sought to examine infants' physiological responding to various fear-relevant and fear-irrelevant stimuli. Using a similar method to DeLoache and LoBue (2009), we presented 6- to 9-month-olds with a series of multimodal (both auditory and visual) stimuli: a video of a snake (fear-relevant) or an elephant (non-fear-relevant) paired with either a fearful or happy auditory track. We measured physiological responses to the pairs of stimuli, including startle magnitude, latency to startle, and heart rate changes. If infants' responses to snakes are related to fearful or defensive responses to negative or threatening stimuli, infants should show higher heart rate and startle magnitude when watching a video of a snake or when listening to a fearful voice. In contrast, if infants' rapid responses to snakes and their propensity to match the image of a snake with a fearful voice reflect a more benign attentional bias, infants should demonstrate lower heart rate and possibly a more rapid startle response and higher startle magnitude to snakes versus non-snakes.

Method

Participants

Participants were 28 6- to 9-month-old infants (M = 7.8 months, range = 6.3–9.1). The sample was recruited from records of birth announcements in the local Charlottesville, Virginia, community in the eastern United States and was predominantly Caucasian and middle class. All infants completed at least half of the trials; therefore, no participants were eliminated from the analyses.

Visual and auditory stimuli

The visual stimuli were six snake and six elephant videos (each 6 s in duration) in which a snake slithered or an elephant walked horizontally from one side of the screen to the other against a natural landscape. The six elephant videos were taken from nature films, and the six snake videos were filmed by the authors and matched to the elephant videos for similar animal size and landscape color. The clips were controlled for consistency from start to finish, depicting the elephants or snakes moving at a constant pace throughout the 6-s presentation so that there were no significantly novel movements from one second to the next. Each video was paired with one of eight audio recordings featuring either a fearful or happy voice. The eight audio recordings were of the same two nonsense phrases consisting of sounds from Eastern European languages spoken by four men and four women. These recordings are validated for emotional content and have been used in several previous studies of adult perception of emotion (Banse & Scherer, 1996).

Visual startle probe

Startle responses are typically elicited by presenting infants with a visual or auditory stimulus and interrupting that stimulus with an aversive startle probe such as a bright flash of light or a burst of loud noise. The startle probe used here was a white video frame presented for approximately 50 ms embedded twice in each presentation block: once during the video/voice pair and once during the intertrial interval. We chose to present the probes 0 to 5 s after the onset of the foreground stimulus in an effort to measure infants' startle reactions while infants were still orienting (Richards & Casey, 1992) but before they had entered a state of sustained attention, which is typically characterized by a different set of behaviors (Posner & Rothbart, 2007). Two probes were presented at different time points in order to reduce habituation from trial to trial. For half of the trials, the first probe was presented 3 s after video onset. For the other half, the first probe was presented 4.5 s after video onset. The second probe was presented during the intertrial interval at random time intervals following

video offset. Because the startle probes during the intertrial interval provided a greater contrast in stimulus level between foreground and probe (e.g., watching a black screen and seeing a flash of light) than during experimental conditions (e.g., watching a bright animal video and seeing a flash of light), startle amplitudes during the intertrial intervals were anticipated to be higher than those during experimental tasks regardless of attention levels. This will likely differ from several studies on visual attention that report greater startle amplitudes during attention-engaging foregrounds compared with the no-stimulus intertrial intervals (e.g., Richards, 2000).

Apparatus

The stimuli were presented using DMDX presentation software (Forster & Forster, 2003). Videos were projected onto an 80 by 110-cm screen area approximately 110 cm from the infant. The projected visual startle probe filled the white screen, and the size of the video projection was 55 by 40 cm. The videos were presented at a frame rate of 15 frames per second, and the monitor refresh rate was set at 60 Hz. The voices came from two speakers located behind the screen. A video camera situated below the screen filmed the infant's head and eyes throughout the procedure. All 12 films were presented twice: once with a fearful voice and once with a happy voice. They were preceded by a 6-s attention-getter (either a flashing dot or a dynamic baby face paired with ringing bells) to focus the infant's attention to the center of the screen prior to video onset. Each video was followed by an 8-s intertrial interval that consisted of a black screen with a small flashing plus sign to encourage the infant to continue looking. DMDX presented the blocks of attention-getter, video/voice pair, and intertrial interval in a random order for a total of 24 trials.

Physiological measures

Startle eye blink responses were assessed by measuring electromyographic (EMG) activity of the orbicularis oculi through two Ag/AgCl miniature electrodes attached under the infant's left eye. Electrocardiogram (EKG) was recorded from two electrodes attached to the left and right sides of the infant's upper back and a ground electrode attached to the center of the infant's lower back.

Procedure

On entering the lab, an experimenter cleaned and abraded the area under the infant's left eye and attached all five electrodes to the infant's body. The infant was then seated on a parent's lap in front of the screen in a darkened room. The parent was blindfolded in order to control for the parent's own visual startle reaction that could influence the reaction of the child. Once set up, the experimenter closed the door and manually began the presentation. From this point, DMDX controlled the presentation of trials automatically. During the stimulus presentation, the participant was monitored through an auditory headset that allowed the experimenter to listen and communicate with the parent if necessary.

Startle quantification

Signal processing was conducted using Neuroscan's Edit software. The signal was amplified at 2010 AC, digitized at 1000 Hz, and filtered online with a digital 60-Hz notch filter. It was then smoothed and filtered offline (bandpass = 80–240 Hz). For each probe presented, startle amplitude was calculated by subtracting the peak amplitude during the 50 ms prior to startle probe onset (baseline) from the peak amplitude during the 30- to 350-ms period following startle probe onset to yield a difference score. Startle latency (latency to peak startle) and magnitude (the average amplitude of all trials) were calculated for each condition. To control for individual differences in startle amplitudes, microvolt (μV) values during all four conditions were standardized by dividing the startle amplitude of each trial by that participant's average startle magnitude during the no-stimulus intertrial intervals, yielding a *proportion change score* for startle amplitude.

Heart rate quantification

Heart rate signal was first filtered online using a digital 60-Hz notch filter. Afterward, QRSTool (Allen, Chambers, & Towers, 2007) was used to calculate the average inter-beat intervals (IBIs) during each 6-s video and 8-s intertrial interval for each participant. IBIs were then used to calculate heart rate. A proportion change score for heart rate was calculated by dividing the average heart rate of each trial by that participant's average heart rate during the no-stimulus intertrial intervals. The proportion change score allowed standardization of heart rate changes across conditions.

Assessment of looking time

Pre-probe, post-probe, and full-trial looking times were assessed using the Supercoder program (Hollich, 2005) and the video recordings by coders blind to the conditions. Supercoder enables one to code looking time frame by frame, allowing for very accurate coding at 30 frames per second. The primary coder coded looking time for all participants, and a second coder coded one fourth of the participants' looking times. Reliability was 96%.

Results

Linear mixed models were used to assess the main effects of animal (snake vs. elephant), voice (happy vs. fearful), and the animal by voice interaction across repeated measurements of proportion change scores for startle magnitude, latency, and heart rate. Trials were excluded from the analyses (222 total trials; 33% of data) if (a) the infant was not attending to the video during startle probe onset, (b) the infant was not attending to the video for at least 1 s prior to startle probe onset, (c) there was excessive noise in the EMG signal during the 50 ms prior to startle probe onset, or (d) there was excessive noise in EMG or heart rate signal throughout the entire trial segment.
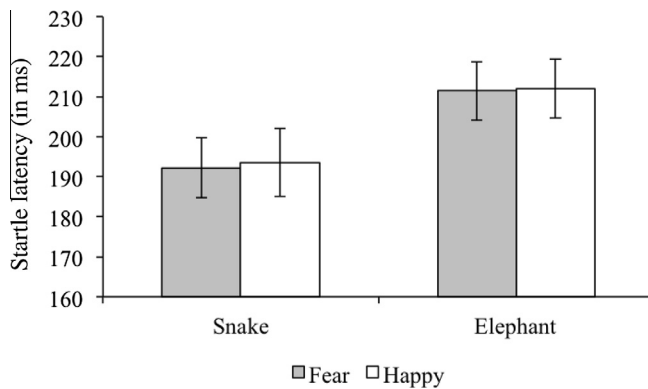
For proportion change scores in startle magnitude, there was a main effect of animal (snake vs. elephant), $F(1, 252) = 5.02$, $p = .026$, with a lower startle magnitude for snake films ($M = .94$, $SE = .10$) than for elephant films ($M = 1.03$, $SE = .09$). There was also a significant animal by voice interaction, $F(1, 252) = 4.96$, $p = .027$, indicating that the startle magnitude for the snake films during the fearful voice ($M = 0.88$, $SE = 0.16$) was lower than that for all other conditions. More specifically, startle magnitude for snakes ($M = 0.88$, $SE = 0.16$) was significantly lower than that for elephants ($M = 1.05$, $SE = 0.13$), $F(1, 131) = 11.81$, $p < .0001$, during the fearful voice; there was no significant difference in startle magnitude for snakes ($M = 1.01$, $SE = 0.13$) versus elephants ($M = 1.00$, $SE = 0.13$) during the happy voice, $F(1, 147) = 0.00$, $p = 1.00$. Furthermore, startle magnitude was significantly lower for snakes during the fearful voice ($M = 0.88$, $SE = 0.16$) than during the happy voice
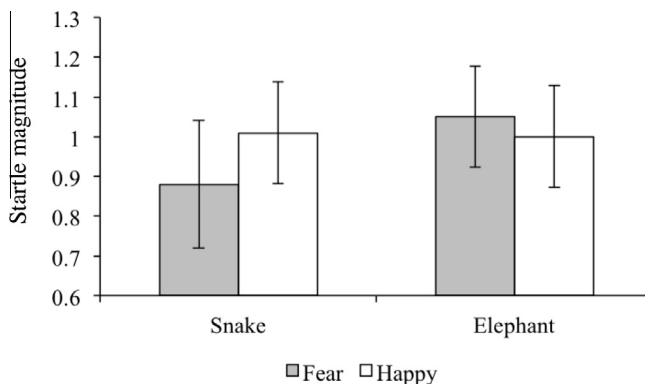
Fig. 1. Proportion change scores (trial amplitude in μV divided by the average amplitude during the baseline intertrial interval for that subject) in startle magnitude for each condition.
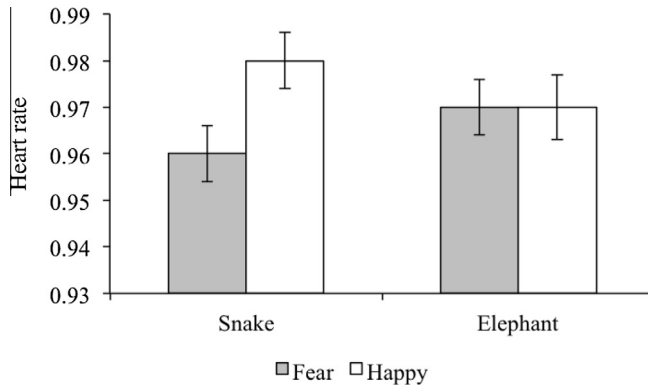
Fig. 2. Proportion change scores (average heart rate during trial divided by the average heart rate during the baseline intertrial interval for that subject) in heart rate (in beats per second) for each condition.

Fig. 3. Startle latency (in ms) for each condition.

($M = 1.01$, $SE = 0.13$), $F(1,98) = 4.90$, $p = .029$; it was not significantly different for elephants based on voice condition, $F(1,157) = 1.07$, $p = .302$ (see Fig. 1).

For proportion change scores for heart rate, there were no significant main effects, but there was a significant animal by voice interaction, $F(1,383) = 6.29$, $p = .013$ (see Fig. 2). Decomposition of this interaction revealed that heart rate was significantly lower for the snakes during the fearful voice ($M = .96$, $SD = .006$) than during the happy voice ($M = .98$, $SD = .006$), $F(1,213) = 6.13$, $p = .014$; there was no significant difference in heart rate change for the elephant videos during the fearful voice ($M = .97$, $SD = .006$) versus the happy voice ($M = .97$, $SD = .007$), $F(1,171) = 1.04$, $p = .307$.

Finally, for startle latency, there was only a significant main effect of animal film, $F(1,400) = 9.61$, $p = .002$ (see Fig. 3); startle latency for snake films ($M = 192.9$, $SE = 5.6$) was significantly shorter than that for elephant films ($M = 211.7$, $SE = 5.2$).

Discussion

The goal of the current research was to examine the physiological correlations to infants' responses to snakes to elucidate whether there is any evidence that infants find snakes aversive or fearful or whether their bias for snakes is more likely attentional. The results support the latter; infants demonstrated the lowest heart rate when viewing snakes paired with a fearful voice. Furthermore, infants startled more quickly when viewing snakes versus non-snakes, but the magnitude of the startle

was, surprisingly, *lower* for snakes (especially when paired with a fearful voice) than for other conditions. This provides evidence consistent with previous work by DeLoache and LoBue (2009) showing heightened attention to videos of snakes when paired with a fearful voice because lower heart rate is generally indicative of heightened attention or an orienting response. It is also consistent with previous work showing that infants more rapidly detect snakes because infants were startled more quickly to the snake versus non-snake videos (LoBue & DeLoache, 2009). However, the results do not provide support for the contention that infants are necessarily afraid of snakes or find them aversive; they did not demonstrate accelerated heart rate or a larger startle magnitude for snakes and/or fearful voices.

The results presented here are partially consistent with those of Erlich and colleagues (2013), who also measured infants' physiological responses to stimuli that are hypothesized to constitute evolutionary threat such as snakes. Erlich and colleagues reported lower heart rate in 9-month-olds listening to evolutionarily threat-relevant sounds (e.g., a snake hiss) when compared with pleasant sounds (e.g., baby laughing) or even modern threat-relevant sounds (e.g., bomb exploding). However, whereas we report a lower startle magnitude for the combination of a threat-relevant video (snake) and sound (fearful voice), Erlich and colleagues reported a higher startle magnitude for threat-relevant sounds. It is unclear why the two studies have produced this inconsistent finding, but differences in the stimuli used (auditory vs. multimodal) and the modality of the startle probe (auditory vs. visual) might account for them. Future research examining infants' physiological responses to stimuli that adults find aversive might help to explain these differences.

Aside from stimulus and probe modality, there are two additional differences between this study and previous infant startle reflex studies that may account for the differing results. First, in previous research using similar methods, there was a large amount of attrition due to fussiness, lack of attention, or failure to startle (e.g., Balaban, 1995; Erlich et al., 2013). Here, we retained data from all participants tested and reduced noise in the data by eliminating particular trials instead of particular infants. This might account for the reduced startle effect because there was no biased selection for strongly orienting or startle-sensitive infants. Second, in previous studies, infants were generally seated alone in a high chair during stimuli presentation with a parent sitting to the side; in the current study, infants sat on their parents' laps. It is possible that the reduced startle response was an expression of an ongoing physical regulation process occurring between infant and caregiver during the study (Beckes & Coan, 2011). Further research can examine these possibilities.

The current results do not support a nonassociative view of fear acquisition, which proposes that fear of snakes and other evolutionarily relevant stimuli are innate (Poulton & Menzies, 2002). However, they do support previous research suggesting that snakes are indeed a special class of stimuli for humans. The prepared learning view of fear acquisition proposes that snake fear is not innate but rather learned very quickly (Öhman & Mineka, 2001; Seligman, 1971). To explain how such fears are learned so fast, Davey (2002) argued that evolutionary threats such as snakes, spiders, heights, water, and enclosed spaces might cause specific bodily sensations, and it is the misinterpretation of these sensations that leads to the heightened prevalence of such fears. Similarly, others have suggested that heightened attention to snakes might be the mechanism that makes snake fears easy to learn if given the opportunity (LoBue, 2013; LoBue & Rakison, 2013). According to both of these perspectives, the mechanism that ensures that stimuli like snakes are the most likely to become fear relevant is bodily or perceptual. Thus, although the current findings do not support the idea that infants are afraid of snakes or find them aversive, they do support previous work suggesting that snakes are privileged in human attention, which could potentially play an important role in later fear learning.

Although previous research has provided behavioral evidence that snakes and other threatening stimuli (e.g., spiders, angry faces) are privileged in human attention, it is important to examine infants' physiological responses to these stimuli as well—a topic that until recently was left untouched (Erlich et al., 2013). However, physiological measures carry some limitations with them as well. First, interpreting heart rate data can be difficult and somewhat controversial. Lowered heart rate has generally been used as an index of interest or orienting, and heart rate acceleration has been used as an index of fear. However, heart rate deceleration has also been shown to accompany heightened startle magnitude in response to threatening stimuli (Cook & Turpin, 1997; Erlich et al., 2013). Furthermore, heart rate changes have been associated with other feelings and situations unrelated to fear (Kagan, 1984), and in general research has found little evidence that behavioral and physiological measures of

emotion are correlated (Barrett, 2006; Coan, 2010), suggesting that there is not a clear or straightforward way in which to interpret heart rate data.

Interpreting startle magnitude can be equally difficult, especially with infants. Previous research has shown that presenting adults with an aversive stimulus primes a defense pathway and augments startle responses, and presenting adults with a pleasant stimulus primes different motivational pathways and causes startle inhibition. Thus, when presented with threatening stimuli, adults tend to orient more quickly to the potential threat and exhibit elevated startle magnitude (Cook & Turpin, 1997). Although Balaban (1995) reported that, like adults, 5-month-old infants show a facilitated startle response when presented with negative stimuli as opposed to positive stimuli, there is little empirical support from other studies suggesting that infants' sensory systems are mature enough to experience adult-like emotionally specific startle modulation. Furthermore, Balaban noted that her findings might have resulted from a sensory selective startle modulation where infants were orienting away from the aversive angry face and toward other modalities. This explanation is supported by research showing that whereas infants tend to visually orient away from angry faces (Grossmann, Striano, & Friederici, 2007; Schwartz, Izard, & Ansul, 1985), they also show event-related potential (ERP) responses with a larger negative component (Nc) at fronto-central leads, suggesting that they allocate more attentional resources to angry faces despite orienting away from them (Kobiella, Grossmann, Reid, & Striano, 2008).

One final issue with studying heart rate and startle magnitude in the context of emotion is that they are difficult to interpret individually outside the context of a larger suite of behaviors generally associated with a single emotional response. Lang, Davis, and Öhman (2000) suggested that heart rate change, startle potentiation, orienting, and fear are all involved in a multifaceted defense cascade. In this cascade, an initial encounter with a remote potential threat might elicit an initial orienting response including heart rate deceleration, whereas an encounter with a more imminent threat that requires immediate action might activate later stages of the defense cascade, characterized by startle potentiation and a rising heart rate. The exact nature of infant startle modulation to threat stimuli is still unknown, and future research is needed to explore this important issue.

Taken together, the work presented here supports previous work suggesting that infants are highly attentive to snakes (especially when paired with a fearful voice) and respond to them differentially when compared with other stimuli (DeLoache & LoBue, 2009; LoBue & DeLoache, 2009; Rakison, 2009). However, there was no evidence to suggest that snakes are aversive or fear relevant for infants at this early stage in development. Research on infants' behavioral and physiological responses is still very limited, and future work is needed in order to elucidate how to best interpret infants' responses to snake and other threatening stimuli.

Acknowledgments

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