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What we fear most: A developmental advantage for threat-relevant stimuli

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ABSTRACT

Fear is one of our most basic emotions. It is an important social signal and alerts us to when a situation is safe or risky. Interestingly, not all fears are created equal: Several researchers have proposed that humans develop specific fears, such as fear of *threatening* stimuli, more readily than others. Here we discuss three major theories of fear acquisition, and consider the possibility that some fears are privileged in learning. Second, we review a growing literature that suggests that humans have perceptual biases that quickly draw attention to threatening stimuli in the environment. In particular, we highlight recent developmental work that shows that even infants and young children respond rapidly to the presence of threat well before they acquire any threat-relevant fears. Finally, we argue that such biases may play a causal role in privileging fear learning for certain threats, and we suggest directions for future work that can clarify whether early biases in perception indeed facilitate the development of our most common fears.

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Introduction

Fear is one of the oldest and most basic emotions. Because fear holds such great importance for survival—for example, by alerting us when a situation is safe or potentially dangerous—it is not surprising that there is considerable debate about how fears and phobias are acquired over the course of development. One of the most interesting aspects of human fears is that many researchers suggest that they are not all created equal; that is, there is some evidence that certain fears and phobias are more

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common than others. Researchers have argued that this is the case for evolutionary recurrent *threat relevant* stimuli in particular, such as fear of heights, other humans, wide-open spaces, snakes, and spiders ([Coelho & Purkis, 2009](#); [Marks & Nesse, 1994](#); [Seligman, 1971](#); [Öhman & Mineka, 2001](#)).

In the current review, we examine three major theories of how fears are acquired, including the possibility that some fears might be learned more readily than others. Next, we review both classic adult research and new developmental data that suggests that some threats—such as snakes and spiders—hold a special status in human perception even in infancy and early childhood, suggesting that perceptual sensitivities or biases for threatening stimuli appear as early as the first year of life. Finally, we discuss the possible relation between early perceptual sensitivities and fear acquisition, and how early biases might facilitate fear learning.

Three models of fear acquisition

General learning model

Traditional models of fear acquisition in the literature are typically domain-general learning models. The term domain-general refers to processes—namely, habituation, conditioning, associative learning, and imitation—that function across a wide range of knowledge areas, sensory modalities, and inputs. Before the 1970's, it was commonly believed that fears were only acquired via direct conditioning, much like John Watson famously demonstrated when he conditioned 9-month-old “Little Albert” to fear a white rat by pairing presentation of the rat with a loud aversive noise ([Watson & Rayner, 1920](#)). More recently, [Rachman \(1977\)](#) modified this traditional model of fear learning by proposing that humans can acquire fear via three domain-general learning pathways, including (1) direct learning through classical conditioning and indirect learning through (2) observation and (3) verbally transmitted information.

Although originally put forth nearly 40 years ago, modern theories of fear acquisition still adopt these three basic pathways, and research supports the existence of all three (e.g., [Askew & Field, 2008](#); [Field & Purkis, 2011](#); [Mineka & Zinbarg, 2006](#)). Findings from naturalistic examinations of trauma confirm the well-accepted notion that individuals can be directly conditioned to fear various stimuli. Studies from the clinical literature show that many adults and children suffer from symptoms of post-traumatic stress disorder (PTSD) after experiencing a trauma, which suggests that fearful behaviors are indeed acquired through conditioning ([Meiser-Stedman, 2002](#); [Meiser-Stedman, Smith, Glucksman, Yule, & Dalgleish, 2008](#); [Trickey, Siddaway, Meiser-Stedman, Serpell, & Field, 2012](#)). One study of the 25 girls who survived the sinking of the ‘Jupiter’ cruise ship in 1988 reported that survivors developed significantly greater fears of stimuli related to the sinking incident when compared to controls ([Yule, Udwin, & Murdoch, 1990](#)). Similarly, a study of 10–13-year-old children and their mothers who observed lightning strike a soccer field during a game reported that observers experienced several fears related to the incident ([Dollinger, O'Donnell, & Staley, 1984](#)). Although research on the effects of trauma cannot necessarily be interpreted as causal and findings with experimental data are absent from the literature because of ethical concerns, it is widely accepted that both children and adults learn fear through direct conditioning experiences.

Researchers have also reported evidence of fear acquisition through indirect pathways, such as vicarious conditioning or observational learning. Mineka and colleagues demonstrated that lab-reared rhesus monkeys learn snake fear through observation, quickly learning to fear snakes by observing the fearful behavior of a wild-reared conspecific (see [Öhman & Mineka, 2001](#), for a review). Although limited in number, there are also a few experimental studies supporting observational fear learning in humans ([Askew & Field, 2007, 2008](#)). In two separate studies, researchers reported that toddlers learn to avoid toy snakes, spiders, flowers, and mushrooms after observing mothers' negative facial expressions ([Dubi, Rapee, Emerton, & Schniering, 2008](#); [Gerull & Rapee, 2002](#)). Similarly, after repeatedly pairing photographs of novel animals with happy or fearful facial expressions, 7–9-year-olds are slower to approach animals paired with the fearful face than those paired with a happy face, and the children report a higher rate of fear when compared to a baseline measure ([Askew & Field, 2007](#)). Additional research has also shown that children can acquire *positive* responses to fear-relevant

stimuli through observation: After watching their mothers model positive behaviors towards a snake or spider toy, children show more approach behaviors toward the toy when compared to a control group (Egliston & Rapee, 2007; Kelly, Barker, Field, Wilson, & Reynolds, 2010). Although the researchers cannot necessarily rule out the possibility that conditioning occurred in these studies, the results suggest that children do learn avoidance behaviors via observation.

Finally, researchers have shown that children can learn to avoid various stimuli by hearing negative verbal information as well (Field, 2006a; Muris & Field, 2010). Field and Lawson (2003), for example, presented 6–9-year-olds with photographs of three novel animals and described each with positive, negative, or neutral information. Results showed that the children's self-reported fear and latency to approach the animals increased when negative information was presented. Similarly, after hearing a scary story about a novel "monster" doll, 7–9-year-olds reported more fearful beliefs about the doll (Field, Argyris, & Knowles, 2001). Such effects are long lasting, with fearful behaviors persisting for a week or up to 6 months after initial exposure to the negative information (Field, Lawson, & Banerjee, 2008; Muris, Bodden, Merckelbach, Ollendick, & King, 2003). Similar findings have been reported using physiological measures of fear, such as increased heart rate (Field & Schorah, 2007).

Together, this work demonstrates that humans (and in some cases, non-human primates) acquire fears through multiple domain-general learning pathways, including classical conditioning, observational learning, and by hearing negative information. These pathways do not necessarily work in isolation or in the absence of other contributing factors such as temperament or trait anxiety that might make some individuals more susceptible to acquiring fears than others (Askew, Kessock-Philip, & Field, 2008; Coelho & Purkis, 2009; Field & Purkis, 2011; Mineka & Zinbarg, 2006). However, despite empirical support for each of these pathways, the general learning model has been criticized for failure to account for the experiences of all individuals who suffer from specific fears or phobias. For example, in one study of how children and adults attribute the origins of their fears, Rachman's pathways accounted for only 94% of the content of these reports (King, Eleonora, & Ollendick, 1998). Further, some researchers have suggested that fears are disproportionately distributed, with our most common fears consisting of recurrent evolutionary threats, such as fear of heights, fear of enclosed spaces, fear of blood or injury, and fear of animals like snakes and spiders, and that general learning mechanisms cannot account for why some of these fears are more common than others (Coelho & Purkis, 2009; Marks & Nesse, 1994; Seligman, 1971; Öhman & Mineka, 2001).

Non-associative models of fear learning

According to evolutionary theories, for individuals of a species to endure it vital that they learn quickly which other species pose no threat to survival, which are prospective prey, and which are potentially dangerous predators. As mentioned above, traditional models of fear acquisition assert that humans learn to fear all stimuli via generalized learning mechanisms such as classical conditioning or observational learning (Mineka & Zinbarg, 2006; Rachman, 1977). However, if all mammals depended on standard learning strategies to identify dangerous entities, many would not survive long enough to reproduce (Bolles, 1970). In other words, one-trial learning about a potential threat to survival is insufficient if that trial leads to death. As a consequence, some researchers propose a non-associative model of fear acquisition. This model accepts Rachman's three pathways for fear learning with the addition a fourth pathway that is specific to evolutionarily recurrent threats. For this particular category of stimuli, fear is early developing or innate and does not require specific experience (Menzies & Clarke, 1995; Poulton & Menzies, 2002). The assumption that underpins this view is that humans, like many other species, have *domain-specific* mechanisms that facilitate fear acquisition (Boyer & Bergstrom, 2011). Such domain-specific mechanisms are dedicated for a specific input from a particular area of knowledge and that often include certain rules or constraints that are present at birth or shortly thereafter. The question that children and adults face for these innate fears is not whether or not they learn them, but instead, whether they can *unlearn* them, by habituating to multiple exposures of the stimulus.

Evidence for the non-associative account generally comes from retrospective reports. Menzies and Clarke (1993) interviewed parents of children with water phobia about the origins of their children's fear. Although instances of direct learning and vicarious conditioning were reported, the majority of

parents claimed that their children demonstrated fearful responses on their very first contact with water. Similarly, one prospective study examined the relationship between conditioning events (serious falls) before the age of 9 and height fear at ages 11 and 18. The results found no relationship between falling events prior to age 9 and height fear at ages 11 and 18. In fact, childhood falls mostly occurred in individuals *without* a height fear; individuals with fear of heights reported the lowest amount of exposure to heights during childhood ([Poulton, Davies, Menzies, Langley, & Silva, 1998](#); [Poulton, Waldie, Menzies, Craske, & Silva, 2001](#)). Several additional studies using similar methods have shown that for fear of water, spiders, and heights (which all have a proposed evolutionary origin), a substantial number of individuals cannot recall any specific conditioning experiences to account for their fears. This is not the case for fears that have no evolutionary significance, such as dental fears, which can generally be attributed to specific experiences (for a review, see [Poulton & Menzies, 2002](#)).

On one hand, these data cast doubt on Rachman's 3-pathway model because they demonstrate that a substantial number of individuals cannot recall direct learning experiences associated with evolutionary fears ([King, Eleonora, & Ollendick, 1998](#)). On the other hand, however, other researchers have reported that individuals have no problem recalling instances of fear learning for evolutionary stimuli. For example, when asked about the origins of their fear, a large proportion of 9–14-year-old girls with a spider phobia were able clearly to describe conditioning or other learning events ([Merckelbach, Muris, & Schouten, 1996](#)). In general, research that supports the non-associative model has been criticized for its reliance on retrospective reports, which depend on adults' limited ability to recall instances of fear learning from their past ([Coelho & Purkis, 2009](#); [Poulton et al., 1998](#)). Further, many of these studies only focus on direct conditioning experiences and ignore the potential contribution of indirect pathways to fear learning ([Muris, Merckelbach, de Jong, & Ollendick, 2002](#)).

Prepared learning model

One final model of fear acquisition adopts features from both the general learning and the non-associative models. Proponents of the preparedness, or prepared learning model, acknowledge that fears are learned via one of [Rachman's \(1977\)](#) three pathways. However, they go on to suggest that fear learning for evolutionarily recurrent threats—the same ones that are the focus of the non-associative model—is privileged and might therefore occur more rapidly than it would for non-recurrent threats ([Seligman, 1971](#)). Although standard learning models predict that mammals should associate the occurrence of any two stimuli with the same degree of ease, some research suggests that there are indeed cases in which learning is privileged for certain combinations of stimuli; that is, some associations are learned more readily than others ([Seligman, 1971](#)). Seminal research by [Garcia and Koelling \(1966\)](#), for instance, demonstrated that rats quickly learn to associate gastric sickness with ingestion of a liquid or food but not with other stimuli such as noises or lights. Given the threat of poison to animals, a readiness to associate food or drink with sickness would be adaptive because it would lead to avoidance of poisonous foods.

The prepared learning model proposes similar mechanisms for the rapid association of evolutionary threats with fear. According to this model, the acquisition of our most basic fears is best understood as being part of a continuum of learning, where some fears require only brief opportunities for learning to be acquired and others require multiple repeated adverse associations to develop ([Marks, 2002](#)). Like the non-associative model, proponents of the prepared learning model argue that fears that are learned most easily include threats that were recurrent and widespread throughout evolutionary history ([Seligman, 1971](#); [Öhman & Mineka, 2001](#)). For humans, such threats would be highly represented in clinical fears and phobias because humans would be likely to quickly learn a long-lasting, and perhaps overly strong, fear of these stimuli. As several researchers have argued that snakes and spiders are two of the most commonly feared stimuli for humans and have a proposed evolutionary origin, a good deal of research in this domain has focused on these two threat-relevant stimuli (e.g., [Seligman, 1971](#); [Öhman & Mineka, 2001](#)).

To examine the possibility that fear of certain threats is privileged in learning, Mineka and colleagues ([Mineka, Davidson, Cook, & Keir, 1984](#); [Mineka, Keir, & Price, 1980](#)) examined how snake fear is acquired in rhesus monkeys, a species that commonly demonstrates snake fear in the wild. They confirmed that snake fear in rhesus monkeys is not present without experience and is instead

acquired through learning: Although wild-reared monkeys are afraid of snakes, laboratory-reared monkeys are not. However, laboratory work with rhesus monkeys demonstrated that they readily acquire snake fear through observational learning ([Mineka et al., 1980, 1984](#)). In a series of classic studies, non-fearful laboratory-reared rhesus monkeys watched as a fearful wild-reared monkey was presented with real and toy snakes. As expected, the wild monkey responded with fear. The previously non-fearful lab-reared monkeys were then presented with the same real and toy snakes. After briefly observing wild monkeys respond fearfully to snakes, the lab-reared monkeys demonstrated the same fearful behaviors. In fact, these fearful reactions showed no signs of having diminished when the monkeys were tested 3 months later. Most importantly, [Cook and Mineka \(1990\)](#) found that fear of snakes was *selective*: After showing one group of lab-reared monkeys a video of a wild-reared monkey displaying fear towards a flower (a fear-irrelevant stimulus) and a second group of lab-reared monkeys a video of the same monkey reacting fearfully towards a snake (a fear-relevant stimulus), only the monkeys in the snake condition acquired fearful responses.

This work suggests that snake fear is privileged in learning for some non-human primates. However, is snake fear also privileged for humans? Öhman and colleagues examined this question in numerous studies using classical conditioning of skin conductance responses (SCRs) ([Öhman, Fredrikson, Hugdahl, & Rimmo, 1976](#)). In the general paradigm, adults are shown pictures of either snakes and spiders or flowers and mushrooms paired with an electric shock. In both cases, the participants learned to anticipate the electric shock regardless of the nature of the conditioned stimulus. However, participants who were conditioned with snakes and spiders showed significantly greater resistance to extinction. These results demonstrate that in human adults, associations between the occurrence of an aversive shock and threat-relevant stimuli last longer than associations between a shock and non-threatening stimuli. Stronger conditioning between an electric shock and threat-relevant stimuli has also been found using threatening facial expressions ([Öhman & Dimberg, 1976](#)) and in several studies where the stimuli were presented only subliminally (i.e., [Esteves, Dimberg, & Öhman, 1994](#); [Esteves & Öhman, 1993](#); [Öhman & Soares, 1993](#)).

Together, this research has rallied support for the prepared learning view. In fact, [Rachman \(2002\)](#) recently advocated for preparedness in his own model of fear acquisition. However, despite wide support for the prepared learning model, it has also received some serious criticisms. The biggest problem with the model stems of the identification of what kind of stimuli are “prepared.” As mentioned above, proponents of the view suggest that “prepared” stimuli would have constituted a recurrent and widespread threat throughout evolutionary history ([Seligman, 1971](#); [Öhman & Mineka, 2001](#)). Such evolutionary stimuli are difficult to identify and even more difficult to test empirically because this type of identification requires assumptions about what was safe and what was dangerous in our evolutionary past ([Coelho & Purkis, 2009](#); [Kleinknecht, 2002](#); [McNally, 2002](#)). Anthropologist Lynne Isbell has studied the relationship between snakes and developing mammals in Africa throughout evolutionary history and has made a compelling argument for why snakes did indeed constitute an important threat to humans over the course of our development ([Isbell, 2006, 2009](#)). Further, medical research on snakes has shown that venomous snake bites do constitute a significant number of deaths worldwide (up to 94,000 a year), making snakes still an important threat for humans ([Kasturiratne et al., 2008](#)). Spiders, on the other hand, are also considered to be an evolutionary threat, but only a very small percentage of spiders are actually dangerous to humans ([McNally, 2002](#)). Further, according to the Centers for Disease Control and Prevention, spider bites caused only 99 deaths in the United States in the 20 years between 1979 and 1999 ([Forrester & Stanley, 2004](#)). Thus, although both snakes and spiders are often used as prototypical evolutionarily fear-relevant stimuli, there is only evidence that snakes might have ever been a serious threat to humans.

Proponents of the prepared learning view also suggest that prepared fears would be highly represented in clinical fears and phobias because humans would be likely to quickly learn a long-lasting and perhaps overly strong fear of these stimuli. Evidence to support this point is mixed as well. In one clinical survey of common fears, intense fears, and clinical phobias, snakes and spiders were indeed identified as the most prominent common and intense fears, but phobias were more likely to consist of illness, injury, and death ([Agras, Sylvester, & Oliveau, 1969](#)). More recent assessments echo these results, and report that fear of heights and fears of animals in general occur significantly more often than any other fear ([Curtin, Magee, Eaton, Wittchen, & Kessler, 1998](#); [Depla, ten Have, van Balkom, & de](#)

Graaf, 2008). Thus, perhaps fear of heights, snakes, and spiders are represented in studies of common and intense fears, but evidence that they are highly represented in clinical phobias is weak. Further, it is unclear whether other fears that have a hypothesized evolutionary origin, such as fear of water or wide-open spaces, are highly represented in the general population. This problem with identifying which threats are evolutionarily relevant has been the main criticism of the prepared learning view in the literature, and will continue to be a problem since it is a difficult one to address empirically.

Attentional biases for threat

Fear and biases for threat in infancy

Together, the research presented above suggests that humans can learn to fear various stimuli via Rachman's three pathways, and that fear of certain evolutionary threats might be innate, or privileged in learning. Although the work described above laid the groundwork for these important theories of fear learning, much of it was either retrospective, or conducted with older children and adults. It is possible that older participants already have negative associations about threatening stimuli like snakes and spiders or fully-developed fears of such stimuli when they enter the lab. To study the origins of these fears, it is crucial to examine how fearful behaviors are acquired over the course of development. Recently, researchers have begun to study behavioral responses in infants and young children to threatening stimuli like snakes and spiders. Results from several programs of research have suggested that threatening stimuli are indeed privileged for humans as early as infancy. Interestingly, this privilege, at least early in development, seems to lie in *visual attention*.

In one of the first studies to examine infants' responses to threat, DeLoache and LoBue (2009) examined whether 9-month-olds have already developed differential responses towards snakes versus other animals. They positioned infants on a parent's lap in front of a television screen. In a series of trials, infants watched as different animals moved across the screen—exotic, unfamiliar animals such as snakes, elephants, and giraffes. They observed two behaviors. First, they measured overall looking to the screen for each animal. If infants had already developed a fear of snakes, they might avoid looking at snakes on the screen, or conversely, show hyper-vigilance and look at snakes on the screen for longer than they looked at other animals. Second, they coded infants' attempts at reaching or grasping at the animals on the screen. Previous work has shown that 9-month-olds treat two-dimensional depictions as if they were three-dimensional objects, and attempt to grasp them from a book page or television screen (DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998; Troseth & DeLoache, 1998). If infants are already fearful of snakes, it is unlikely that they would try to pick up a moving snake.

The 9-month-olds showed no differences in behavior towards the snakes versus non-snake animals; that is, they showed equal looking time to both and made equal attempts to grasp for them. Indeed, the 9-month-olds did attempt to pick up a moving snake from the screen and showed no behavioral evidence of fear. The experimenters concluded that there was no evidence that 9-month-olds have a fear of snakes (DeLoache & LoBue, 2009). Moreover, in a recent examination of 18–36-month-old children's approach and avoidance responses to live animals, researchers again report no evidence that young children avoid a live snake and spider (LoBue, Bloom Pickard, Sherman, Axford, & DeLoache, 2013). In contrast, the children demonstrated an avid *interest* in all of the live animals, an interest that was equal for non-threatening animals like a hamster and a fish and for threatening animals like a snake and a spider.

This work casts doubt on the non-associative view of fear acquisition, suggesting that snake and spider fears are not widely present in infants and children ranging from 9 months to 3 years of age. However, these data do not speak to the generalized learning or preparedness models of fear acquisition. To contrast these models, the next question the researchers asked was whether infants would readily associate a snake with something fearful or negative. Thus, in a second experiment, DeLoache and LoBue (2009) used an audio-visual matching paradigm to examine whether infants readily match the image of a snake with something fearful. The procedure takes advantage of the fact that between 4 and 7 months of age, infants begin to look preferentially at a video that matches a corresponding

sound: They look longer at a video of a drum than at a video of a woman playing peek-a-boo when they hear the sound of a drum beating in the background ([Spelke, 1976](#)); they also look longer at an image of a happy face than at an image of a sad face when they hear the sound of a happy voice ([Walker, 1982](#)). Using this procedure, the experimenters presented 7–16-month-olds with two of the videos side by side on a large screen—one snake and one non-snake (e.g., elephant, giraffe). During each presentation, the infants also listened to either a happy or fearful voice emanating from a central speaker. Infants looked longer at the snakes when listening to fearful voices than when listening to happy voices, 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.

[Rakison \(2009\)](#) reported that similarly aged female infants demonstrate a propensity to learn the relation between the image of snakes and spiders and fearful faces. He showed 11-month-old infants images of snakes and spiders paired with either a schematic happy face or a fearful face. After repeated presentations, infants were tested to see whether they learned to associate the animal and the face by showing them a new snake or spider paired with the opposite facial expression (e.g., a happy face if previously shown fearful faces). Results demonstrated that female infants—but not male infants—readily associated the images of snakes and spiders with fearful faces but not with happy faces. When the experiment was repeated with non-threatening stimuli such as flowers and mushrooms, infants did not make any associations between the non-threatening stimuli and happy or fearful faces, suggesting that female 11-month-olds infants readily associate snakes and spiders with a fearful stimulus.

Together, these studies demonstrate that infants do not necessarily fear stimuli such as snakes and spiders in the first years of life, but they are biased to match the image of a snake or spider with something fear-relevant. Further experiments suggest that infants are biased to quickly *detect* the presence of stimuli like snakes and spiders in visual attention as well. [LoBue and DeLoache \(2009\)](#) presented 9–12-month-old infants with two images side by side on a large screen—one snake and one flower. They measured how quickly the infants turned their heads to look at each one. They found that the infants turned more quickly to look at images of snakes than flowers. Further, they also turned more quickly to look at angry faces than at happy faces, suggesting that infants detect the presence of threat particularly quickly in visual attention ([LoBue & DeLoache, 2009](#)). In line with these findings, it has been proposed that infants may have a perceptual template for threats that attracts infants' attention to these stimuli early in development ([Rakison, 2009](#); [Rakison & Derringer, 2008](#)). [Rakison and Derringer \(2008\)](#) found that 5-month-olds look longer at a schematic image of a spider or a snake relative to scrambled versions of the same schematic image, and they look equally long at non-threatening images such as flowers ([Rakison, in preparation](#); [Rakison & Derringer, 2008](#)). These results are parallel to those found for young infants when they track human faces over other stimuli ([Johnson & Morton, 1991](#)).

Biases for threat in early childhood and adulthood

The work described above was the first to establish that threatening stimuli like snakes and spiders are privileged in attention early in development. It is not clear whether such biases are learned (before 5–7 months of age) or biologically based, but they are certainly evident early in the first year of life. Importantly, further work has shown that biases for the rapid detection of threat remain consistent into later childhood and adulthood. In the standard adult visual search paradigm, participants are presented with nine photographs arranged in 3×3 matrices. The matrices contain nine photographs from the same category, or eight photographs from the same category with a single image from a discrepant category. Participants are generally instructed to detect as quickly as possible whether a discrepant photograph is present in each matrix by pressing one of two buttons on a keyboard. Using this paradigm and others (e.g., dot probe, flanker tasks), researchers have consistently reported that adults detect evolutionary threats like snakes and spiders more quickly than a variety of benign stimuli, such as flowers, mushrooms, frogs, and cockroaches ([Flykt, 2005, 2006](#); [Hayakawa, Kawai, & Masataka, 2011](#); [Lipp, 2006](#); [Lipp & Derakshan, 2005](#); [Lipp, Derakshan, Waters, & Logies, 2004](#); [Lipp, Price, & Tellegen, 2009](#); [Lipp & Waters, 2007](#); [LoBue, 2010b](#); [LoBue & DeLoache, 2008, 2011](#); [Masataka &](#)

Shibasaki, 2012; Purkis & Lipp, 2007; Soares, Esteves, Lundqvist, & Öhman, 2012; Tipples, Young, Quinlan, Broks, & Ellis, 2002; Öhman, Flykt, & Esteves, 2001). They also consistently detect threatening or angry faces more quickly than happy, neutral, or even sad faces (Calvo, Avero, & Lundqvist, 2006; Eastwood, Smilek, & Merikle, 2001; Esteves, 1999; Fox et al., 2000; Hansen & Hansen, 1988; LoBue, 2009; Lundqvist & Öhman, 2005; Schubo, Gendolla, Meinecke, & Abele, 2006; Tipples, Atkinson, & Young, 2002; Williams, Moss, Bradshaw, & Mattingly, 2005; Öhman, Lundqvist, & Esteves, 2001). Together, the overwhelming majority of work in this area demonstrates a clear bias for threat in visual detection tasks.

Recently, developmental researchers have begun to examine these effects in younger participants. Wolters et al. (2012) used a dot-probe paradigm to show that 8–18-year-olds respond more quickly to threatening than to non-threatening stimuli. Waters and Lipp (2008) used the standard visual detection paradigm described above to show that 9–13-year-old children detect snakes and spiders more quickly than a variety of other animals. Others have modified the standard visual search paradigm to examine threat detection in even younger children. Using a child-friendly touch-screen visual detection paradigm, LoBue and DeLoache (2008) examined whether preschool children would also quickly detect the presence of various threats. They presented 3–5-year-olds with three by three matrices of images on a touch-screen monitor. Each child's task was to locate the position of a single "target" image as quickly as possible and touch it on the screen. Results showed that children as young as three detect image of snakes more quickly than flowers, and more quickly than other animals that look like snakes, such as frogs and caterpillars (LoBue & DeLoache, 2008). They also detected spiders more quickly than mushrooms and cockroaches (LoBue, 2010b) and threatening facial expressions more quickly than happy or benign faces (LoBue, 2009).

Using the same touch-screen methodology, other labs have replicated and extended these findings. For example, several additional studies report that preschool children more quickly detect both color and black and white images of snakes versus flowers and frogs (Hayakawa et al., 2011; LoBue & DeLoache, 2011; Masataka, Hayakawa, & Kawai, 2010). Further, when snakes are depicted in an attack pose, preschoolers show an even greater detection bias (Masataka et al., 2010). Finally, using the same touch-screen procedure, even Japanese monkeys have been reported to detect a single snake among eight flowers more quickly than a single flower among eight snakes (Shibasaki & Kawai, 2009).

Together, this work shows consistently that infants, preschool children, adults, and even non-human primates have perceptual biases for the rapid detection of evolutionary threats. However, despite a clear pattern in the literature with regard to detection, evidence about the mechanisms that drive this phenomenon is more ambiguous. Some researchers have suggested that threat-relevance, or the emotional content of the stimuli, is what captures attention (e.g., Calvo & Esteves, 2005; Eastwood, Smilek, & Merikle, 2003; Eastwood et al., 2001; Lipp & Derakshan, 2005; Lipp & Waters, 2007; Lundqvist & Öhman, 2005; Öhman et al., 2001). Indeed, several studies have shown that the more aversive or negatively adults rate threatening stimuli, the more quickly they detect them (Beaver, Mogg, & Bradley, 2005; Lundqvist & Öhman, 2005). Others have shown that there is no search advantage for threatening faces when simple features of the faces are scrambled, or when they are presented in a non-face-like context (Schubo et al., 2006; Tipples, Atkinson, et al., 2002). Similarly, others have shown that adults only detect threatening faces when they are presented upright: When the faces are inverted, which generally results in impaired face processing, they no longer detect angry faces more quickly than happy faces (Eastwood et al., 2001; Fenske & Eastwood, 2003; Fox et al., 2000).

Some researchers who suggest that emotional content drives rapid threat detection also generally support the idea that the processing of threatening stimuli occurs automatically, and is immune to cognitive influences. More specifically, these researchers propose that humans evolved a fear module in the brain that is activated quickly and efficiently at the sight of threat (Öhman & Mineka, 2001). To test empirically whether stimuli are processed automatically, detection of the targets should not be affected by variations in the number of distracters present in a visual search display (Treisman & Gelade, 1980). Accordingly, many have demonstrated that the number of distracters present in a matrix does not affect the speed of detection for threat-relevant stimuli. In other words, when participants are asked to detect targets in both 2×2 and 3×3 matrices, performance does not vary as a function of the number of distracters (3 or 8) when the targets are stimuli like snakes and spiders. However, when flowers and mushrooms are the targets, participants are significantly slower at

detecting their presence when more distracters were present in the matrix ([Eastwood & Smilek, 2005](#); [Fox et al., 2000](#); [Öhman et al., 2001](#)).

Other investigators propose that threats are not detected more quickly than non-threats at all; instead, participants have difficulty *disengaging* from stimuli with a negative or threatening valence when they are used as distracters. [Fenske and Eastwood \(2003\)](#), for example, presented participants with three images of schematic faces and on each successive trial they were told to identify the center image while ignoring the other two. Participants were slower to detect the center image when the distracter images were negative faces. Additional studies using the standard visual search procedure described above have shown that participants are slower to detect happy faces when angry faces are used as the distracters ([Horstmann, Scharlau, & Ansorge, 2006](#)) and slower to detect pictures of cats or rabbits when snakes and spiders are the distracters ([Forbes, Purkis, & Lipp, 2011](#); [Lipp & Waters, 2007](#)).

Not all research has supported the automaticity (e.g., [Nothdurft, 1993](#)) or the negative valence hypothesis. [Purkis and Lipp \(2007\)](#), for example, examined threat detection in snake and spider experts and demonstrated that even individuals with no negative bias towards snakes and spiders still detect them very quickly. An alternative explanation for how threatening stimuli are detected so quickly is that low-level perceptual features that are highly represented in threatening stimuli drive detection ([Becker, Horstmann, & Remington, 2011](#); [Horstmann, 2009](#); [Horstmann, Borgstedt, & Heumann, 2006](#); [LoBue, 2013](#); [LoBue, Rakison, & DeLoache, 2010](#)). For example, some researchers have shown that particular regions of face stimuli (e.g., mouth or eye region) are solely responsible for the detection advantage in angry faces ([Calvo & Nummenmaa, 2008](#); [Fox & Damjanovic, 2006](#); [Lundqvist, Esteves, & Öhman, 1999](#)). Other studies have shown that specific geometric shapes, such as the “V” shaped brow characteristic of angry faces or simple curvilinear figures common to snakes are sufficient in eliciting rapid detection ([Larson, Aronoff, & Stearns, 2007](#); [LoBue, in preparation](#); [LoBue & DeLoache, 2011](#); [LoBue & Larson, 2010](#)). Further, presenting participants with specific features of angry faces in non-face-like configurations maintains the advantage ([Coelho, Cloete, & Wallis, 2011](#); [Horstmann, Borgstedt, et al., 2006](#)), while eliminating or manipulating these important features eliminates it ([Becker, Horstmann, et al., 2011](#)). Finally, an advantage for snakes and spiders has been found even when the stimuli were degraded, obscuring the content of each stimulus ([Forbes et al., 2011](#)).

It is possible that the reason why these low-level stimuli are detected particularly quickly has nothing to do with threat-relevance per se. Indeed, there are various simple shapes that are detected very efficiently by the human visual system for reasons that are not always clear ([Treisman & Gelade, 1980](#); [Wolfe, Yee, & Friedman-Hill, 1992](#)). Alternatively, [Cave and Batty \(2006\)](#) suggested that individuals learn to associate particular features or configurations with threat that they later use to guide detection. In support of this idea, [Koster, Crombez, Van Damme, Verschuere, and De Houwer \(2004\)](#) found that after conditioning participants to associate a neutral stimulus (gray square) with an aversive burst of noise, participants detect that stimulus more quickly than another neutral stimulus (white square) in a visual search procedure. Similarly, [Milders, Arash, Logan, and Donnellon \(2006\)](#) conditioned participants to associate a loud noise with pictures of neutral faces. After the conditioning phase of the experiment, participants detected neutral faces significantly faster than before conditioning. Finally, [Purkis and Lipp \(2009\)](#) found that after conditioning adult participants to associate non-threatening animals, such as dogs, birds, or fish, with an aversive shock, those animals were then detected very quickly in a visual search task—just as quickly as snakes and spiders were detected. Even children can learn to detect neutral stimuli very quickly; after learning negative facts about novel animals, 7–9-year-olds demonstrated an attentional bias for those animals in a dot probe task ([Field, 2006a, 2006b](#)).

This work indicates that attentional capture can be learned through negative experience with neutral stimuli, and it may not necessarily be unique evolutionary threats. Research on the detection of modern threats also supports this notion. [Brosch and Sharma \(2005\)](#) examined whether humans quickly detect both phylogenetic and ontogenetic threats, comparing the detection of snakes and spiders (threatening – phylogenetic) to flowers and mushrooms (non-threatening – phylogenetic), and the detection of guns and syringes (threatening – ontogenetic) to cups and mobile phones (non-threatening – ontogenetic). Both types of threatening stimuli were detected more quickly than the non-threatening stimuli. Similarly, [Blanchette \(2006\)](#) examined detection of snakes and spiders versus

flowers and mushrooms and also detection of guns and knives versus clocks and toasters. Again, all threatening stimuli were detected more quickly than non-threatening stimuli, regardless of ontogenetic versus phylogenetic fear-relevance. Studies using ERPs confirm these results, showing equal responsiveness to both evolutionary and modern threats ([Brown, El-Deredy, & Blanchette, 2010](#)).

Some recent developmental work provides further evidence that perceptual biases for threats can be learned. Although it is impossible to account for the full range of children's experiences in everyday life, [LoBue \(2010a\)](#) pointed out that preschool children generally have a predictable amount of experience with two types of modern threats that adults detect very quickly, namely, syringes and knives. All children raised in the United States are required to obtain a certain number of vaccinations, so by the age of 3, all children should have some negative experience with syringes. In contrast, it is unlikely that children of this age are permitted to interact with knives. Thus, [LoBue \(2010a\)](#) asked preschoolers to detect both syringes and knives among two neutral control stimuli (pens and spoons). The results revealed that while [Blanchette \(2006\)](#) and [Brosch and Sharma \(2005\)](#) reported that adults quickly detect both syringes and knives, preschool children only detected the syringes more quickly than the neutral controls.

This work casts doubt on the potential evolutionary origins for threat biases. However, one final possibility is that rapid detection of *various* stimuli, including threats that have a proposed evolutionary origin and modern threats that do not, is driven by dynamic interactions between multiple factors. As [Frischen, Eastwood, and Smilek \(2008\)](#) so eloquently put it: “. . . visual search is a complex task that requires a dynamic interplay of different cognitive mechanisms. Partly as a result of this, the search process is highly sensitive to contextual variables, such that performance may vary widely depending on perceptual and strategic factors associated with both the target and distractor items.” Thus, rapid threat detection might be best conceptualized as a continuum of search efficiency that can be driven by a variety of individual and interacting factors ([Horstmann & Becker, 2008](#)). One recent study suggests that this indeed might be the case. In five experiments, [LoBue \(in preparation\)](#) examined the unique and interacting roles of low-level perceptual cues, cognitive factors such as threatening labels, and emotional state to rapid threat detection. Across studies, low-level perceptual features of snakes—namely, simple curvilinear shapes—consistently elicited rapid detection in the absence of any threat-relevant cues. Further, using threatening labels (e.g., calling a stimulus a “snake”) and a fearful emotional induction (e.g., being afraid or anxious) facilitated detection even further. These results are corroborated by other studies showing that emotional state ([Rutherford, MacLeod, & Campbell, 2004](#)) and negative information ([Field, 2006a, 2006b](#)) can lead to rapid detection. Collectively these findings suggest a more complex picture of the mechanisms by which humans quickly perceive threat, and that rapid threat detection can result from several individual and interacting factors, including perceptual biases for low-level features of threats, and cognitive and emotional components that are learned via experience with threatening stimuli.

Attentional biases and fear acquisition

In the current review, we have summarized three major theories of fear acquisition. Based on the evidence reviewed above, all fears are likely acquired as [Rachman \(1977\)](#) originally proposed—through domain-general mechanisms such as conditioning, associative learning, or the transmission of negative information. In other words, fear of most stimuli is learned in a similar way and at similar rates (assuming equivalent exposure) through the same learning mechanisms that we use to acquire other forms of knowledge that are unrelated to fear. Thus, in most cases, learning to fear stimuli would be relatively slow—bar a significantly traumatic event—and may require multiple exposures to acquire. Fear learning for evolutionarily relevant threats like snakes and spiders is in all likelihood the same as that for non-recurrent threats. However, it is possible that we learn to fear such threats with a greater degree of ease ([Marks, 2002](#)).

Researchers have proposed various mechanisms to explain how fears of evolutionary threats may be acquired so quickly. Some have suggested that acquisition of these fears requires no learning at all and are acquired on an individual's first encounter with the stimulus ([Poulton & Menzies, 2002](#)). Others have proposed the existence of an evolved fear module in the brain that is responsible for the rapid

acquisition of these fears (Öhman & Mineka, 2001). Davey (2002) proposed that evolutionary threats like 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. In other words, the mechanism that ensures that these stimuli are most likely to become fear-relevant is bodily or perceptual. Here we have reviewed substantial evidence that humans indeed have perceptual biases that orient them to some evolutionary threats, and that such biases are visible before we can see any evidence of snake and spider fear in infants and young children (e.g., DeLoache & LoBue, 2009; LoBue et al., 2013). Our proposal, similar to Davey's, is that these biases in perception may facilitate fear learning, potentially serving as the causal mechanism in privileging fear learning for such stimuli. Again, such biases might be part of a larger innate fear module, as Öhman and Mineka (2001) suggest, or they might be the byproduct of a visual system that quickly processes some low-level perceptual cues more quickly than others (Treisman & Gelade, 1980; Wolfe et al., 1992).

This perspective is novel in that it uses biases in perception to explain how humans learn to fear some threats more quickly than others. A few others have proposed a similar account, suggesting that all individuals have biases for threat early in development, and children that do not learn to inhibit such biases are particularly susceptible to developing later fear and anxiety (Field & Lester, 2010; Kindt & van den Hout, 2001). While other perspectives assume that the learning mechanisms might be specialized or domain specific in some way, we suggest that the processes that underpin fear learning are similar for all kinds of stimuli, but the presence of various perceptual biases is what expedites learning for specific stimuli. Our view is supported by the ever-growing literature we have outlined here that shows that infants, young children, and adults possess perceptual biases to attend to snakes and spiders and threatening conspecifics (e.g., angry faces). As we have already discussed, the fact that infants and young children orient more quickly to these stimuli rather than to others means that they might be more likely to associate them with a conspecific's emotional reaction. Second, work by Rakison (2009) and DeLoache and LoBue (2009) suggests that infants more readily associate fearful faces and voices with stimuli like snakes and spiders. This associative bias to readily match stimuli like snakes and spiders with something fear-relevant could easily facilitate fear learning as well.

There is also specific evidence in the clinical literature that links heightened threat perception with anxiety. Participants high in trait anxiety are faster to detect angry faces than non-anxious controls (Bar-Haim, Lamy, Pergamin, Bakersman-Kranenburg, & van Ijzendoorn, 2007; Byrne & Eysenck, 1995; Gilboa-Schechtman, Foa, & Amir, 1999; Mogg & Bradley, 2002). They are also slower to detect happy faces when angry faces are distracters (Byrne & Eysenck, 1995; Gilboa-Schechtman et al., 1999; Waters & Valvoi, 2009). In dot probe tasks, anxious participants take longer to disengage from a face when it is angry than when it is happy or fearful (Fox, Russo, & Dutton, 2002; Reinholdt-Dunne et al., 2012), or when a stimulus has threatening content more generally (Yiend & Mathews, 2001). Similarly, spider and snake fearful participants are faster to detect the object of their fear than are non-fearful participants (Flykt & Caldara, 2006; Soares, Esteves, & Flykt, 2009; Öhman et al., 2001) and slower to detect non-threatening targets when spiders are used as the distracters (Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005).

There are also studies that show that attentional biases for threat early in development predict later anxiety. In one study, LoBue and Pérez-Edgar (in press) compared detection of angry versus happy faces in 4-year-old children who are temperamentally shy and at increased risk for the development of later anxiety. They found that the at-risk group demonstrated a heightened bias for the detection of angry faces when compared to non-shy controls. This suggests that biases for social threats are evident in young children at risk for anxiety before any clinical diagnosis is made (LoBue & Pérez-Edgar, in press). Further, Pérez-Edgar et al. (2011) found that children who are behaviorally inhibited at ages 2 and 3 are socially withdrawn or shy at age 5. Importantly, this effect is moderated by an attentional bias to threat—the relationship between behavioral inhibition and social withdrawal is only significant in children who show a heightened bias for angry versus happy faces. The same relationship was shown in a longitudinal study examining behaviorally inhibited children from 4 months through adolescence—children who were identified as behaviorally inhibited at 4 months of age were socially withdrawn at the age of 15; again, this effect was moderated by a perceptual bias for angry faces in that only 15-year-olds who showed heightened attention to angry versus happy faces demonstrated this relationship (Pérez-Edgar et al., 2010).

Although these studies suggest a link between rapid detection and anxiety, the data are correlational and not causal. Indeed, previous work suggests that anxiety or negative experience with threatening stimuli can cause heightened attention to those threats (e.g., [Koster et al., 2004](#); [LoBue, 2010a](#); [Milders et al., 2006](#); [Purkis & Lipp, 2009](#)). However, the causal relation might work in both directions, with heightened perceptual biases causing anxiety, and anxiety leading to enhanced perceptual biases ([Matthews & MacLeod, 2002](#)). Some researchers who specialize in clinical or anxious populations have begun to examine the possibility that heightened perceptual biases for threats can increase (or reduce) anxiety and fear. To test this hypothesis, [MacLeod, Rutherford, Campbell, Ebsworthy, and Holkder \(2002\)](#) trained participants on a dot probe task in which two words, one neutral and one negative, appeared on the screen, followed by a small probe in place of one of the two words. Half the participants were trained to identify probes that appeared in place of the neutral word, and the other half were trained to identify probes that appeared in place of the negative word. After the dot probe manipulation, participants were required to complete a series of difficult anagrams while being videotaped. Results indicated that participants trained to attend to negative words experienced heightened negative mood during the anagram task. This suggests that heightened attention to negative stimuli subsequently increases negative mood during a stressful task.

These researchers used the same logic to examine whether training individuals to direct attention *away* from threat-relevant stimuli would *decrease* anxiety. Using the same methodology, several studies have demonstrated that highly anxious individuals who are trained to repeatedly direct their attention away from threatening words (e.g., respond to probes that appeared in the place of neutral as opposed to negative words) show a lower attentional bias for negative words after training, and report significantly lower levels of anxiety ([Amir, Beard, Burns, & Bomyea, 2009](#); [Matthews & MacLeod, 2002](#)). Similarly, [Amir, Weber, Beard, Bomyea, and Taylor \(2008\)](#) presented two groups of socially-anxious participants with happy and disgusted faces followed by a probe in the place of one of the two faces. For half the participants, the probe always appeared behind the neutral face, and for the other half, the probe always appeared behind the disgusted face. The group of participants whose probes always appeared behind the neutral face showed decreased levels of anxiety *and* a decreased bias for disgusted faces in a post-test. [Amir, Beard, Taylor, et al. \(2009\)](#) used the same paradigm with threatening (angry) instead of disgusted faces to examine individuals suffering from Generalized Social Phobia (GSP) who generally show a heightened attention bias for threatening faces. After being trained to detect probes behind neutral faces (and thus ignore angry faces), individuals with GSP not only experienced reduced self-reported symptoms of social anxiety compared to a group that did not experience training, but they also no longer met clinical criteria for GSP.

Such a procedure—called Attention Bias Modification Treatment—is now being used to treat several types of clinical anxiety. A recent meta-analysis on published research using this treatment procedure showed that training participants to ignore threatening stimuli is effective in significantly reducing anxiety in clinical populations ([Hakamata et al., 2010](#)). Together, this work suggests that there is indeed a causal relationship between attentional biases and anxiety. It is currently uncertain whether the same procedure can be used as an intervention for young children who are behaviorally inhibited or temperamentally shy. It is also unclear whether the procedure can be used to prevent the development of snake and spider fears and phobias in non-clinical populations, as the procedure is generally used with individuals who already show symptoms of anxiety. Further, the dot-probe procedure is not appropriate for children of all ages, but perhaps newer touch-screen technology will provide researchers with the opportunity to further examine the causal role that early attentional bias might play in the development of anxiety and fear.

Limitations and future research

There are several limitations to this body of research as a whole that can be addressed in future work. First, although research with humans suggests that we strongly associate snakes and spiders with aversive stimuli, actual studies of fear *learning* have only been conducted with non-human primates (e.g., [Cook & Mineka, 1990](#)). As described above, Öhman and colleagues demonstrated that human adults strongly associate images of snakes and spiders with an aversive shock, but this work does

not directly examine the process of fear learning. Further, DeLoache and LoBue (2009) and Rakison (2009) reported that infants readily associated images of snakes and spiders with fearful faces and voices. Although these studies are strong tests of the evolutionary account, they were not designed to examine fear learning and suggest only that infants have a propensity to associate the occurrence of a snake or spider with an aversive stimulus. Neither of these studies reports behavioral evidence that infants are actually fearful of any of the stimuli presented. Presumably a propensity to associate the occurrence of snakes and spiders with aversive negative stimuli or emotion leads to, or mirrors, rapid fear learning, but experiments that examine the process of learning such fears are still necessary. Based on previous work, we would predict that just as with rhesus monkeys and other non-human primates, a bias in humans quickly to associate snakes and spiders with fear would lead to an advantage in learning. However, it is unclear whether it would affect the extinction process and explain why extinction is slower for snakes and spiders as opposed to non-threatening stimuli when paired with an aversive shock. Future research is needed in these areas.

Future research is also needed to elucidate the role of perceptual biases in the formation of anxiety disorders. The research reviewed here suggests that all participants (regardless of trait anxiety) detect threats more quickly than non-threats in visual search tasks, and are slower to detect non-threatening targets when threats are used as the distracters. However, this work also indicates that anxious or phobic participants detect the object of their phobia even more quickly than typically developing participants (Flykt & Caldara, 2006; Soares et al., 2009; Öhman et al., 2001), and have difficulty disengaging from threat in dot-probe tasks (Fox et al., 2002; Reinholdt-Dunne et al., 2012). Longitudinal studies examining how perceptual biases might lead to anxiety disorders in some participants and not in others is important for future research.

Despite the large body of work reviewed above that supports the notion that humans have perceptual biases for various threats and that these biases might play a causal role in the development of fear and anxiety, there are several limitations to research in threat detection as well. As mentioned above, one of the biggest problems with this research as a whole stems of the identification of what kind of stimuli should be privileged in detection. Although the preparedness model would suggest that only evolutionarily relevant stimuli should hold this privilege, rapid detection of threat has been found for modern as well as evolutionary threats (Blanchette, 2006; Brosch & Sharma, 2005). Further, Purkis, Lester, and Field (2011) demonstrated that adults are also biased toward stimuli that hold personal relevance, citing evidence that individuals who habitually watch the British TV show *Dr. Who* detect images from the show just as quickly as spider fearful participants detect images of spiders.

Additionally, although both snakes and spiders are generally used as the prototypical evolutionarily threat-relevant stimuli, there is only evidence that snakes constituted (and still constitute) a recurrent threat to humans (Isbell, 2006, 2009). Recently, Öhman and colleagues found that there is a larger advantage for snakes than for spiders in threat detection (Öhman, Soares, Juth, Lindstrom, & Esteves, 2012), suggesting that snakes might be a stronger threat cue than spiders. Similarly, there is only evidence that non-human primates rapidly detect and learn to fear snakes; no such evidence exists for spiders (e.g., Cook & Mineka, 1990; Shibasaki & Kawai, 2009). Studies that look at commonly feared animals suggest that perhaps spider phobia is more related to disgust sensitivity than threat-relevance (Davey et al., 1998; Matchett & Davey, 1991).

Stimulus issues go beyond identification of what categories constitute threat. For example, although many researchers have found an advantage for angry faces in detection studies, most of this work has been done with schematic face stimuli (Calvo et al., 2006; Esteves, 1999; Horstmann, Scharlau, et al., 2006). This is problematic, as schematic faces are exaggerated, stereotypical versions of human emotions, and do not capture the true variability in posed emotional expressions (Calvo, Nummenmaa, & Avero, 2008; Horstmann & Bauland, 2006). Despite consistency with schematic faces, results with real faces are mixed (Calvo & Marrero, 2009; Öhman, 2009). Some studies using real faces have replicated the advantage for angry over happy faces (Fox & Damjanovic, 2006; Hansen & Hansen, 1988; Horstmann & Bauland, 2006; LoBue, 2009), but others have not (Purcell, Stewart, & Skov, 1996). In fact, many studies using real face stimuli report evidence of a *happy* bias instead of an angry bias (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Calvo & Nummenmaa, 2008; Juth, Lundqvist, Karlsson, & Öhman, 2005; Purcell et al., 1996). Further, Williams et al. (2005) found that angry and happy faces are detected equally quickly, and more quickly than sad or fearful faces. Others report that

happy, surprised, and disgusted faces are detected faster than angry, sad, and fearful faces (Calvo & Nummenmaa, 2008; Calvo et al., 2008). Öhman and colleagues recently argued that the advantage for angry faces is only driven by *male* angry faces, and not female faces (Öhman, Juth, & Lundqvist, 2010). Further, they suggest that the advantage for anger is most likely produced when the distracter stimuli are redundant (Öhman et al., 2012). This might explain why angry schematic faces are so easy to detect—all schematic faces are generally identical and resemble males. However, this still presents a problem for threat detection research as a whole because redundant schematic face stimuli are artificial, and not ecologically valid (Horstmann & Bauland, 2006).

Stimulus issues are not unique to research with face stimuli—researchers have reported problematic results for snake and spider stimuli as well. In much of the classic work with adults, detection of snakes and spiders is generally compared to detection of flowers and mushrooms (e.g., Öhman et al., 2001). However, flowers and mushrooms differ from snakes and spiders on a number of levels—most importantly, they are not animals. Thus, the advantage for snakes and spiders might just be an advantage for animacy when the comparison groups are made up of plants. Indeed, several studies have reported a general advantage for animals in detection. For example, Lipp et al. (2004) examined the detection of snake, spider, horse, and cat targets among flower and mushroom distracters, and report no differences in the detection of threat-relevant versus non-threat-relevant animals. Similarly Lipp (2006) examined detection of snakes, spiders, cats, wolves and horses (also compared with flowers and mushrooms), and found a search advantage for all animals as well, not just threatening animals. Tipples, Young, et al. (2002) report similar results, finding an advantage for non-threatening animals like bunnies, kittens, and horses over plants.

In all detection research, careful attention must be paid to the selection of appropriate comparison stimuli. As Frischen et al. (2008) suggested, visual detection is highly sensitive to context, so the distracters play an important part in driving results. Indeed, using threatening stimuli as distracters slows the detection of non-threatening targets (Byrne & Eysenck, 1995; Fenske & Eastwood, 2003; Fox et al., 2002; Gilboa-Schechtman et al., 1999; Horstmann, Scharlau, et al., 2006; Lipp & Waters, 2007). Thus, it is vital to choose appropriate distracter stimuli in visual detection studies. Recent research has compared snakes and spiders to other animals, such as frogs, caterpillars, and cockroaches, which are much stronger control stimuli than flowers and mushrooms (e.g., LoBue, 2010b; LoBue & DeLoache, 2008). Further, recent work has also used uniform distracter stimuli to ensure that any differences in detection can be attributed to the effect of the targets (e.g., LoBue & DeLoache, 2011).

Besides stimulus issues, recent studies using eye-tracking technology have suggested that there might not be an advantage for threat in *detection* per se. A few studies have now reported that participants fixate threatening and non-threatening stimuli equally quickly, and the advantage for threat instead lies in quickly *deciding* that a threat is present. In other words, fixations to all stimuli occur at the same rate, but making a behavioral response (e.g., pressing a button; touching a screen) is faster after participants fixate threatening stimuli than after they fixate non-threatening stimuli (Derakshan & Koster, 2010; Flykt, 2006). Such studies are still relatively new. Future research using new eye-tracking methodologies might shed light on some of the mechanisms by which we detect threat so quickly, as eye-tracking can provide us with important information about the strategies individuals use in these paradigms. Eye-tracking can reveal whether detection of threat is *automatic*, and occurs within very few fixations; whether detection of threat is highly *efficient*, and occurs after very rapid scanning of the distracter stimuli; or whether there is no advantage in detection for threat at all, but *behavioral responding* is faster after a threat has been fixated than after a non-threat has been fixated.

Finally, despite strong evidence for the existence of detection biases for some commonly feared stimuli, there is still limited research providing causal evidence linking such biases to later fear learning. As discussed above, research has certainly linked attentional biases to anxiety in clinical populations, but it is still unclear whether there is a causal relationship between attentional biases for threat and later development of fear or anxiety in non-clinical populations. This is important—as we have seen from research with clinical populations, establishing this causal relationship has implications for potentially preventing the development of maladaptive fears and anxieties. Thus, one of the most important goals of for research is to further clarify whether early biases in perception indeed facilitate the development of our most common fears. If our hypothesis is supported, this work would have implications for the understanding of emotional development more broadly, suggesting that

perception plays an important role in the formation of specific fears, and opening the door for further research on the role of perception in the development of other emotions as well.

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