Clin Child Fam Psychol Rev (2010) 13:315–332
DOI 10.1007/s10567-010-0078-8

Is There Room for 'Development' in Developmental Models of Information Processing Biases to Threat in Children and Adolescents?

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Published online: 2 September 2010

Abstract Clinical and experimental theories assume that processing biases in attention and interpretation are a causal mechanism through which anxiety develops. Despite growing evidence that these processing biases are present in children and, therefore, develop long before adulthood, these theories ignore the potential role of child development. This review attempts to place information processing biases within a theoretical developmental framework. We consider whether child development has no impact on information processing biases to threat (integral bias model), or whether child development influences information processing biases and if so whether it does so by moderating the expression of an existing bias (moderation model) or by affecting the acquisition of a bias (acquisition model). We examine the extent to which these models fit with existing theory and research evidence and outline some methodological issues that need to be considered when drawing conclusions about the potential role of child development in the information processing of threat stimuli. Finally, we speculate about the developmental processes that might be important to consider in future research.

Keywords Anxiety · Information processing biases · Child development

Introduction

Anxiety is the most common childhood disorder and is associated with wide-ranging and serious impairments. Children as young as 3 years of age display symptoms associated with subclinical and clinical levels of anxiety (Egger and Angold 2006). Understanding the causal processes underlying child anxiety is important because symptoms of childhood anxiety often persist beyond childhood, through adolescence and into adulthood (see Weems 2008 for a review). Childhood anxiety is also associated with academic difficulties and underachievement (Ashcraft 2002; Crozier and Hostettler 2003), impaired social functioning and peer difficulties (Asendorpf et al. 2008) and is a major risk factor for subsequent psychological (Kim-Cohen et al. 2003; Lewinsohn et al. 2008; Roza et al. 2003) and physical health problems (Beesdo et al. 2009).

Childhood anxiety is associated with distinctive patterns of information processing biases (see Hadwin and Field 2010a for a review); clinical and experimental theories assume that processing biases in attention and interpretation represent a causal substrate that operates to influence cognitive representation in such a way as to mediate anxiety vulnerability directly (A. T. Beck and Clark 1997; Williams et al. 1997). As in anxious adults, there is prima facie evidence that anxious children selectively attend to threat in their environment, i.e., attentional bias (Garner 2010; Heim-Dreger et al. 2006; Nightingale et al. 2010), and disproportionately draw threatening interpretations of ambiguous stimuli, i.e., interpretation bias (e.g., Barrett et al. 1996; Bögels and Zigterman 2000; Creswell and O'Connor 2006; Hadwin et al. 1997; Muris and van Doorn 2003; Taghavi et al. 2000). Past research in adults indicates that attention and interpretation biases are causally implicated in creating anxiety (Mathews and MacLeod 2002); if these biases are trained in non-anxious adults their anxiety increases (e.g., Mathews and Mackintosh 2000; Wilson et al. 2006; Yiend et al. 2005) and if these biases

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are untrained in clinically anxious individuals they become less anxious (e.g., Amir et al. 2009; Schmidt et al. 2009; See et al. 2009). These training paradigms could be an analogue of how information processing biases develop in the real world; biases develop early in life through reinforcement for paying attention to threat or making threat interpretations in the face of ambiguity (Field and Lester 2010).

Hadwin and Field (2010b) stress the urgent need to consider the ongoing development of the child in theories and research into information processing in childhood anxiety. Therefore, this review is an attempt to place information processing biases in anxiety within a theoretical developmental framework. After defining what we mean by development, we will consider three broad possibilities[1]: (1) that child development has no impact on information processing biases to threat (*integral bias model*); (2) that child development moderates the expression of an existing bias (*moderation model*), and (3) that development affects the acquisition of a bias to threat (*acquisition model*). We will examine how each of these models fits with existing data, considering the evidence for attentional and interpretation biases in turn, and we explore some methodological issues. Finally, we look at how each conceptualization fits with existing theories of information processing biases and speculate about the developmental processes that might be important to consider in future research.

Theoretical Models of Anxiety-Related Information Processing Biases in Children

What is 'Development'?

When we talk about 'development,' we really mean change in an organism across its lifespan. In terms of information processing biases, we, therefore, are asking the question of how these processing biases to threat change: are they present from birth but change over time or do they come into existence as a result of experience? We might also ask what experiences or individual differences mediate these changes. Ollendick and colleagues have reviewed the models that historically have been used to characterize change and identified three conceptualizations of development (Ollendick et al. 2001; Ollendick and Vasey 1999): the *organismic model*, the *mechanistic model*, and the *transactional model*. The organismic model assumes that maturational processes intrinsic to the organism lead to qualitatively different ways of engaging with the environment. Piaget's developmental theory (e.g., Piaget 1936/1953; Piaget and Inhelder 1956) is an example of this conceptualization; the 'child as a scientist' actively constructs their environment. The mechanistic model is the polar opposite and sees the organism as changing in response to contingencies and reinforcers in the environment, with little influence from maturational or age-related process. As exemplified by Skinner's 'radical behaviourism' (Skinner 1971, 1974) the organism is a passive recipient of environmental experience that shapes their cognition and behaviour. The middle ground is occupied by the transactional model, which as the name suggests characterizes change as the product of transactions between the organism and environment. Development, therefore, involves "systematic, successive, and adaptive changes within and across life periods in the structure, function, and content of the individual's mental, behavioural, social and interpersonal characteristics" (Ollendick and Vasey 1999, p. 458). Events in the environment may well shape behaviour as in the mechanistic model, but the 'systematic and successive' nature of development implies that changes within the individual will also affect future events within the environment (the organismic model). When we use the term development we, therefore, assume a transactional model in which maturational processes (be they social, emotional or cognitive) interact with learning experiences within the environment to create changes in information processing.

Child clinical psychologists have given a lot of thought to how developmental psychology theory should inform classification and treatment of child psychological problems (Beesdo et al. 2009; Grave and Blissett 2004; Ollendick et al. 2001; Ollendick and Vasey 1999; Peterson and Tremblay 1999); however, rather less attention has been paid to how development fits into the aetiology of anxiety (but see Ollendick and Hirshfeld-Becker 2002) and especially information processing (Alfano et al. 2002; Vasey and MacLeod 2001 are noteworthy exceptions). Muris and Field (2008) note that models of anxiety increasingly emphasize the importance of biases in the detection and processing of threat-related information, and there is ample evidence (reviewed in Hadwin and Field 2010a) that processing biases to threat exist in child samples. The exact role of development in this process is unclear though. Prospective longitudinal (MacLeod and Hagan 1992; Pury 2002; Warren et al. 2000) and experimental studies (Mackintosh et al. 2006; MacLeod et al. 2002; Wilson et al. 2006) have demonstrated that biases in attention and interpretation can play a causal role in the onset of anxiety. These studies have typically trained information processing biases to threat in adults and,

[1] We have chosen these three models because we believe that they reflect the main broad ways in which child development influences information processing. As such, these models provide a convenient framework for reviewing the literature.

although they provide an invaluable proof of concept, they have two limitations. First, they fit with a mechanistic model; they demonstrate that through environmental reinforcement and contingency, humans can learn a negative processing style. However, if we take a transactional view of development then we need to also know how such learning interacts with maturational processes in childhood. Second, these computerized training methods are useful analogues, but they tell us little of whether this is the process through which information processing biases develop (if indeed they do) in the real world.

'Adult' Theories

The dominant theories of information processing biases to threat ignore developmental processes as we have defined them but agree that there is innate brain circuitry dedicated to evaluating threat in the environment: (1) Öhman and Mineka (2001) suggest that humans have an evolved fear module, originating in dedicated neural circuitry, that responds automatically to threat stimuli and is impervious to cognitive control; (2) Williams et al. (1988) proposed that humans have an Affective Decision mechanism (ADM) that evaluates the threat value of a stimulus event; and (3) Gray and McNaughton (2003) have identified circuitry (the behavioural inhibition system, BIS) in the septo-hippocampal area of the brain believed to be an evolved mechanism that, upon detecting threat, increases physiological arousal, inhibits ongoing behaviour and directs attentional resources to that threat. Although these models place a greater importance on automatic processing (they are all based on systems that are assumed to act automatically and without controlled processing), the role of controlled processing is acknowledged. For example, one interpretation of Gray's theory suggests that the BIS 'tags' automatic motor processes as 'needing to be checked', which heavily implies a role for cognitive control (Zinbarg and Mohlman 1998). Similarly, Öhman (1993) acknowledges that although some threat stimuli might be processed rather automatically, other stimuli might be passed onto a 'conscious perception system' that allows a conscious appraisal of the personal meaning of that stimulus. In contrast to these models that emphasize automatic processing, Wells and Matthews' (1994) propose a model of attentional bias based almost entirely on controlled processing. In their model, individuals execute voluntary monitoring plans that locate threat stimuli and then chose to attend to them, or not.

Most relevant to explaining information processing biases to threat is Mathews and Mackintosh's (1998) model, which is based on an automatic threat evaluation system (TES) but also acknowledges the role of controlled processing. Essentially, Mathews and Mackintosh argue that when potentially threatening and benign stimuli are in competition for cognitive resources, the sensory input from them leads to the respective activation of threat and benign representations that compete for attention. Similarly, if the sensory input is ambiguous then threat and benign interpretations are formed that compete for attention via inhibitory links. If the threat representation/interpretation is strong then it inhibits the benign representation/interpretation and vice versa, until a dominant representation/interpretation reaches a threshold activation level and enters awareness. The strength of the threat representation/interpretation is determined by the TES, which processes the sensory input and evaluates its threat potential, whereas the strength of the benign representation/interpretation is determined by a positive emotional evaluative system (PES), concerned with cues relevant to attaining rewards. Controlled processing comes into the model in the form of effortful control over task demands. The attention allocated to and interpretation placed upon stimuli and events depends on both the cognitive effort that a person exerts and the perceived threat of the stimulus/situation based on the extent to which it matches representations previously associated with threat and stored in the TES (or matches representations previously associated with reward and stored in the PES).

Most of the aforementioned theories share a common foundation that processing biases to threat have their roots in dedicated brain circuitry and that control of this circuitry or the responsiveness of this circuitry somehow differs in anxious and non-anxious people (Mogg and Bradley 1998). They differ in the relative emphasis they place on automatic and controlled processing of stimuli. Cognitive, social and emotional development has not explicitly been mentioned in any of these theories. Although there is an implication that the basic functionality of the brain circuitry should be unaffected by the child's development and we might expect controlled processing to 'develop' along with other skills, these theories make no firm predictions about what role development might have.

There are three main ways to conceptualize how child development might play a part in processing biases to threat; it does not influence it (the *integral bias model*), it moderates an existing bias (the *moderation model*), or it contributes to acquiring a processing bias that did not previously exist (the *acquisition model*). We will now describe each of these models in more detail.

The Integral Bias Model

Hadwin and Field (2010b) conclude that researchers have typically adopted an integral bias model (Fig. 1), that is, they assume that information processing biases are innate constituents of emotion, which are present during early

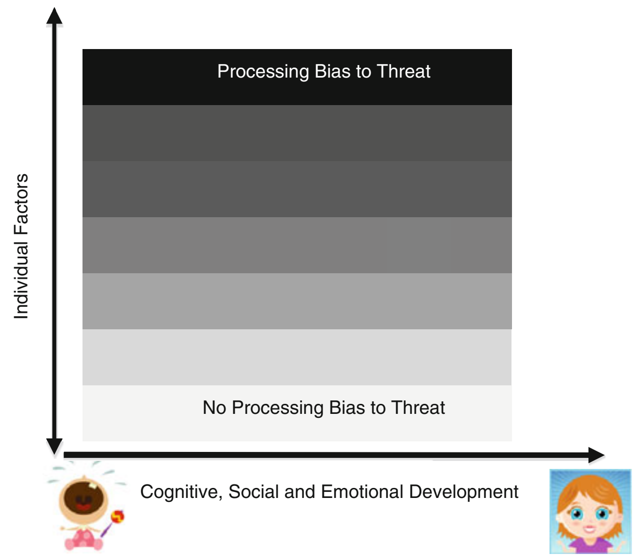

Fig. 1 An *integral bias model* of the information processing biases. The *shaded area* represents the degree of processing bias to threat (*dark shading* is a strong processing bias, *pale shading* is a reduced bias to threat). Where the child lies on the processing bias spectrum is determined solely by individual factors (such as anxiety) and does not change or interact with the development of the child

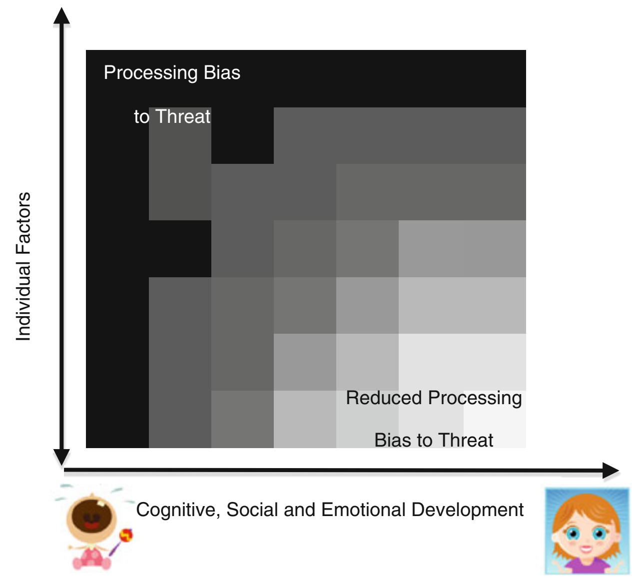

Fig. 2 *Moderation model* of the development of information processing biases. The *shaded area* represents the degree of processing bias to threat (*dark shading* is a strong processing bias, *pale shading* is a reduced bias to threat). All infants have a processing bias to threat, but where the child lies on the processing bias spectrum at a given later stage of development is determined by the interaction of development and individual factors (such as anxiety)

childhood and which do not change with development (Martin et al. 1992; Martin and Jones 1995). As such, individual factors (such as anxiety) determine the degree to which a processing bias is present, and the degree of processing bias remains unchanged by development (individual factors and development do not interact to change the processing bias). Put another way, information processing biases should not differ across children at different stages of development. In practical terms, this means that the child's development should not affect performance on measures of processing biases to threat (assuming that these measures are developmentally appropriate). Also, if development is assumed not to affect information processing then it is reasonable to believe that adult models can be applied downward to children.

Developmental Models of Information Processing Biases for Threat

If a child's development does have a role to play in biased information processing, then we believe that there are two main conceptualizations of how it could affect the course of information processing biases to threat: what we have called a *moderation model* (Fig. 2) and an *acquisition model* (Fig. 3). The moderation model proposes that information processing biases towards threat are present in all young children, but diminish over time as a function of individual factors (such as anxiety). As such, cognitive, social and emotional development act in different ways for different children (e.g., high vs. low anxious, children differing in temperament, neuroticism, etc.) resulting in different developmental trajectories whereby biases decrease with age in some children (e.g., non-anxious) and are maintained or increase with age in others (e.g., anxious children). Put simply, individual factors such as anxiety, personality and temperament interact with child development. The aspects of cognitive, social and emotional development that might interact with individual factors will be discussed later but could include the development of emotional regulation, the development of representational knowledge, social perspective taking, etc. For a moderation model to be a plausible conceptualization, we would need to have evidence that (1) processing biases to threat exist in *all humans* at a very early stage of development (as a presumably automatic process), and (2) the developmental trajectory of this processing bias varies as a function of individual factors such as anxiety levels. Ideally, of course, we would also want evidence for what aspects of development cause the change in developmental trajectory.

In contrast, many theorists have argued that children might need certain abilities in place prior to acquiring information processing biases. Acquisition models (Fig. 3) propose that the emergence of information processing biases towards threat may be linked to the development of the cognitive, social and emotional skills necessary to sustain them and which emerge during specific developmental stages in childhood (see Alfano et al. 2002;

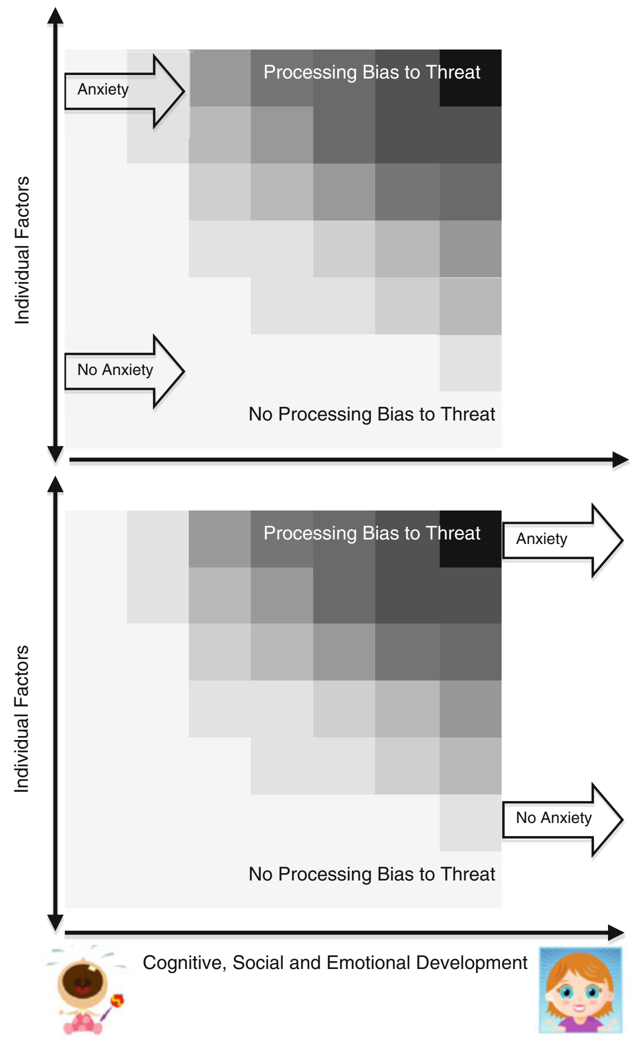

Fig. 3 An *acquisition model* of the development of information processing biases. The *shaded area* represents the degree of processing bias to threat (*dark shading* is a strong processing bias, *pale shading* is a reduced bias to threat). All infants begin without a processing bias to threat, but where the child lies on the processing bias spectrum at a given later stage of development is determined by the interaction of development and individual factors (such as anxiety). The two models differ in whether they assume that trait anxiety is one of the individual factors that interacts with development (*top*) or a consequence of acquiring a processing bias (*bottom*)

Manassis and Bradley 1994; Muris 2007). As such, the acquisition model assumes that information processing biases towards threat are not present (or are present but not fully formed) in young children, but they emerge with developmental sophistication. As in the moderation model, development will interact with individual factors such as temperament; however, the role of anxiety is quite different. In the moderation model, anxiety is assumed to feed into development to change the developmental course of the processing bias; anxiety could have a similar role in the acquisition model (top panel Fig. 3) in that trait anxious children are more likely to acquire a bias. However, it is also possible that trait anxiety emerges as a result of acquiring a processing bias (bottom panel, Fig. 3). In other words, previously non-anxious children become anxious because of acquiring a processing bias to threat.[2] This later possibility is consistent with research that has shown that training processing biases to threat has a causal effect on anxiety (e.g., Mackintosh et al. 2006; MacLeod et al. 2002; Wilson et al. 2006). For the acquisition model to be plausible, we need evidence that (1) processing biases to threat are not present in all humans, but emerge only in certain children, and (2) the child's cognitive, emotional or social development influences the emergence of the processing bias. There is then also the issue of whether existing anxiety feeds into the development of the bias, or the bias creates anxiety.

Distinguishing Between the Models

To distinguish integral bias, moderation and acquisition models we need to answer two simple questions as illustrated in Table 1: (1) is there evidence that processing biases for threat exist from very early in a child's development (this question distinguishes integral bias and moderation models from the acquisition model); (2) is there evidence that processing biases to threat have a developmental trajectory (this question distinguishes the integral bias model from the moderation and acquisition models). Both integral bias and moderation models assume that children begin life with processing biases for threat. However, the moderation model (see Fig. 2) differs by assuming that these biases change as a function of cognitive, emotional or social development (Kindt et al. 1997; Kindt and van den Hout 2001). The integral bias model assumes instead that processing biases vary as a function of individual differences, but essentially remain constant over time and development (see Fig. 1). Therefore, the extent to which a person shows a processing bias to threat (or not) will reflect the innate sensitivity of the relevant neural circuitry. For example, people with a temperament such as behavioural inhibition, which is evident as young as 4 months old and reflects avoidance of novel objects and withdrawal from unfamiliar social interactions, might be expected to have greater processing biases to threat (White et al. 2010). Therefore, we can further distinguish the integral bias and moderation models by asking not only whether processing biases to threat are present from very early in a child's development, but also whether *at this early stage of development* they are present in all people (moderation model) or in only a subset of people (integral

[2] These two possibilities are extremes, and there is a middle ground: already anxious children become more anxious having acquired a processing bias to threat.

Table 1 Distinguishing models of information processing biases to threat

	Integral bias	Acquisition	Moderation
Is there evidence for information processing biases to threat from birth?	Yes	No	Yes
Is there evidence that cognitive or social development affects information processing biases for threat?	No	Yes	Yes

bias). We will attempt to answer these questions for attentional and interpretational processing biases in turn.

Attentional Biases to Threat

Do Attentional Biases for Threat Exist from Very Early in a Child's Development?

There is evidence that attentional processing biases to threat exist in all children and begin very early in life; children appear to have the capacity to demonstrate attentional biases to threat from very early in their development. Both pre-school age children (LoBue and DeLoache 2008) and infants as young as 5 months (LoBue and DeLoache 2010; Rakison and Derringer 2008; Thrasher et al. 2009) show attentional biases to fear-relevant stimuli such as snakes, spiders and threatening faces. Rakison and Derringer (2008), for example, observed that 5-month-old infants had significantly longer looking times in a preferential looking paradigm to schematic spider figures relative to scrambled or reconfigured spider stimuli. They argue that this finding is consistent with infants possessing a perceptual template for evolutionarily relevant stimuli. The presence of such a perceptual automatic template for "attention grabbing" fear-relevant stimuli may represent a mechanism by which potential threats can be rapidly identified. Similarly, LoBue and colleagues (LoBue 2009; LoBue and DeLoache 2008, 2010) have established that infants and preschool children orient more quickly to snake stimuli than flowers and to angry faces compared to happy faces. Furthermore, pre-school children's previous experience of snakes did not influence their bias towards them. Only one study provides any evidence that groups of infants differ in their processing of threat information; Creswell et al. (2008) measured looking times by coding videotapes of infants viewing faces displaying different intensities of angry, happy and fearful emotions. There were no significant differences in face processing between behaviourally inhibited children and controls in looking times to emotional faces, which support a moderation model over an integral bias model. However, children of socially phobic mothers showed a reduction in looking times to high-intensity fearful faces compared to controls, but only when the face was presented on the right. Although these later findings support an integral bias model, they are a little hard to unravel (as the authors acknowledge). First, attentional biases to angry faces are frequently found in socially anxious individuals (e.g., Mogg et al. 2004), yet Creswell et al., did not find significant group differences in infants; they did, however, find a general bias (in all children) when angry faces were presented on the left,[3] which supports a moderation model. For fearful faces, at 10 weeks old there was a significant interaction between group (mothers are socially anxious or not) and intensity (high vs. low) of the displayed emotion; children of socially anxious mothers showed a bias for avoiding high-intensity fearful faces presented on the right. Although this finding prima facie supports an integral bias model, this significant group by intensity interaction was not present at 16 weeks and 10 months[4] suggesting moderation of this initial bias.[5] This study highlights the need for more research on attentional processing biases to threat in infancy; although Creswell et al.'s study is unique and highly innovative, the results are complex and provide support (to some degree) for both integral bias and moderation models.

There are studies in older children too that suggest a general attentional bias to threat in all children. For example, Kindt et al. (1997) investigated whether high and low non-clinically anxious children aged 8–9 exhibited a preferential attentional bias for threat in a stressful situation (immediately prior to a vaccination) using a single-trial word-based emotional Stroop task. Although the medical stressor elicited greater anxiety in the high-anxious children, both high- and low-anxious children exhibited selective attention for threat words relating to the medical situation (e.g., injection, fainting). However, the attentional bias found in all children could be explained by them adopting a strategy to prioritize the processing of stressor-related information because of the acute medical stressor directly priming cognitive representations of threat (Mogg et al. 1990). Therefore, in a second experiment, Kindt et al. used a neutral situation (a school setting) and again found that both high- and low-anxious children exhibited a bias to threat words related to the medical situation suggesting that

[3] This left-visual field bias is consistent with other research (e.g., Field 2006b; Mogg & Bradley 1999, 2002).

[4] There was some evidence for group differences at 10 months consistent with those at 10 weeks, but the group × intensity interaction was not significant.

[5] This finding suggests a hybrid model that we have not considered in this review—that is an integral bias (the degree of bias in infancy is determined by individual factors) that is later moderated.

the presence of an acute medical stressor was not necessary for a processing bias to emerge. Furthermore, a processing bias towards more generally threatening words emerged in both high- and low-anxious children, although this bias was significant for girls only. Waters et al. (2004) used a pictorial dot-probe task and similarly demonstrated an attentional bias towards threat in both clinically anxious and non-selected children up to 12 years of age.

So far we have seen that there is evidence for attentional biases very early in life (which supports the integral bias and moderation models, and goes against an acquisition model). In very early life, attentional biases are typically found in all children, which supports the moderation model over the integral bias model. These biases are certainly stronger for evolutionarily significant stimuli. One study showed some tentative support for group differences in threat processing in infancy (Creswell et al. 2008), and in older children, numerous studies have shown an attentional bias for threat stimuli that is specific to anxious children and adolescents (e.g., Dalgleish et al. 2001, 2003; Martin et al. 1992; Monk et al. 2006; Moradi et al. 1999; Pine et al. 2005; Stirling et al. 2006; Taghavi et al. 1999; Waters et al. 2008; Waters and Valvoi 2009) or children with anxiety-related temperaments such as behavioural inhibition (Perez-Edgar and Fox 2003, 2007; White et al. 2010). In addition, a recent meta-analysis on attentional biases in anxious and non-anxious individuals determined that the pattern of attentional biases is equivalent in adults and children with anxious children and adults demonstrating a significant bias towards threat while non-anxious children and adults show no significant threat-related bias (Bar-Haim et al. 2007). The extent to which this body of work supports the integral bias model over a moderation model depends upon whether these group differences arose through a developmental process. We shall evaluate this possibility in the next section.

Do Attentional Biases to Threat have a Developmental Trajectory?

The integral bias model assumes that inherent processing biases are unaffected by the child's development. A couple of studies support this hypothesis (e.g., Martin and Jones 1995; Moradi et al. 1999) by showing that the magnitude of attentional bias is consistent across age, and presumably, therefore, development. However, these studies did not directly look at the children's development. In addition, behavioural genetic research suggests that processing biases to threat are moderated by environmental influences; only 30–40% of the variance in processing biases to threat is heritable (Eley and Zavos 2010), leaving environmental factors to explain the remaining two-thirds.

The moderation and acquisition models both assume that processing biases to threat are altered by child development. Although there is relatively little research that directly looks at the developmental trajectory of processing biases to threat, there is circumspect evidence in that learning influences the expression of attentional biases; after giving children verbal information about a novel animal, they showed an attentional bias to pictures of these animals compared to control animals about which they had heard no information (Field 2006b). The effect that verbal information had in producing this attentional bias was exacerbated by levels of trait anxiety in the children (Field 2006a). The likely explanation of these findings is that the children's TES (to use Mathews and Mackintosh's terminology) became sensitive to those animals once the verbal information had caused the children's mental representations to be associated with 'threat' or 'danger'. In a similar vein, in an attentional task LoBue (2010) showed faster detection of stimuli with which 3-year-old children had previously had negative experiences (syringes) compared to those to which there was no evidence of previous negative experience (knives). These three studies demonstrate that even an innate attentional threat processing system has to be sensitive to learning to adapt to new information.

The only direct evidence that development moderates attentional biases to threat comes from studies by Kindt and her colleagues. While consistent with a moderation model, this work is not without its shortcomings, most noticeably the role of development is considered only in terms of increasing age rather than actual cognitive, social or emotional developmental abilities. Kindt et al. (1997) broadly replicated their aforementioned findings of an attentional bias to threat when comparing spider fearful and control children aged 8–12 years; all children selectively processed spider-related information in a spider Stroop task. However, they also found a differential association between age and processing bias: the bias towards threat increased with age in the spider fearful group, but decreased in the control group. Kindt et al. (2000) extended these findings in two experiments with spider fearful and control girls aged 8–11 years. A processing bias for spider words was present in all children aged 8; however, this processing bias decreased with age in non-fearful children, but was maintained across age in the fearful children. The differentiation between spider fearful and non-fearful children arose at approximately 10 years of age. Kindt et al.'s *inhibition hypothesis*, which is a moderation model, suggests that normally developing children learn to inhibit automatic processing of potential threat from middle to late childhood, but anxious children do not. Kindt and van den Hout (2001) suggest that anxiety experienced during childhood creates a failure to inhibit selective attention to threat, which in turn, increases susceptibility to developing an anxiety disorder in adulthood (see Nightingale et al. 2010 for a review). However, one other study that directly tested Kindt's inhibition hypothesis found little evidence of the predicted differential age effects; in a large sample of high and low spider fearful children aged 7–11 years, Morren et al. (2003) failed to find the expected bias for spider words in either spider fearful or control children.[6] However, we consider that as it currently stands, a moderation model is most consistent with the evidence for attentional biases in childhood. Attentional biases to threat appear to be present in early childhood as a normal phenomenon, but these biases then change as a function of a child's development and anxiety levels, with the critical developmental period arising at around 10 years of age.

Interpretation Biases to Threat

Do Interpretation Biases for Threat Exist from Very Early in a Child's Development?

Infants can draw inferences in the presence of ambiguous information (Hamlin et al. 2009) and modulate their behaviour to ambiguous stimuli on the basis of other people's emotional reactions (Moses et al. 2001). However, there is no research to show whether infants interpret ambiguous information in a threatening way; evidence for interpretational bias to threat in anxious children has typically been shown only in children aged 7 or older (see Muris 2010; Muris and Field 2008 for reviews), but by this age a significant amount of cognitive, emotional and social development has already occurred. This focus on older children is partly because the majority of studies have employed straight adaptations of adult interpretive bias tasks, which rely on language (for example, giving children a written ambiguous scenario and asking them to generate a likely outcome). These measures are likely to be inappropriate or insensitive to detecting biases in younger children. As such, there is an urgent need to develop age-appropriate measures to determine whether interpretation biases are present at earlier ages (Hadwin and Field 2010b) because only then will it be possible to determine whether interpretation biases develop in accordance with an integral bias, moderation or acquisition model.

As such, there is no evidence either way to answer the question of whether interpretation biases are present from a very young age (and, therefore, support integral bias and moderation models over acquisition). All we do know is that, in general, the evidence for biased *interpretations* to threat is consistent with the presence of a threat-related interpretation bias in anxious children and no threat-related bias in non-anxious control children; childhood anxiety is associated with a bias towards making threat interpretations of ambiguous scenarios (Barrett et al. 1996; Bögels and Zigterman 2000; Creswell and O'Connor 2006), selecting the threat interpretation of ambiguous homophones (Hadwin et al. 1997; Taghavi et al. 2000) and being faster and requiring less information to conclude that ambiguous vignettes will have a threatening conclusion (Muris et al. 2000). As with attentional biases, this evidence can discriminate integral bias and moderation models only once we know whether development contributed to these group differences. To discriminate moderation and acquisition models, we would need to know whether these interpretation biases are present in all humans from early infancy. However, identifying the best methods by which to demonstrate the presence or absence of interpretation biases in infancy, using tasks that do not rely on language abilities remains a methodological challenge.

Do Interpretation Biases to Threat have a Developmental Trajectory?

There is evidence that interpretation biases can be 'trained' in children, but the effects on anxiety are less clear than in adults (Muris et al. 2008, 2009). There has been a paucity of research attempting to systematically link child development to interpretation biases. Previous research has focused largely on exploring associations between cognitive and social developmental concepts, namely Theory of Mind (ToM) and Piagetian conservation principles and interpretation biases. Muris et al. (2004) examined children's interpretation of anxiety-related physical symptoms in a sample of 4- to 12-year-old children. They found that from the age of 7, children were increasingly able to link physical symptoms with fear and anxiety, suggesting that this ability may represent a normal, developmental phenomenon that particularly emerged in children aged 7 and above (supporting an acquisition model). However, some 4- to 6-year-olds were able to correctly associate fear with anxiety-linked physical symptoms, which might simply reflect more cognitive maturity in these children or greater exposure to certain learning experiences, that have primed the link between fear/anxiety and physical symptoms (Muris et al. 2004). Replicating his earlier research, Muris found that from 7 years of age, children were increasingly able to relate physical symptoms to fear and anxiety (Muris et al. 2008); both age and cognitive development, as

[6] The results were rather more complicated than this statement suggests; for non-integrated stimuli (the target and distracter are not integrated into a single stimulus) no bias was found, but for integrated stimuli (the target and distracter are a single entity) a bias was found in the first block of trials but not the second. The important point for our argument is that the predicted change in processing bias with age was not found.

measured by performance on Piagetian conservation tasks, independently predicted children's ability to relate physical symptoms to anxiety. In a further study, both performance on Piagetian conservation tasks and a Theory of Mind (ToM) test predicted anxious interpretations and emotional reasoning scores (Muris et al. 2007); ToM ability was a stronger predictor of children's interpretations than conservation. It may be that with increasing age, children have encountered more learning experiences, providing them with more direct or indirect information about physical symptoms and their relation to emotion. Furthermore, older children, who have more advanced cognitive skills, may be even better in linking physical symptoms to fear and anxiety (Muris et al. 2002a). The greater predictive power of ToM ability could be because this test more closely measured children's conception of emotions and was, therefore, more closely associated with what children had to do during the interpretation task.

All of these studies seem to suggest an acquisition model of interpretation biases: as the child develops cognitive and social sophistication they concurrently develop interpretation biases. The implication is that only once certain cognitive and social building blocks are in place can the child express a biased interpretation of ambiguous cues (such as bodily sensations). Unlike with attentional biases, there is no evidence to suggest that trait anxiety (or fear of a specific relevant stimulus) moderates the developmental trajectory of these interpretation biases. This conclusion implies that anxiety is causally influenced by the acquisition of an interpretation bias rather than feeding into their creation (i.e., the model in the bottom panel Fig. 3).

Methodological Issues

It is clear that there are inconsistencies in the available data. For example, studies that have used 'adult' tasks to measure information processing biases in children such as the emotional Stroop task, the dot-probe task, visual search, and interpretation bias measures have found both evidence for and against biases to threat in anxious children (see Donnelly et al. 2010; Garner 2010; Muris 2010; Nightingale et al. 2010 for reviews). Researchers have tended to apply downward adult tasks to measure these biases; consequently, procedural details vary enormously because researchers differ in both the amount that they have attempted to make the tasks developmentally appropriate and the strategies they have employed to do so. Consequently, the evidence for processing biases to threat in anxious children tends to be considerably less consistent than in adults, particularly in relation to threat-related attentional biases (Waters et al. 2008). These inconsistent findings could imply that a child's development is an important component of the expression, and perhaps acquisition, of information processing biases, which would rule out the integral bias hypothesis. However, it is also highly likely that methodological issues can in part, explain the inconsistency in results.

For example, the number of trials used by Morren et al. (2003) was significantly greater compared to previous studies from the same research team (e.g., Kindt et al. 2000); therefore, Morren et al.'s failure to find evidence for a moderation model, could simply be because children in their study became task fatigued.[7] There are other examples of procedural factors that influence the extent to which processing biases are apparent in the data (see Puliafico and Kendall 2006). For example, when integrated stimuli (the target and distracter are presented together) are used, processing biases to threat were found in all children, but when non-integrated stimuli (the target and distracter are presented independently, e.g., visual probe tasks) processing biases to threat have been shown both in all children (e.g., Ehrenreich and Gross 2002; Waters et al. 2004) and only in anxious children (e.g., Stirling et al. 2006; Vasey et al. 1995; Waters et al. 2008). It is also true that although Kindt's work used word stimuli, studies using pictorial stimuli have also found both anxiety-specific bias effects (e.g., Monk et al. 2004; Pine et al. 2005) and a general threat processing bias (Waters et al. 2004).

Age is also an important moderator of research findings. Studies showing an attentional bias to threat have mostly sampled younger children (8–12 years), whereas studies demonstrating an anxiety-related attentional bias have included children from an older age range (9–19 years). Although this pattern of results supports the moderation model, there are related performance issues too; developing cognitive abilities could affect performance on measures of cognitive processing. For example, younger children might experience fatigue more easily or produce more unreliable reaction times. As such, there is likely to be excessive measurement error when using 'adult' tasks to measure processing biases both in samples focusing on younger children and in those with wide age ranges. This concern is particularly pertinent because many studies that have investigated processing biases towards threat have recruited children with wide-ranging ages. In addition to the performance variability between older and younger children, there is an important developmental point too: adult models of cognitive processing are more relevant to older adolescents than pre-teenage children because, cognitively speaking, they differ very little from adults (whereas pre-teenage children's cognitive abilities are still developing).

[7] As noted above, there was greater evidence for a processing bias in the first block of trials than the second.

It could be that the success or failure to show processing biases to threat depends on the sample characteristics (samples of teenagers are cognitively more similar to adults than samples of children under 10 years old). For example, child studies included in Bar-Haim et al.'s (2007) meta-analysis included participants up to 18 years of age. They acknowledged that the older children could have driven the anxiety-related attentional bias effects in their analysis, but there were not enough studies using children to allow a more detailed examination of the developmental course of attentional bias. To sum up, a major problem with research in this area is that age might moderate performance on the tasks rather than information processing (i.e., information processing biases to threat might be found in younger children using different, more sensitive, tasks).

Variations in anxiety severity could also, in part, account for the inconsistent evidence for processing biases to threat in children (Waters et al. 2008). For example, studies that have observed attentional biases to threat only in anxious children have tended to compare more severe or clinically anxious children to non-anxious controls (e.g., Monk et al. 2006; Moradi et al. 1999; Pine et al. 2005; Taghavi et al. 1999; Vasey et al. 2005), whereas studies demonstrating a general threat bias have often compared analogue samples of high- and low-fearful children (Ehrenreich and Gross 2002; Kindt et al. 1997) or clinically anxious versus non-selected children (Waters et al. 2004). To sum up, methodological issues inherent in the literature hinder the extent to which we can draw conclusions about the role of child development in information processing of threat stimuli. Child development does not just affect emotional processing, but also a child's ability to understand and engage with tasks that measure this processing. A major challenge for researchers is, therefore, to think of innovative ways to capture information processing biases so that age-dependent change in task performance does not confound age-dependent change in processing of threat information.

The Role of Child Development in Theories of Information Processing Biases to Threat

On balance, we believe that the existing evidence suggests that the role of development may be rather different for attentional and interpretation biases. The research suggests that attentional biases to threat are a normal phenomenon in early childhood, but these biases then change as a function of child development, consistent with a moderation model. Evolved brain circuitry guides all children's attention to potential threat in the environment, probably through a habitual learning system (see Field and Lester 2010), but the child develops effortful control of this process as they mature cognitively. Children with anxiety disorders may fail to gain control of these biases (Kindt and van den Hout 2001). In MacLeod and Mathews' (1991) and Mathews and Mackintosh's (1998) models, anxiety leads to selective attention only when an individual is exposed to two simultaneous stimuli and the subject must prioritize processing of a target stimulus while inhibiting processing of a distracter stimulus. Anxiety acts in this situation not to increase the availability of threatening information, but instead skews the mechanisms involved in controlling the assignment of processing priorities towards the processing of threatening information. This selective processing of threat information occurs at the expense of processing other information, due to the limited information processing capacity of the human cognitive system. Information processing capacities are thought to be even more limited in children than in adults (Flavell 1985) which implies that as children gain greater cognitive processing abilities they will exert more cognitive control over their automatic processes.

Although the evidence for our conclusions about attentional biases is far from unequivocal, it is a shining beacon of clarity compared to the evidence relating to interpretation biases. All we can say with any degree of certainty is that interpretation biases to threat seem to vary as a function of anxiety and child development, which rules out only the integral bias model (which predicts no role for development). In terms of deciding between the moderation and acquisition models, there is no evidence of interpretation biases in infancy and we are faced with a methodological conundrum regarding how such a bias would be demonstrated using tasks that do not require language abilities.

Theoretically speaking it is possible to argue for both moderation and acquisition models. According to Mathews and Mackintosh's model (1998), interpretation and attentional biases are driven by the same cognitive processes; therefore, it follows that interpretation of ambiguity, like attentional biases, might also develop according to a moderation model. This conceptualization would imply that the aforementioned threat processing circuitry in the brain initially processes ambiguous information in a threatening way, but as children's cognitive capacities develop they learn to control the processing of threat information so as to sometimes process such information in a non-threatening way. However, anxious children may be less successful in learning to control threat processing and inhibit threat interpretations. If this is the case, then we might expect to observe a similar common bias to threat interpretations in young children but with increasing cognitive, social and emotional development and age, differential effects should begin to emerge with threat biases decreasing in non-anxious children while being maintained in anxious children. As we saw in the previous section, there is little current evidence for this moderating role of anxiety.

In terms of arguing (theoretically) for an acquisition model, Mathews and Mackintosh suggest that if the input into the system is ambiguous then both threat and benign interpretations are formed that compete for attention via inhibitory links. Creating benign and threat interpretations might require some cognitive sophistication (at least in some circumstances), which tends to suggest an acquisition model: as children's understanding of interpretation and multiple realities develops so might their capacity to generate threatening interpretations. Consistent with this line of reasoning, Field and Lester (2010) suggest that attentional biases are probably underpinned by habitual associations, which can be formed without the need for higher level cognition, but can be influenced by cognition as the child develops. In contrast, the associations underlying interpretation biases probably rely on cognition to be formed. For example, a child might need to understand what ambiguity is before they can form an association of the kind 'ambiguity → threat'. Cognitive development can affect the associations underlying both attentional and interpretive biases, but attentional biases can be based on both habitual and cognition-based associations whereas interpretation biases will be based only on cognition-based associations. Therefore, in accordance with an acquisition model, we might expect interpretation biases to develop later in childhood than attentional biases and aspects of a child's cognitive development will influence their emergence. As such, we do not anticipate that threat-related interpretation biases are present as a normal developmental phenomenon from infancy. Instead in early childhood, exposure to ambiguity leads to threat or non-threat interpretations in a fairly arbitrary way, but over time developmental factors influence learning processes, which result in some children adopting more threat interpretations and others more non-threat interpretations. The research to date certainly suggests that children's abilities to worry and draw inferences about ambiguous symptoms is related to child development, but considerably more work is needed to determine how these interpretation biases become more entrenched and what role anxiety plays in this process (is it a cause or effect of the bias).

What Aspects of Development Might Affect Information Processing Biases?

There is an important challenge for researchers to identify which aspects of development underpin information processing biases and whether the bias and cognitive, emotional or social abilities develop in parallel (the bias emerges or changes at the same time as some cognitive ability) or sequentially (the bias is acquired or changes only after certain cognitive building blocks are in place). These issues are not easy to tease apart, not least because it is not clear which 'abilities' might or might not be important. The picture is further complicated by the often-artificial demarcation between cognitive, emotional and social development. For example, infants as young as 7 months can distinguish (both in terms of preference and neural activity) between prototypes of threat and non-threat facial expressions (Creswell et al. 2008; Hoehl and Striano 2008) but that even in late childhood the ability to distinguish threat and non-threat facial expressions in a more fine-grained way is still developing (Thomas et al. 2007). This apparent 'emotional' development is presumably interacting with cognitive processes that emerge post-infancy and enable a more interpretative processing of emotional expressions. Similarly, aspects of social development such as how one presents oneself to others (so called 'display rules'), are linked to cognitive skills such as an ability to take another person's perspective (Banerjee and Yuill 1999). The previous example also highlights how social development is intrinsically linked with emotional development: for example, when it is appropriate, or not, to display certain emotions. In this section, we highlight some important markers of social, emotional and cognitive development that could mediate information processing biases.

Initial 'developmental' research into information processing biases looked at sensible global markers of cognitive and social development such as Piagetian conservation and theory of mind (e.g., Muris et al. 2007). However, these developmental markers might be relatively insensitive ways to assess the skills on which information processing biases and anxiety depend; it is not clear how these tasks relate specifically to the abilities necessary and sufficient to have information processing biases to threat. The obvious question then is what specific markers of development are necessary to have an interpretation or attentional bias to threat? Depending on whether you adopt a moderation or acquisition model, then you want to know what skills might moderate a pre-existing bias (this is probably the case for attentional biases), or what aspects of development enable the acquisition or expression of a bias (this is more likely to be relevant to interpretation biases). We consider first interpretation biases.

Child Development and Interpretational Biases

In theoretical terms, Piaget (1936/1953) suggested that during the concrete operational stage of development (which typically occurs around age 7) the child begins to be able to perform mental operations on actual or imagined concrete objects. There are various abilities associated with this stage one of which is 'conservation', which tests a child's ability to mentally reverse the transformation of one of the objects to understand that although its visual appearance has changed, its critical properties have not. This is the ability assessed in some studies (Muris et al. 2007, 2002a, b, 2008) with a standard task in which a child sees two objects that are the same (e.g., balls of clay, beakers of liquid, etc.), one of which is then transformed (the liquid is poured into a taller, thinner beaker; the clay ball is rolled into a sausage shape). The child is said to be able to conserve if they correctly answer a question that assesses whether they recognize that the objects remain the same despite the transformation (e.g., 'is there the same amount of liquid in the two beakers?' 'Which object has more clay?'). Although an ability to mentally reverse a transformation might correlate with an ability to generate multiple possibilities in the face of ambiguity (which is important in Mathews and Mackintosh's model of processing biases to threat), it is not directly obvious that this cognitive ability enables an interpretation bias. There are other abilities associated with the concrete operational stage that arguably have a more direct link. According to Mathews and Mackintosh's model (1998) an interpretation bias requires an ability to hold multiple potential outcomes in mind; perhaps then, decentring, which is a child's ability to entertain multiple aspects of a problem to solve it, is a more relevant cognitive skill to sustain an interpretation bias.

During the concrete operational stage, a child's thinking is based on concrete reality and it is not, until the formal operational stage, at approximately 11 years of age that the child becomes more able to consider abstract ideas. An appreciation of ambiguity, arguably involves an appreciation of abstract ideas and an ability to entertain multiple perspectives, skills that according to Piaget developmental stages do not emerge until around 11 years of age. Therefore, we might reasonably expect that children under the age of 11 do not (in Piagetian terms) have the cognitive skills to misinterpret ambiguity.

The other theoretical framework that has been employed is Theory of Mind (ToM), which has been used as an index of children's developing understanding of social and emotional knowledge (e.g., Muris et al. 2007). By 4–5 years, children begin to understand knowledge as representation and with that start to appreciate characteristics associated with representation (Perner 1991). Arguably, as well as gauging social and emotional development success on false belief tasks and other measures of theory of mind depend on cognitive skills such as a child's appreciation that the same object can be represented in different and seemingly contradictory ways (Flavell et al. 1993, 1995). For example, in the classic theory of mind task, a character believes that an object (usually a ball or sweet) is in one location, but this object is moved to another location without the character's knowledge. The child has to say where the character thinks the object is. To do this successfully, the child needs to know that in reality the object is in one location but that the character has a representation of that object being in a different location. As such, a child needs an interpretational understanding of representation to pass the task (Wellman and Hickling 1993). If this view of the development of a child's understanding of mental states is adopted, then theory of mind probably is a necessary condition for understanding ambiguity, but not necessarily a sufficient one.

Like the Piagetian developmental framework, there is a sense in which theory of mind can tell us only so much about social, emotional and cognitive abilities that might relate to interpretational biases. Carpendale and Chandler (1996) argue that ToM insufficiently explains the complex process of understanding the interpretative nature of knowledge. They argue that an interpretive theory of mind does not develop at the age of 4–5 years as suggested by ToM tasks, but instead begins to emerge only at 6–8 years and is by no means complete at this age. They suggest that only at 7–8 years can children begin to understand than an object or message can have multiple meanings. This observation has direct implications for interpretational biases, which presumably require a child to understand multiple consequences of a situation (we will discuss later whether this meta-cognition is necessary to have a response bias). In two experiments, Carpendale and Chandler gave children a standard false belief task and also several tasks involving (1) lexical ambiguity (e.g., two characters are waiting for a 'ring', where it is not clear if they are waiting for a diamond ring or a phone call); (2) ambiguous communication (e.g., a penny is hidden under one of three cards, two of which depict a red block, and a puppet is told that the penny is hidden under a card with a red block); and (3) visual ambiguity (e.g., Jastrow's (1900) 'duck-rabbit'). Although children aged 5 routinely passed the false belief task, they generally did not have competence in the interpretation tests until several years later. It was only at 7–8 years of age that, when discussing matters of interpretation, children could explain differences in opinion in terms of the ambiguity of the original situation. In a later study, using the 'droodle' task, Lalonde and Chandler (2002) observed that 5- and 6-year-old children reliably assigned false beliefs to a puppet (63.4% of 5-year-olds and 79.9% of 6-year-olds), but the vast majority failed to demonstrate an interpretive theory of mind by attributing different false beliefs to two puppets viewing the same ambiguous stimuli (10.2% of 5-year-olds and 29.6% of 6-year-olds did attribute different false beliefs). In contrast, 7-year-olds demonstrated mastery of both tasks attributing a false belief in 95% of cases while 83.3% were able to attribute different interpretations. It seems clear from this literature that children's explicit reasoning about ambiguity does not develop until around the age of 7. However, a child might well be able to demonstrate a response bias to ambiguous input without needing to articulate an understanding of ambiguity or their response to it. For example, children can make correct responses in the face of ambiguity at 5–6 years old (Beck and Robinson 2001; Beck et al. 2008), even though they cannot explicitly reason about it until age 7 (Lalonde and Chandler 2002).

In Piagetian terms, we might argue (on theoretical grounds) that an interpretation bias should not develop until the age of 11, but based on work on interpretational theory of mind, this age might be lowered to around 7, and based on children's abilities to respond to ambiguity could even be lowered to 5. Interpretation biases have been shown in children as young as 7, which contradicts Piagetian theory and highlights some important issues. First, Piaget's developmental stages are entrenched in logical reasoning and, so perhaps it is not the best framework to think about children's emerging cognitive understanding of ambiguity, interpretation, and emotional states generally. Information processing biases are not logical. Second, it is fairly widely known that skills such as decentring and conservation are easily demonstrated in children much younger than Piaget's theory predicts: for example, using developmentally appropriate tasks, children as young as four can conserve (Donaldson 1984). Therefore, researchers need to be mindful not just of theoretical constructs that should predict how ambiguous or threat information is processed, but also how these skills are measured. As with assessing the biases themselves, the developmental appropriateness of the tasks is key. Finally, there could be an important distinction between having a response bias, and having meta-cognition about that response bias. This final point is particularly important for researchers to bear in mind when considering the role of development (especially cognitive) in information processing biases.

Child Development and Attentional Biases

Turning to attentional biases, we assume a moderation model, like Kindt's inhibition hypothesis. As was the case with interpretation biases, it is not clear how Piagetian skills such as the ability to conserve (or decentre), or theory of mind, would influence an existing attentional bias to threat (other than as general markers of cognitive sophistication that perhaps correlates with better control of the attentional system). Instead, the likely developmental moderator of attentional biases is, as Kindt proposed in her inhibition hypothesis, effortful control. Effortful control is an important facet of temperament and involves the ability to employ self-regulatory executive functions to engage and allocate attention in response to positive and negative emotionality (Lonigan et al. 2004). Effortful control is defined as the ability to "inhibit a dominant response in order to perform a subdominant response" (Rothbart and Bates 1998, p. 137) and has two components: self-regulation of attention—attentional control—and the ability to regulate and inhibit behaviour—inhibitory control (Rothbart et al. 2004). High effortful control is associated with the ability to flexibly manage and redirect attentional processing, modulate and constrain the experience of distress in response to emotional stimuli, in particular threat cues (Derryberry and Rothbart 1988, 1997; Rothbart et al. 1984, 2004). As such, effortful control is seen as an important component of emotional development, but the conscious control on which it is based arguably reflects cognitive development too.

Effortful control first emerges early in development, between 6 and 12 months of age concomitant with the development of the anterior attention network (Rothbart et al. 1994). However, consistent with the idea that this ability develops rather than being stable, efficiency in executive attention increases between the ages of 7 and 10 (Simonds et al. 2007). The development of effortful control, while in part genetically based, is also shaped by environmental experiences in the social world (Goldsmith et al. 1997). Interactions with caregivers are of particular importance; caregivers' efforts early in development to soothe the infant likely help to train regulation of emotion (Posner and Rothbart 2006) while adaptive, sensitive or warm parenting have also been shown to predict effortful control (Eisenberg et al. 2005).

Effortful control features in a prominent developmental model of anxiety symptoms in which markers of trait anxiety such as negative affectivity and neuroticism predict anxiety both directly and through an attentional bias to threat. Most pertinent, the model includes effortful control as a gatekeeper of these relationships; anxiety will develop only when trait anxiety/negative affectivity is accompanied by low effortful control (Lonigan et al. 2004). As such, two models in the literature suggest that some form of effortful cognitive control is an important developmental skill in inhibiting attentional biases to threat. There is evidence supporting this idea: (1) anxious children show deficits in effortful attentional control and have difficulty in disengaging from unpleasant stimuli (Derryberry and Reed 2002; Lonigan et al. 2004); (2) low effortful control (over attention) is related to changes in anxiety-related maladjustment in children with an average age of 7 (Eisenberg et al. 2009); (3) attentional control is negatively related to anxiety symptoms in 8-to 13-year-old children (Muris et al. 2004); (4) the relationship between negative affectivity (a predictor of anxiety symptoms) and selective attention to threat in high trait anxious adolescents is moderated by effortful control (Lonigan and Vasey 2009); and (5) anxiety and effortful control might also share common genes (Lemery-Chalfant et al. 2008) suggesting that the two constructs are genetically linked. Therefore, the failure to develop effortful and attentional control in middle to late childhood (e.g., 10–14 years) represents a viable developmental mechanism by which common attentional biases to threat may become extreme and maladaptive. Children low in effortful control may struggle to manage their attentional processes and as such the threat bias common to all young children may persist into late childhood and early adolescence (Lonigan et al. 2004).

Conclusions

It is impossible for us to give a definitive model of how child development contributes to information processing biases to threat. However, we hope to have given a flavour of some of the pertinent issues. Although the evidence does not allow us to rule out any of the models unequivocally, we believe that there is better support for the moderation and acquisition models than there is for the integral bias model. However, there are still several important questions that researchers need to answer to enable theorists to decide whether moderation or acquisition models better represent the phenomenon of interest (or whether both conceptualizations are unrealistic—they are not an exhaustive set of possibilities). The first major research question is how young can interpretation biases be expressed? To answer this question researchers will need to think carefully and innovatively about the research methods and tasks necessary to demonstrate a biased interpretation of ambiguity (especially in the absence of language). The second question is whether anxiety or other developmental factors moderate the developmental trajectory of interpretation biases. We have suggested some likely developmental correlates of attentional biases, but we first need to know whether interpretation biases exist in infancy, and if not, when they develop and whether they rely on certain cognitive building blocks. Finally, although there is much useful research showing that attentional biases to threat occur in infancy, we can, at present, only speculate about the developmental course of these biases. There is a need for longitudinal research with a large sample of children from infancy to allow a systematic analysis of the development of attentional bias across age. Such longitudinal designs would permit an examination of the causal relations between processing biases to threat, cognitive, social and emotional developmental factors and the emergence or maintenance of anxiety in childhood. This type of research brings with it a unique set of challenges, not least of which is the difficulty of constructing stimulus materials appropriate for measuring processing biases that are useable in both infants and adolescents.

Acknowledgments This research was funded by Economic and Social Research Council grant number RES-062-23-0406 awarded to Andy Field and Sam Cartwright-Hatton.

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