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PAPER

Superior detection of threat-relevant stimuli in infancy

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Abstract

The ability to quickly detect potential threat is an important survival mechanism for humans and other animals. Past research has established that adults have an attentional bias for the detection of threat-relevant stimuli, including snakes and spiders as well as angry human faces. Recent studies have documented that preschool children also detect the presence of threatening stimuli more quickly than various non-threatening stimuli. Here we report the first evidence that this attentional bias is present even in infancy. In two experiments, 8- to 14-month-old infants responded more rapidly to snakes than to flowers and more rapidly to angry than to happy faces. These data provide the first evidence of enhanced visual detection of threat-relevant stimuli in infants and hence offer especially strong support for the existence of a general bias for the detection of threat in humans.

Introduction

Reacting defensively in threatening situations has been important for survival throughout our evolutionary history. Individuals who acted quickly when faced with threat would have been more likely to survive than those who were slow to respond. Consequently, according to the prepared learning view, humans and non-human primates evolved an innate predisposition to quickly associate fear with certain classes of threats, such as poisonous snakes and spiders, that were widespread throughout human evolution (Seligman, 1970; Ohman & Mineka, 2001).

The strongest evidence in favor of this view comes from research with non-human primates (Cook & Mineka, 1987, 1989). In one study, lab-reared rhesus monkeys, who previously showed no fear of snakes, observed a wild-reared monkey react with fear to a snake. Simply from observing a conspecific's fearful behavior, the monkeys very rapidly developed an intense, long-lasting fear of snakes themselves (Cook & Mineka, 1987). Further, the vicarious acquisition of this fear was *selective*: When shown a video of a monkey reacting fearfully to a rabbit, a new group of monkeys did not acquire a fear of rabbits (Cook & Mineka, 1989).

There is also empirical support for the prepared learning view in human adults. In a series of Pavlovian fear-conditioning studies with adult humans, conditioned skin conductance responses (SCR) – a measure of emotional activation – were more resistant to extinction when evolutionarily fear-relevant stimuli, including snakes and spiders, serve as the CS than when the CS is not fear-relevant (e.g. flowers and mushrooms). (See Ohman & Mineka, 2001, for a review.)

In a related vein, it has also been proposed that because of the survival advantage of responding rapidly to potential danger, the human visual system gives priority to stimuli that represented recurrent and widespread threat throughout the course of evolution (Isbell, 2006). In other words, we may be biased to detect evolutionarily threat-relevant stimuli very quickly (Ohman, 1993; Ohman, Flykt & Esteves, 2001). Support for this view comes from research with two different categories of stimuli – threatening animals (snakes and spiders) and threatening facial expressions (angry faces). Ohman and his colleagues (Ohman, Flykt & Esteves, 2001) first demonstrated a bias in adults' detection of snakes and spiders. They presented participants with matrices consisting of pictures of snakes or spiders (fear-relevant) and flowers or mushrooms (fear-irrelevant). For each matrix, one of the two types of stimuli was designated as the target, and participants had to decide as quickly as possible whether or not a single target was present. They reliably detected the presence of a snake or spider target among flowers or mushrooms more quickly than a flower or mushroom target among snakes or spiders. This basic finding has been replicated by several investigators (e.g. Blanchette, 2006; Brosch & Sharma, 2005; Flykt, 2005; Lipp, Derakshan, Waters & Logies, 2004; LoBue & DeLoache, 2008; Waters, Lipp & Spence, 2004).

Facial expressions that signify threat are also detected especially rapidly. Using the visual search paradigm described above, researchers have consistently found faster detection of angry schematic faces than happy ones (Calvo, Avero & Lundqvist, 2006; Esteves, 1999; Fox, Lester, Russo, Bowles, Pichler & Dutton, 2000; Lundqvist & Ohman, 2005; Mather &

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Knight, 2006; Ohman, Lundqvist & Esteves, 2001; Schubo, Gendolla, Meinecke & Abele, 2006). The same pattern of particularly rapid responding to threatening facial expressions has been found for anxious participants (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van Ijzendoorn, 2007). Further, even adults with Autism and Asperger Syndrome (neurodevelopmental conditions that are characterized by many deficits including abnormal face processing) respond to angry schematic faces more quickly than to happy ones (Ashwin, Wheelwright & Baron-Cohen, 2006).

Although this research provides important evidence that humans are biased to quickly detect the presence of threat, adults have a lifetime of experience and knowledge about snakes and threatening faces. If humans have an evolved predisposition to quickly detect threat, evidence of such a propensity should be found regardless of the amount of experience individuals have had with threat-relevant stimuli.

Recently, LoBue and DeLoache (2008) investigated the visual detection of threat in young children. In three experiments, a modified visual search paradigm was used in which preschool children and adults were shown a single target stimulus among eight distracters on a touchscreen monitor and were asked to find the target and touch it as quickly as possible. Both the adults and the 3- to 5-year-old children detected snakes faster than three categories of non-threatening stimuli – flowers, frogs, and caterpillars. Further, using the same procedure, LoBue (2009) found that 5-year-old children and adults also detect the presence of both angry and fearful faces more quickly than happy and sad faces. This research was the first to establish that young children share adults' propensity to rapidly detect evolutionarily threat-relevant stimuli, and it is consistent with the existence of an inborn bias to detect threat. However, the *strongest* test of such a bias would come from research with infants who have even less experience than preschool children with threatening facial expressions and likely *no* experience with snakes.

DeLoache and LoBue (2008) have already found evidence that infants between 7 and 9 months and between 14 and 18 months orient more quickly to films of snakes than a variety of other animals. Further, Rakison and Derringer (2008) recently reported that 5-month-old infants looked longer at pictures of schematic spiders than at representations of spiders with their features scrambled. By comparison, the infants did not show a preference for schematic pictures of non-threat-relevant stimuli, such as flowers. Based on these results, the researchers proposed that infants may have an innate perceptual representation of spiders that underlies their preferential orientation to them.

Although this research suggests that infants may have a tendency to preferentially orient to threat-relevant stimuli, the question of whether infants detect these stimuli particularly quickly has never been examined directly. Accordingly, the goal of the current research was to directly examine the detection of threat-relevant stimuli in 8- to 14-month-old infants. If 7- to 9- and 14- to 18-month-olds orient quickly to snakes, as reported by DeLoache and LoBue (2008), presumably the same should be true for all infants. A procedure analogous to the visual search paradigm used with preschool children by LoBue and DeLoache (2008) and LoBue (2009) was adopted. Infants saw pairs of pictures presented side by side on a screen – one threat-relevant and the other non-threat-relevant. For each trial, the variable of primary interest was how quickly the infants turned to look at the two types of pictures. Based on previous visual search research, if threat-relevant stimuli attract attention more quickly than non-threat-relevant stimuli, infants might turn to look at the threatening target stimuli more quickly than the non-threatening ones.

General method

Participants

Participants were 96 (48 in each experiment) 8- to 14-month-old infants (m = 10.6 mos, r = 8.2–14.0 mos), half male and half female.[1] All children were recruited from records of birth announcements in the local community. The sample was predominantly Caucasian and middle class. An equal number of boys and girls were assigned to one of two stimulus presentation orders. An additional four participants were excluded because of fussiness.

Materials

The stimuli for Experiment 1 were 12 brightly colored photographs of snakes, frogs, and flowers used in LoBue and DeLoache (2008). The stimuli for Experiment 2, which were used in LoBue (2009), were 12 color photographs of angry, fearful, and happy faces from the NimStim face set from the MacArthur Foundation Research Network on Early Experience and Brain Development. Equal numbers of male and female faces were used.

A Sony LCD Projector was used to present the images on a 91.4 cm by 121.9 cm white screen. The projected images measured 29.2 × 40.0 cm. A video camera sat on the table behind the screen and filmed the infant through a small hole cut near the bottom of the screen. The projector was positioned opposite the screen and was connected to an Apple Computer in an adjoining room. A 33.0 cm television monitor was connected to the video camera so that the experimenter could monitor the infants' looking behavior during the experiment.

[1] Forty-eight participants were tested Experiment 1 and a second set of 48 participants were tested in Experiment 1a. The same participants tested in Experiment 1 were tested in Experiment 2, and the same participants tested in Experiment 1a were tested in Experiment 2a. Participants in Experiments 1 and 2 received 12 trials for each experiment. The order with which they saw the stimuli was counterbalanced. The same was true for the participants in Experiments 1a and 2a.

Procedure

Each infant was seated on a parent's lap approximately 91.4 cm from the screen. The parent was blindfolded to avoid giving the child any cues. The stimuli were presented using PowerPoint. In each study, the 12 pictures from the relevant two target categories were randomly arranged in pairs. Each pair of photos was presented side by side for 4 seconds, with the side on which each stimulus category appeared counterbalanced over trials. A random order was created, with a second order created by reversing the first. Before each test trial, an attention-getting device (a green dot with a 'ding' sound) attracted the infant's attention to the center of the screen. From an adjoining room, the experimenter manually began each trial when the infant's gaze was focused on the attention-getter, but each trial ended automatically 4 seconds after the infant first looked at it.

Coding

Looking time for each infant was coded using the Supercoder program designed by Hollich, Rocroi, Hirsh-Pasek and Golinkoff (1999). The videos showed only the infants' faces without any images of the stimuli, so all coding was blind. For each trial, the coder recorded the beginning and end of the trial and the beginning and end of each look to each stimulus within the trial. This allowed for the examination of two variables of interest: (1) Latency – the total amount of time from the onset of each trial to the infant's first look, and (2) Looking Time – total looking time to each picture per trial. We also recorded the total number of first looks to each picture over trials. A second coder randomly selected 25% of the participants and coded their looking time for reliability. Reliability was 93%.

Analyses

To see if there were any age differences in the infants' behavior toward the stimuli, the infants were divided into three groups: 8- and 9-month-olds, 10- and 11-month-olds, and 12-, 13-, and 14-month-olds. Preliminary analyses for all experiments revealed no effects of order or gender, so these variables were not included in any of the analyses. For both experiments, extreme outliers were identified in the latency data and were removed from the analyses.[2]

[2] Data points were conservatively identified as outliers only if they were 3 times the interquartile range outside of the interquartile range (Cohen, Cohen, West & Aiken, 2003) and were more than three standard deviations above or below the mean. Of the 576 potential data points in each experiment, seven data points were identified and eliminated from Experiment 1, 23 from Experiment 1a, two from Experiment 2, and nine from Experiment 2a.

Experiment 1: Snakes versus flowers

Previous research using the touchscreen procedure described above has established that both adults and preschool children detect the presence of snakes faster than flowers (LoBue & DeLoache, 2008). Flowers were used as the comparison stimuli, because the original studies by Ohman and colleagues with adults used brightly colored snakes and flowers. Experiment 1 examined how quickly infants would turn to look at snakes versus flowers.

Results and discussion

Latency

The question of primary interest concerned latency – specifically, whether the infants would turn to look at the snakes more quickly than at the flowers. A 2 (stimulus: snakes versus flowers) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA was performed on the latency of first looks (the time from when the infant looked away from the center light to the first fixation of one of the pictures).[3] The most important result was a significant effect of stimulus, $F(1, 515) = 3.91$, $p < .05$. As predicted, the infants turned more quickly toward the snakes than the flowers. Thus, these infants exhibited the same pattern of responding with respect to snakes and flowers as adults and preschool children have done in previous studies (LoBue & DeLoache, 2008). The current result provides evidence that rapid orientation to snakes does not depend on prior experience with snakes.

There were also significant main effects of trial, $F(1, 515) = 5.04$, $p < .05$, and side, $F(1, 515) = 21.31$, $p < .05$. The infants turned more rapidly on earlier than on later trials, suggesting a general habituation effect with repeated exposure to stimuli from the same categories. In addition, the infants turned more quickly to the pictures on the left side of the screen than to those on the right side. While it is unclear why this difference was found, it has been reported in previous research (e.g. Cohen, 1972; Guo, Hall, Hall, Meints & Mills, 2007).

[3] Mixed effects ANOVAs were used for all analyses presented here. Mixed effects ANOVAS have several advantages over standard repeated-measures ANOVAs, the most important of which is that they use all of the data, and that the analyses account for missing data (Bagiella, Sloan & Heitjan, 2000; Gueorguieva & Krystal, 2004). Because every data point was used (48 participants × 12 trials per participant × 2 possible data points per trial results in a maximum of 1152 data points for analysis on overall looking time, and 576 data points per analysis on latency to look), the degrees of freedom for each analysis was rather large, and varied based on missing data (trials in which the infants did not look at the screen at all or looked at only one of the two pictures).

First looks

The infants looked to the snakes first 47% of the time, and to the flowers 53% of the time. Neither of these percentages differs from chance.

Looking time

Although an advantage in detection (latency) was predicted for snakes, there was no reason to expect a difference in overall looking time to snakes versus flowers, and none was found. A 2 (stimulus: snakes versus flowers) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA on total looking time revealed significant effects of side, $F(1, 1096) = 4.93$, $p < .05$, and trial, $F(1, 1096) = 15.93$, $p < .05$, but no significant effect of stimulus, $F(1, 1096) = 2.08$, *ns*. The infants looked longer at pictures presented on the right side of the screen than on the left, a common bias in infant research (e.g. MacKain, Studdert-Kennedy, Spieker & Stern, 1983; Patterson & Werker, 1999; Walker, 1982). The significant effect of trial reflected the fact that the infants looked less overall over trials, indicating general habituation as the session progressed.

Experiment 1a: Snakes versus frogs

The results of Experiment 1 supported the hypothesis that infants, like adults and young children, would respond more rapidly to snakes than to non-threatening stimuli (flowers), providing evidence of superior detection of threat-relevant stimuli very early in life. In Experiment 1a, we compared infants' detection of snakes versus frogs. Although the two types of picture stimuli were very similar in color and texture, preschool children detect snakes more quickly than frogs (LoBue & DeLoache, 2008). Would infants do the same?

Results and discussion

Latency

To determine whether snakes capture attention more quickly than frogs, the latency of the infants' first looks was examined in a 2 (stimulus: snakes versus frogs) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA. There was a significant effect of side, $F(1, 786) = 12.95$, $p < .05$, and trial, $F(1, 786) = 4.64$, $p < .05$, but no significant effect of stimulus. The infants turned slightly but not significantly more quickly to the snakes than to the frogs.

The images of the snakes and the frogs in this study were very closely matched for color, texture, and background, so it is possible that the infants had trouble discriminating between them in the periphery. In fact, as shown in Figure 1, the overall latencies in Experiment 1a were longer than those in Experiment 1, supporting this suggestion. The same was true for the adults and children in LoBue and DeLoache (2008): The difference in the latency for detection of snakes versus frogs was larger than that for snakes versus flowers. Thus, overall, it took longer for the children to find snake targets among multiple frogs than among flowers.

First looks

There was no difference in how frequently the infants looked to the snakes first (48% of the time) versus the frogs (52%).

Looking time

As expected, there was no difference in overall looking time to snakes versus frogs in a 2 (stimulus: snakes versus frogs) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA on total looking time. There were, however, significant effects for side, $F(1, 1675) = 14.89$,

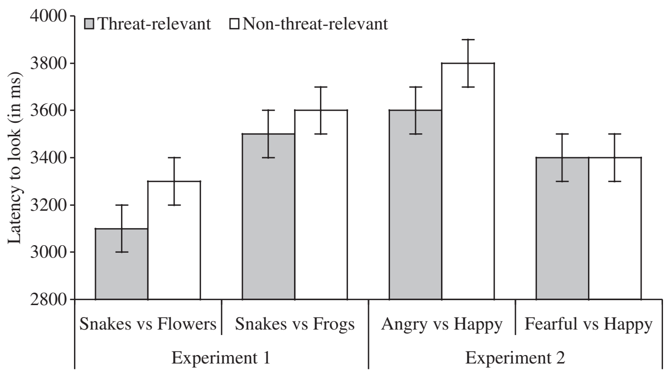

Figure 1 *Latencies to look at the target stimuli in each experiment. In Experiment 1, infants turned more quickly to look at snakes than at both flowers and frogs. In Experiment 2, infants turned more quickly to look at the angry than at the happy faces, but there were no differences between fearful and happy faces.*

$p < .05$, and trial, $F(1, 1675) = 59.57$, $p < .05$ (as in the previous experiment).

In summary, Experiment 1 demonstrated that snakes capture infants' attention more rapidly than flowers, and in Experiment 1a there was a slight (non-significant) bias towards more rapid detection of snakes than frogs. This is the first research suggesting that, like adults and preschool children, infants demonstrate a bias for the rapid detection of snakes. More generally, these findings are consistent with the existence of an inborn bias for the detection of threat-relevant stimuli.

Experiment 2: Angry versus happy faces

It is well established that adults detect threatening facial expressions (especially anger) particularly quickly (Calvo *et al*., 2006; Esteves, 1999; Fox *et al*., 2000; LoBue, 2009; Lundqvist & Ohman, 2005; Mather & Knight, 2006; Ohman, Lundqvist & Esteves, 2001; Schubo *et al*., 2006). LoBue (2009) recently showed the same pattern of response for preschool children. Here we ask whether infants would also detect angry faces more quickly than happy faces.

Results and discussion

Latency

The question of interest is whether angry (threatening) faces would capture infants' attention more quickly than happy (non-threatening) faces. According to a 2 (stimulus: angry versus happy) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA on the latency of first looks, the main effect of stimulus was significant, $F(1, 804) = 7.50$, $p < .05$. There was also a significant effect of side $F(1, 804) = 11.10$, $p < .05$. The significant main effect of stimulus indicates that, as predicted, the infants turned more quickly toward the angry than the happy faces. Thus, these infants exhibited the same pattern of responding with respect to angry and happy faces that adults and preschool children have shown in previous research (LoBue, 2009).

First looks

The infants turned first to the angry faces 52% of the time and to the happy faces 48% of the time. Neither of these percentages differs from chance.

Looking time

Again, there was no reason to predict a difference in overall looking time to angry versus happy faces, and none was found. In a 2 (stimulus: angry versus happy) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA on total looking time to each image per trial, there were significant effects of side, $F(1, 1675) = 61.31$, $p < .05$, and trial, $F(1, 1675) = 10.00$, $p < .05$, but no significant effect of stimulus, $F(1, 1572) = 0.04$, *ns*.

Experiment 2 thus demonstrated that infants detect angry faces more quickly than happy faces, providing strong support for a very early bias in the detection of threatening facial expressions. Would the bias for the rapid detection of fearful faces that has recently been established for children (LoBue, 2009) also be present in infancy?

Experiment 2a: Fearful versus happy faces

Although an angry face is a *direct* sign of threat, a fearful face can offer *indirect* evidence of the presence of something threatening (Whalen, Shin, McInerney, Fischer, Wright & Rauch, 2001). Thus, a predisposition to detect threat-relevant facial expressions might extend to fearful expressions and be observable in infancy. Experiment 2a examined how quickly infants turn to look at fearful versus happy faces.

In the previous experiments, there was no reason to expect a difference in overall looking time between the threat-relevant and non-threat-relevant stimuli. However, in the current study, there was good reason to expect that infants would look longer at fearful faces than happy ones. Kotsoni, de Haan and Johnson (2001) reported that 7-month-old infants look longer at fearful faces than happy faces, a result interpreted as 'vigilance' to fearful faces because of their threat-relevance. Thus, we expected that the infants in the current experiment might also look longer overall at the fearful than at the happy faces.

Results and discussion

Latency

According to a 2 (face: fearful versus happy) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA on the latency of first looks, the only significant effect was for trial, $F(1, 512) = 8.78$, $p < .05$. Thus, the infants did not turn more quickly to the fearful faces than to the happy faces.

First looks

The infants looked to the fearful faces first 51% of the time, and to the happy faces 49% of the time – obviously not different from chance.

Looking time

In a 2 (stimulus: fearful versus happy) by 2 (side: left and right) by 3 (age) by 12 (trial) mixed effects ANOVA on total looking time, there was a significant main effect of stimulus, $F(1, 1099) = 7.58$, $p < .05$, reflecting longer looking at the fearful faces than at the happy faces. There was also a significant effect of trial, $F(1, 1099) = 10.70$, $p < .05$.

In summary, the latency results for Experiments 2 and 2a indicate that angry – but not fearful – faces capture infants' attention more rapidly than happy faces.

General discussion

The experiments reported here provide the first evidence of which we are aware for a bias in the detection of evolutionarily relevant threat stimuli in the first year of life. The results of these four studies establish that infants orient more quickly to snakes than flowers and to angry faces more quickly than happy ones. Thus, two categories of threat-relevant stimuli recruit visual attention more readily than do non-threat-relevant stimuli even in the first year of life.

The current findings are consistent with previous research indicating that both adults and preschool children detect snakes and threatening facial expressions more quickly than several types of non-threatening stimuli (LoBue & DeLoache, 2008; LoBue, 2009). The fact that three very different age groups – infants, young children, and adults – all demonstrate the same propensity for the rapid detection of threat-relevant stimuli is remarkable; such a similar pattern of behavior over such a wide age range is relatively rare. These developmental findings thus offer strong support for the existence of a general predisposition in humans to quickly detect evolutionarily relevant threat stimuli.

It is important to note that although the infants turned more quickly toward snakes versus flowers and to angry versus happy faces, there was no difference in whether they turned *first* to the threat-relevant or the non-threat-relevant stimulus.[4] This pattern of equal first-look responding suggests that the infants, who were always looking straight ahead at stimulus onset, could not discriminate between the two classes of stimuli when they simultaneously appeared in the infants' visual periphery. However, once they began to orient in one direction, they *could* identify the nature of the stimulus to which they were turning. Presumably, it was at this point that their response speeded up to the threat-relevant stimuli, resulting in overall lower latencies.

One difference between the current results and the results of previous research with preschool children and adults is that the infants did not orient significantly more quickly to snakes than to frogs. As mentioned above, we assume that this result primarily indicates difficulty in differentiating between frogs and snakes in the infants' peripheral vision. However, an alternative possibility is that the infants in the present research turned to look at snakes faster than at flowers because of a preference for animate stimuli in general, rather than a bias for the detection of threat-relevant stimuli. Although this idea could account for the results for snakes and flowers in Experiment 1, previous research with preschool children has established that snakes are detected more quickly compared to other animals, including frogs and caterpillars (LoBue & DeLoache, 2008). Further, LoBue and DeLoache (2008) found no differences in children's detection of two sets of stimuli that were both non-threat-relevant – frogs and flowers. Thus, the overall pattern of results across the studies reported here and previously supports the conclusion that infants show enhanced attention to threat-relevant stimuli just as older individuals do.

Another interesting difference between the current results and previous research concerns the infants' responses to fearful faces. Although LoBue (2009) recently reported that preschool children and adults detect fearful faces particularly quickly, the infants in Experiment 2a did not orient more rapidly to fearful than to happy faces.

One possible reason for this result is that humans have an inborn attentional bias for the detection of angry but not fearful faces. As mentioned previously, although both of these facial expressions are threat-relevant, they indicate *different kinds* of threat. An angry face can be a direct sign of the existence and source of impending danger to the perceiver. A fearful face, on the other hand, is ambiguous, indicating the presence of threat, but not its source. Thus, it is possible that an evolved attentional bias supports the detection of angry faces, but experience is required for the development of an attentional bias for fearful faces.

This suggestion is consistent with recent ERP research showing that 7-month-old infants allocate more attentional resources to angry than to fearful faces (Kobiella, Grossman, Reid & Striano, 2008). Further, Hoehl and Striano (2008) reported differential ERP responding to angry and fearful faces, with 7-month-olds showing particularly enhanced attention to angry faces with direct eye gaze. The researchers reasoned that since angry faces are the most obvious indicators of human threat – particularly when depicted with direct eye gaze – they should elicit more attention and arousal than fearful faces (Hoehl & Striano, 2008). These findings are also consistent with recent behavioral research indicating that adults are faster at labeling angry faces than fearful faces when they are presented with direct gaze, and are faster at labeling fearful faces than angry faces when they are depicted with indirect gaze (Adams & Kleck, 2003). Together, these findings suggest that infants and adults treat angry faces and fearful faces differently based on their differing meaning.

Even though the infants in the current research did not orient to fearful faces particularly quickly, they did look longer at them than at happy faces. This result is consistent with the suggestion by Kotsoni *et al.* (2001)

[4] We thank an anonymous reviewer for drawing our attention to the significance of the latency results.

that infants maintain vigilance with respect to fearful faces because of their threat-relevance. However, one might expect that they would also detect them particularly quickly.

One explanation for these seemingly inconsistent findings is that fearful faces are simply more novel for infants than angry or happy faces, so they look at them longer. A second possibility is that infants react to angry and fearful faces differently because they represent different kinds of threat. As mentioned above, angry faces provide a direct, relatively clear message about the source and kind of threat that is present. Fearful faces, on the other hand, are more ambiguous, indicating the presence of something threatening, but not the specific nature of the threat. It could thus be advantageous to look longer at these faces to gather additional information before acting.

Conversely, one could argue that it would be adaptive to maintain attention to *any* threat-relevant stimulus. However, a bias to maintain attention to all threat-relevant stimuli could be counterproductive. In the case of fearful faces, more information is needed in order to assess the nature of the threat, so prolonged looking could be adaptive. In the case of angry faces, in contrast, no further information is needed to ascertain the nature of the threat, so prolonged looking may be costly to a fast escape. More research is needed to achieve a better understanding of infants' differing responses to angry and fearful faces.

Another important question for future research is whether the pattern of results reported here would also be found with spiders – another threat-relevant class of stimuli. There is substantial evidence with adults and preschool children for a bias in the visual detection of spiders (LoBue, 2009; Ohman, Flykt & Esteves, 2001). Further, Rakison and Derringer's (2008) recent report that 5-month-old infants looked particularly long at pictures of schematic spiders suggests the possibility that infants might also detect spiders particularly rapidly. Future visual search studies should examine the detection of spiders in infants.

Finally, it would also be interesting in future research to examine the specific features of snakes and angry faces that attract infants' visual attention. Presumably, there are some low-level perceptual feature(s) that cause snake stimuli to visually 'pop-out' and attract attention, one obvious possibility being shape. Snakes are virtually unique in having a very elongated body that can be coiled (DeLoache & LoBue, 2008). Because curved targets 'pop out' among rectilinear stimuli more than rectilinear targets among curves (Treisman & Gormican, 1988), it is possible that their curvy shape makes snakes particularly detectable. Similarly, the 'V'-shaped brow of angry faces has been proposed as the effective stimulus in their rapid detection (Tipples, Atkinson & Young, 2002). Research is currently ongoing to investigate these possibilities.

Another possibility is that their unique, sinuous pattern of movement may enhance visual attention to snakes (DeLoache & LoBue, 2008). The current research and all of the visual search research discussed above found comparatively rapid detection of snakes using still photographs, indicating that their movement pattern is not essential for rapid detection. However, it is possible that movement would make them even easier to detect. The same might be true for dynamic angry facial expressions, consistent with research indicating that 5-month-olds prefer face stimuli only when presented with faces that have moving internal features (Johnson, Dziurawiec, Bartrip & Morton, 1992; Johnson & Morton, 1991; Morton & Johnson, 1991). Further research is needed to establish the specific features of snakes and angry faces that enable humans of all ages to rapidly detect them.

In conclusion, the results of the current experiments provide evidence that infants share the propensity of adults and preschool children for the particularly rapid detection of two types of threat-relevant stimuli – snakes and angry faces. The results of the current experiments are remarkably consistent with previous research, demonstrating that even in infancy humans detect the presence of threatening stimuli more quickly than non-threatening stimuli. The existence of such a tendency in infancy provides strong support for an evolved bias in the detection of evolutionarily threat-relevant stimuli.

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