Behavioral Inhibition and the Associative Learning of Fear

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Abstract Fear and anxiety symptoms can be acquired through (1) a direct traumatic experience, (2) the transmission of verbal information, and (3) vicarious (observational) learning. All three pathways have gained empirical support, and all appear to conform to predictions made by theories of Pavlovian associative learning. Consequently, a number of integrated models of fear learning based on associative learning principles have been proposed. Field and Purkis' (Anxiety disorders in children and adolescents: Research, assessment and intervention, 2011) model suggests that learning experiences evoke links between a neutral stimulus (CS) and threat-related US. Therefore, a single mechanism underlies all three fear learning pathways, and thus the pathways can have additive and multiplicative effects on the strength of the CS-US link. Crucially, the model acknowledges the role of individual differences in learning. This chapter will discuss the evidence demonstrating the influence of two temperamental constructs, behavioral inhibition (the tendency to react to a novel or unfamiliar situation with excessive apprehension and avoidance) and the behavioral inhibition system (a neurological system, which is linked to behavioral inhibition, that controls the experience of anxiety in response to anxiety-relevant cues). In particular, the chapter will explore the effect of behavioral inhibition and the behavioral inhibition system on both the strength of the CS-US link formed during a learning episode, as well as post-learning processes. Taken together, it is clear that behavioral inhibition interacts with the associative learning of fear to facilitate fear learning.

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Childhood fears and anxieties are highly prevalent developmental problems (Gullone, 2000). Typical childhood fears include fears of animals (e.g., spiders), medical issues (e.g., injections), and situational and environmental factors (e.g., heights) (Muris & Field, 2010). For most children, fears are considered mild and a normative part of development with adaptive value (King, Hamilton, & Ollendick, 1988), often being short-lived and spontaneously receding as quickly as they first appeared (e.g., Ferrari, 1986). However, for a sizable minority of children (approximately 22%), childhood fears can persist, becoming severe and taking on pathological properties reflecting more severe phobias and anxiety disorders (Muris, 2007; Muris, Merckelbach, Mayer, & Prins, 2000). Subsequently, fears and anxieties significantly interfere with daily functioning and often continue into adulthood (Muris et al., 2000). In such cases, a diagnosis of a specific phobia or an anxiety disorder may be warranted (see Diagnostic and Statistical Manual of Mental Disorders, fifth edition; American Psychiatric Association, 2013).

The fear and anxiety response are made up of subjective (cognition), behavioral (avoidance), and physiological (e.g., heart rate increases) components (Lang, 1968). With respect to cognition, distinctive patterns of processing threat information have been causally implicated in creating anxiety (Mathews & MacLeod, 2002). Anxious people tend both to attend selectively to threat in their environment (attentional bias) and overinterpret ambiguity as threat (interpretation bias). Any model of fear learning has to explain how these processing styles develop as well as behavioral and physiological responses.

Theories of Fear Learning

Developmental Trajectories of Anxiety

Developmental models of anxiety symptoms (i.e., attention, interpretation) distinguish between *integral bias*, *moderation*, and *acquisition* trajectories for anxiety-related cognition (Field & Lester, 2010a). "Integral bias" equates to the mechanisms underpinning anxiety-related symptoms being unaffected by the environment. In other words, the growth trajectory for anxiety-related symptoms is flat: your early (presumably inherited) propensity for anxiety-related symptoms is unwavering in the face of environmental influence. Acquisition and moderation models both represent growth trajectories for anxiety-related symptoms that change over time and, therefore, imply some environmental influence. The difference between them lies in whether it is assumed that the propensity for anxiety-related symptoms is low in very early life and acquired over time (acquisition) or whether it is high early in life but gets toned down through environmental influences (moderation). In both the acquisition and moderation models, it is assumed that the change in anxiety

symptoms over time will not just be a function of learning from environmental experiences but that these experiences will interact with inherited characteristics of the child (e.g., temperament).

Although, at present, there is not sufficient evidence to determine which trajectory is most likely, a review of what evidence there is suggests that the integral bias model can be ruled out because of the considerable evidence that anxiety-related cognitions in children change over time (Field & Lester, 2010a). The same review concludes that because attentional biases to threat stimuli have been found very early in life (see LoBue & Rakison, 2013, for a review), a moderation model is most likely for attentional components of the anxiety response. Conversely, because there are currently no evidence that interpretational components of threat processing are present early in life and good reasons to assume that such relatively high-level processing would depend upon developmental foundations, such as understanding ambiguity, and multiple outcomes from an event, it is assumed that the development of anxiety-related symptoms is best characterized by an acquisition model.

Mechanisms of Fear Learning

Irrespective of whether anxiety symptoms follow a moderation or acquisition model of growth, some learning is involved, and, therefore, it is important to identify the mechanisms underlying that learning. Models of fear and anxiety learning implicate several contributing mechanisms including biological (e.g., genes, temperament) and behavioral processes (e.g., classical and operant conditioning, observational learning), as well as interpersonal (e.g., attachment, parent/child interaction) and cognitive factors (e.g., information processing biases) (see Silverman & Field, 2011, for a review). Even after accounting for genetic transmission, a strong relation between parental and offspring anxiety still exists, thus leaving a large proportion of variance explained by shared environmental factors (Eley et al., 2015; Gregory & Eley, 2011)

An obvious cause of anxiety symptoms is direct traumatic experience. Nearly a century ago, Watson and Rayner's (1920) "Little Albert" study implicated direct negative experiences (aversive classical conditioning) in fear development. Put simply, fear of a neutral stimulus (a conditioned stimulus, CS; e.g., a dog) can be learned through that stimulus becoming associated with an aversive event (an unconditioned stimulus, US; e.g., a bite). Through this association, the formerly neutral stimulus comes to elicit a conditioned fear response (CR). This is a highly conserved learning mechanism, providing opportunities for comparative studies across human and nonhuman models of fear-learning and behavioral inhibition (see the chapter "Behavioral Inhibition in Rodents: A Model to Study Causes and Health Consequences of Temperament" by Cavigelli).

A century of clinical practice and laboratory research has established that direct traumatic experiences (e.g., road traffic accidents) are commonly associated with anxiety symptoms such as re-experiencing the event, intrusive images, nightmares, hyperarousal, and avoidance. For example, 37.1% of people exposed to

"intentional" traumas (e.g., war, assault) develop post-traumatic stress symptoms (Santiago et al., 2013). However, within that group 34.8% remit within 1 month, whereas symptoms in 39.1% are chronic. These figures suggest that the impact of direct traumatic experiences is moderated by other factors. For example, in a meta-analysis on child post-traumatic stress symptoms, predictors of trauma response were categorized as pre- (e.g., demographic characteristics), peri- (e.g., perceived threat during the trauma), and post-trauma (e.g., social support, strategies for dealing with trauma). Broadly speaking, the severity of symptoms after trauma increased as a function of these categories, with the severest symptoms associated with post-trauma variables (Trickey, Siddaway, Meiser-Stedman, Serpell, & Field, 2012). Interestingly, these post-traumatic predictors of trauma severity included characteristics of the individual such as comorbid psychological problems, social withdrawal, and thought suppression.

Direct trauma is not the only pathway through which fears are acquired. It has long been acknowledged that verbal information and observational learning are powerful pathways through which anxiety symptoms evolve (Rachman, 1977). These pathways have been substantiated both through retrospective studies in which anxious people reflect back on earlier experiences related to their anxiety and laboratory studies in which subjective, behavioral, and physiological responses to novel stimuli (typically animals) are measured after different types of verbal information or vicarious experiences.

For example, in numerous studies with children aged 6–13, threat information (compared to positive or no information) about a novel animal has been shown to increase directly and indirectly measured subjective feelings of fear (Field, 2006a, 2006c; Field & Lawson, 2003; Field & Lawson, 2008; Field & Price-Evans, 2009; Field & Schorah, 2007; Field & Storksen-Coulson, 2007; Price-Evans & Field, 2008), latency to approach (Field, 2006a; Field & Lawson, 2003; Field & Lawson, 2008; Field, Lawson, & Banerjee, 2008), and heart rate (Field & Schorah, 2007) when approaching a box that the child believes contains the animal. Similar effects have been found using a "nature reserve task" in which children are given a board decorated as a nature reserve with animals positioned within it and are asked to place a toy figure in the park to represent where they would like to be. The distance from the threat information animal relative to other animals is taken as a measure of avoidance (Field & Storksen-Coulson, 2007). These effects persist at least up to 6 months (Field et al., 2008).

Similar experiments have been conducted in youths in which pictures of novel animals are presented alongside facial expressions of fear or videos of others acting afraid (or neutral or happy). As with the verbal information studies, it has been shown repeatedly that an association with another person's fear response is sufficient to increase directly and indirectly measured subjective feelings of fear (Askew, Dunne, Özdil, Reynolds, & Field, 2013; Askew & Field, 2007; Askew, Reynolds, Fielding-Smith, & Field, 2016; Broeren, Lester, Muris, & Field, 2011; Dunne & Askew, 2013; Reynolds, Field, & Askew, 2014, 2015), latency to approach (Askew & Field, 2007; Reynolds et al., 2014), and heart rate (Reynolds et al., 2014) when approaching a box that the child believes contains the animal. The same pattern is

evident when examining distance from the animal using the nature research task described above (Askew et al., 2013; Askew et al., 2016). These effects persist for weeks after the initial learning (Askew & Field, 2007; Reynolds et al., 2014).

To cut a very long story short, fear learning through direct experience, verbal information, and observational learning all appear to conform fairly consistently to predictions that emerge from theories of Pavlovian associative learning. Given this, several authors have proposed integrated models of fear learning based on associative learning principles (Davey, 1997; Field, 2006b; Field & Purkis, 2011; Mineka & Zinbarg, 2006). These models all have at their heart a stimulus-stimulus (S-S) association formed between a CS and US (i.e., between a previously neutral stimulus and an aversive stimulus). Traditionally, this "association" was seen as a mental connection between the relevant events and stimuli encountered during a learning episode (Hall, 2002; Pearce & Bouton, 2001).

However, decades of research has shown that these associations are not simple, automatic connections between two discrete stimuli but are highly detailed representations of the environment that contain information about past experience, learning context, features of the stimuli (and their existing associations to other things), and individual characteristics of the organism and can be influenced by nonautomatic processing. To reflect this complexity, Field and Purkis (2011) refer to a CS-US "link' because, unlike "association," this term does not imply automatic processing.

Figure 1 shows Field and Purkis' (2011) model, which integrates and updates ideas from earlier models (Davey, 1997; Field, 2006b; Mineka & Zinbarg, 2006). Direct traumatic experiences are at the center of Davey's and Mineka and Zinbarg's models. Verbal information and vicarious learning are conceptualized as vulnerability

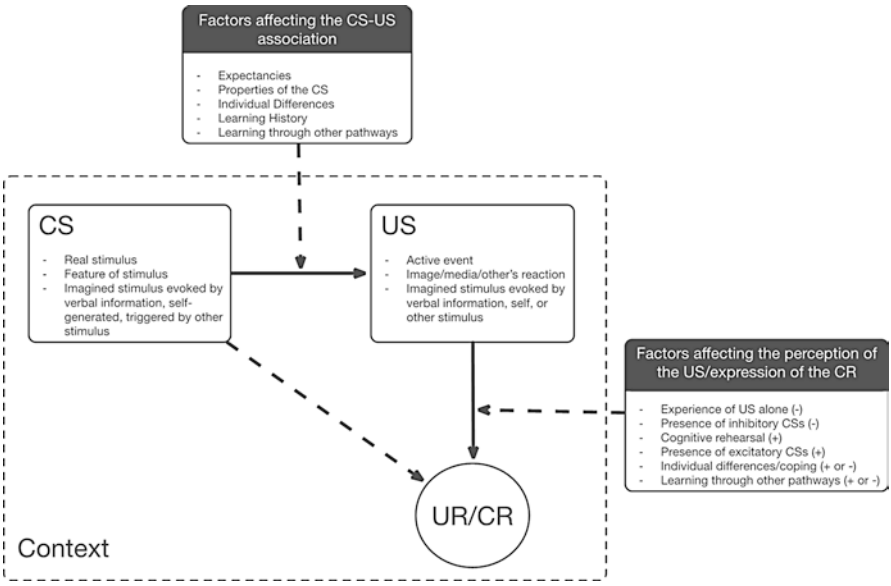

Fig. 1 Field and Purkis's (2011) associative learning model of fear

factors before learning (they create expectations that influence the strength of the link formed between the CS and US during a learning episode) or modifying factors after learning (e.g., information after the event that strengthens or weakens the CS-US link). In contrast, Field and Purkis suggest all three pathways can create a mental link between a stimulus and a threat-relevant outcome.

For example, in an informational learning event, a novel stimulus (CS) becomes linked with the threat information (US) and the related representations of threat (and its related qualia) that it evokes (Field, 2006b). Similarly, in vicarious learning the CS becomes linked with another person's observed response to threat (Mineka & Cook, 1993) and the related representations evoked by observing that response. Field and Purkis' model (2011; and Field, 2006c before it) also acknowledges work demonstrating that mental representations can act as CSs and USs (Dwyer, 1999, 2001, 2003; Dwyer, Mackintosh, & Boakes, 1998). For example, a US does not need to be a direct aversive experience; it can be an aversive thought, idea, or image.

To summarize the model, learning experiences forge links between a real or imagined neutral stimulus (CS) and real or imagined threat-related US (be it a direct experience, a distressing mental image, verbal information, or observing a fearful response to something). The link may be formed between the whole CS or specific salient features of it. Once the link is formed, it drives a fear response to the CS that was formerly evoked by the US. The strength of this response is determined by the strength of the link which itself is influenced by prior learning/experience (e.g., protective positive experiences), properties of the CS (e.g., the so-called "fear-relevant" stimuli such as spiders are primed to rapidly form a link to threat), and individual characteristics (such as behavioral inhibition). The strength of the conditioned fear response can also be influenced post-learning by habituation to the US, subsequent learning (e.g., verbal information that revalues the US as more threatening), the presence of other stimuli that reduce or enhance fear, and individual differences in how the learning event and US are processed (which, again, could be influenced by characteristics such as behavioral inhibition). Finally, the learning event itself occurs within a context that influences what is learnt. For example, CS-US links formed in specific contexts may only elicit fear responses in those same contexts.

Field and Lester (2010b) have further argued that associative learning can explain the emergence of attentional and interpretational aspects of anxious cognition. In the case of attentional bias to threat, if we assume that we are primed to attend to threat from an early age, then this system must learn what is and is not threatening (see the chapter "Attention Mechanisms in Behavioral Inhibition: Exploring, and Exploiting, the Environment" by Pérez-Edgar). When attending to the environment, an infant might pick up on the stimuli to which a caregiver is attending (through social referencing). In other words, caregivers direct attention to particular facets of the environment that then become a CS. The caregiver's own responses (vicarious learning) and responses involving the infant (e.g., removing them from the situation) act as a US that is linked to the facet of the environment to which attention was drawn.

Similarly, with interpretational biases, ambiguity (CS) in the environment will typically be resolved by a caregiver through verbal information or their reaction to the situation (vicarious learning). If the caregiver tends to resolve these situations in

a threatening way, then their child will form a strong link between ambiguity (CS) and threat outcomes (US). Essentially, over many trials, a caregiver prone to threat interpretations will "train" their child to have similar responses by forging an association between ambiguity and threat representations (see the chapter "The Social World of Behaviorally Inhibited Children: A Transactional Account" by Henderson et al.). Children's tendencies to interpret ambiguity in a threatening way have been linked to their mother's tendency to react cautiously to ambiguous situations (Lester, Seal, Nightingale, & Field, 2010).

Field and Purkis' (2011) model is a parsimonious account of how the three pathways to fear contribute to fear learning because it assumes that a single mechanism underlies all three pathways and that the pathways can, therefore, have additive and multiplicative effects on the strength of the CS-US link. It also allows for a coherent set of variables that impact on the CS-US link and the expression of fear regardless of which pathway, or combination of pathways, contributed to the formation of the CS-US link.

Theories of Behavioral Inhibition and the Behavioral Inhibition System

The models of anxiety just discussed acknowledge the role of individual differences in learning. For example, temperamental characteristics are believed to affect the strength of the link formed during a learning episode, as well as how the event is processed after learning (Fig. 1). Similarly, the trajectories of attentional and interpretational aspects of anxiety are assumed to interact with temperamental characteristics of the person. Many temperamental constructs predict fear and anxiety, including negative emotionality (Tellegen, 1985), negative affect (Clark & Watson, 1991), neuroticism-negative affect (Lonigan, Vasey, Phillips, & Hazen, 2004), fear (Rothbart, Ahadi, & Evans, 2000), and behavioral inhibition (Kagan, Reznick, & Snidman, 1987), suggesting that such constructs may be best viewed as different conceptualizations of trait anxiety (e.g., Field, 2006c; Lonigan et al., 2004). We discuss two of these—behavioral inhibition and behavioral inhibition system—in detail.

Behavioral Inhibition

Behavioral inhibition is a biologically driven trait defined by Kagan (Kagan, Reznick, Clarke, Snidman, & García-Coll, 1984) to describe a tendency to react to novel or unfamiliar situations with excessive apprehension, avoidance, and reticence (e.g., Fox, Henderson, Marshall, Nichols, & Ghera, 2005; Kagan, 1994; Kagan et al., 1987; Kagan, Reznick, & Gibbons, 1989; Kagan & Snidman, 1999). It is typically associated with a disposition to display extreme shyness, fearfulness,

and withdrawal (e.g., Hirshfeld-Becker, Biederman, & Rosenbaum, 2004) and is believed to have its basis in amygdala reactivity. Approximately 15% of infants show high levels of behavioral inhibition (Fox et al., 2005), and around 50% of children demonstrate stability in their behavioral inhibition from infancy through childhood (Kagan, 1994; Kagan, Reznick, Snidman, Gibbons, & Johnson, 1988) and adolescence (Kagan, Snidman, Kahn, & Towsley, 2007).

The persistence of behavioral inhibition may be influenced by other temperament or personality traits such as positive emotionality. Johnson et al. (2016) demonstrated that behavioral inhibition at age 3 was predictive of behavioral inhibition at age 6 only when children also presented with low to moderate levels of positive emotionality. This makes intuitive sense because children who have high levels of both behavioral inhibition and positive emotionality in early childhood may gradually become less inhibited as they develop due to positive emotionality encouraging approach behaviors and increasing exposure to novelty.

Early behavioral inhibition can be predictive of later psychopathology. Research on temperament has found that 21-month-old children categorized as having high levels of behavioral inhibition have a greater likelihood of presenting with specific fears and phobias at age 7–8 years compared to uninhibited children (Biederman et al., 1990). Behaviorally inhibited children are at greater risk of a number of other anxiety disorders (for a review, see Biederman, Rosenbaum, Chaloff, & Kagan, 1995; Rosenbaum et al., 1993), particularly social anxiety disorder (Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012). Hudson and Dodd (2012) demonstrated that children categorized as high in behavioral inhibition at age 4 were at increased risk for social phobia, separation anxiety disorder, and generalized anxiety disorder at age 9. Highly behaviorally inhibited children were already at risk for specific phobia at age 4. In addition, Hudson and Dodd found that even after controlling for early anxiety at age 4, behavioral inhibition remained a significant predictor of anxiety at age 9 suggesting that while behavioral inhibition and early anxiety both contribute to later anxiety risk, they are relatively independent constructs (see the chapter "Behavioral Inhibition as a Precursor to Psychopathology" by Klein and Mumper).

The fact that behavioral inhibition in infancy predicts later anxiety symptoms suggests that (1) behavioral inhibition is an early manifestation of anxiety, (2) measures of behavioral inhibition act as proxy measures for trait anxiety, or (3) behavioral inhibition facilitates learning about threat. The first two possibilities both imply that behavioral inhibition and trait anxiety are the same or at least overlap conceptually. For example, the increased risk for fear and anxiety in behaviorally inhibited children may be part of a larger defensive response, or neurological system, which is triggered more easily in children with reactive temperaments. Such a system is described in Gray's (1970, 1987) reinforcement sensitivity theory of temperament. Gray suggested that a subcortical circuit known as the behavioral inhibition system, with its anatomical substrate in the septohippocampal system, controls the experience of anxiety in response to anxiety-relevant cues.

The Behavioral Inhibition System (BIS)

The BIS is thought to be sensitive to novelty, punishment, and lack of reward (or frustrative non-reward when, e.g., positive reinforcement is expected but not received). As such, the BIS activates when an individual is confronted with an unpredictable, aversive, or novel stimuli, leading to a fear response. Thus, from this perspective, sensitivity in arousal of particular brain areas leads to both behavioral consequences (such as avoidance behavior) as well as influencing fear conditioning itself (Gray, 1981). The behavioral outputs of the BIS include increases in attention and arousal and inhibition of ongoing behavior. In addition, higher sensitivity in the BIS leads to higher trait anxiety (Gray & McNaughton, 2003). Anxiety proneness may therefore be attributed to a lowered threshold for behavioral inhibition system activation (Gray, 1987). It is likely that there are temperamental differences between individuals in BIS functioning (Muris, Merckelbach, de Jong, & Ollendick, 2002). Gray (1987; Gray & McNaughton, 2003) argued that *activity* in the BIS/septo-hippocampal system corresponds to state anxiety and that individual differences in the *sensitivity* of the BIS to unpredictability and novelty corresponds to trait anxiety.

The BIS is, therefore, seen as a neurological system that underpins trait anxious responses to environmental stimuli. It can also be linked to the temperamental construct of behavioral inhibition. According to Lonigan et al. (2004), affect and temperament can be described by two high-order factors they call negative affectivity/neuroticism (NA/N) and positive affectivity/surgency (PA/S), with BIS aligned in particular with the NA/N factor. Lonigan and colleagues draw attention to the conceptual overlap between NA/N and behavioral inhibition, with children classified as high in behavioral inhibition also showing high NA/N characteristics such as verbal distress and inhibited approach. As a neurological construct, inhibited behavior is theorized to be one of the outputs of the BIS (Gray & McNaughton, 2003). Together this suggests that the BIS may be the neurological system underpinning at least one of the dimensions of behavioral inhibition. Given this link, high BIS sensitivity is often interpreted as indicative of high behavioral inhibition (though see Morgan, 2006).

Behavioral Inhibition and Associative Learning Models of Anxiety

As discussed, models of fear acquisition (e.g., Davey, 1997; Field, 2006c; Field & Purkis, 2011; Mineka & Zinbarg, 2006) emphasize the importance of the strength of the link between a CS and US. Field and Purkis argue that both direct and indirect experiences (i.e., contact with a direct aversive event, vicarious learning, and verbal information) reflect associative learning episodes that can lead to a mental representation in which a CS is linked with a US. In their model, temperament (e.g., trait anxiety, BIS sensitivity, behavioral inhibition) moderates the effects of these learning experiences. We will now look at the evidence supporting this model.

With respect to direct aversive learning experiences, Zinbarg and Mohlman (1998) used an approach-avoidance task in which participants discriminated cues (numbers on a computer screen such as 22 or 29) that signaled financial punishment (loss of 25 cents) and reward (gaining 25 cents) when a key was pressed. Essentially, participants had to decide for which cues they should press the key. Participants received blocks of 72 trials, and researchers measured the number of key presses to cues within each block and expectancies (a rating on a 9-point scale how likely they felt it was that they would lose/gain money) at the end of each block. Individuals high on self-reported BIS sensitivity acquired punishment expectancies faster than participants low in BIS sensitivity. As such, BIS sensitivity affected the speed of acquisition of punishment contingencies. This study shows how behavioral inhibition (as marked by BIS sensitivity) might contribute to fear learning by speeding up the rate of acquisition of threat contingencies.

There is also work showing that behavioral inhibition facilitates fear learning through the so-called indirect pathways. For example, a wealth of research has demonstrated that non-clinically anxious children show increased fear responses and attentional bias toward novel animals following threatening information about them, compared to other animals they have received positive or no information about (see above). Attentional bias effects found by Field (2006b) were relatively weak. This lead to further research exploring whether external factors, such as temperament, may have moderated the effects. Field (2006a) measured children's (age 6–9 years) behavioral avoidance (via a touch box task) and attentional bias (via a dot-probe task) toward novel animals paired with either threatening, positive, or no information. BIS sensitivity, measured via an age-downward version of Carver and White's (1994) BIS scale, was found to facilitate avoidance behavior for animals paired with threatening information, as well as attentional bias toward the threatening animal.

Field and Price-Evans (2009) extended these findings, demonstrating that children with greater BIS sensitivity also showed greater physiological responding (increases in heart rate) when they believed they were touching the threat information animal during an approach task. Therefore, findings suggest that children who were inherently vulnerable to acquire fears were more sensitive to the effects of threatening verbal information with the elicitation of fear responses in all three of Lang's (1968) fear response systems: cognition, behavioral avoidance, and physiological responding.

With regard to vicarious learning, Askew, Hagel, and Morgan (2015) explored the relation between levels of behavioral inhibition and the strength of vicarious learning of social anxiety in children. They measured social anxiety-related fear beliefs and emotional Stroop interference for social anxiety-related words after children watched animated films with either socially negative or socially neutral outcomes. They found that socially negative vicarious learning led to increases in children's social fear beliefs and an emotional Stroop bias for socially anxious words. Higher behavioral inhibition was associated with higher levels of social fear beliefs before and after vicarious learning.

These findings are all consistent with Field and Purkis' notion that temperamental characteristics such as behavioral inhibition/BIS sensitivity interact with associative fear learning processes to facilitate fear learning. As mentioned earlier,

attention to threat and the tendency to interpret ambiguity in a threatening way may be "trained," through associative learning, by parents and other key caregivers directing a child's attention toward threatening outcomes/situations (Field & Lester, 2010b) via social referencing. Social referencing, or social information gathering, is a crucial skill that infants develop around 10 months of age. This is the ability of infants to use emotional signals from adults to determine and modify behavioral and emotional responses when confronted with a novel or ambiguous situation or stimulus (Feinman, 1982; Feinman, Roberts, Hsieh, Sawyer, & Swanson, 1992). Feinman et al. (1992) suggested that children's responses in social referencing situations correspond to parental reactions, suggesting that parental appraisals in a novel or ambiguous situation directly influence the infant's response. Thus, social referencing may arguably be a mechanism involved in, and contributing to, vicarious fear learning (Aktar, Majdandzic, de Vente, & Bögels, 2013).

Behavioral inhibition can influence social referencing (e.g., Murray et al., 2008). Maternal anxiety may interact with behavioral inhibition to increase vulnerability to anxiety by encouraging avoidance behaviors, rather than facilitating positive engagement with novelty. Avoidance may also be coupled with a lack of positive reinforcement when approaching novel or potentially threatening situations (Fisak & Grills-Taquechel, 2007; Murray, Creswell, & Cooper, 2009). Using a range of situations (home and lab visits) and standardized tasks, Aktar et al. (2013) demonstrated that 12-month-old infants' avoidance of novel strangers or toys was predicted by the interaction between infant behavioral inhibition and expressed parental anxiety. Infants who were categorized as highly behaviorally inhibited showed greater fear and avoidance during social referencing, and this temperamental predisposition was more influential in determining fear responses than parental anxiety expressions.

De Rosnay, Cooper, Tsigaras, and Murray (2006) also demonstrated that 12- to 14-month-old infants categorized as highly inhibited were more vulnerable to the negative impact of anxious maternal expressions in response to strangers. In an experimental design, mothers' expressions were manipulated to be either socially anxious or nonanxious. They demonstrated that behavioral inhibition and maternal expressions of social anxiety predicted increased stranger avoidance in the anxious condition only, in that highly behaviorally inhibited infants were significantly more avoidant than low behaviorally inhibited infants. This finding indicates a causal role for expressed maternal anxiety on infant avoidance, moderated by infant behavioral inhibition.

Similarly, Murray et al. (2008) used a social referencing paradigm in which a female stranger conversed with mothers for 2 min with their child present; then the stranger approached the infant and picked them up. Findings indicated that behavioral inhibition moderates the effects of parental social anxiety disorder on children's avoidance. That is, infants high in behavioral inhibition who had clinically socially anxious mothers demonstrated more avoidant behaviors from 10 to 14 months. The relationship between parental anxiety and infant behavioral inhibition was attributed to lower levels of maternal encouragement to infants high in behavioral inhibition

As children develop and gain experience and confidence in novel situations, the effect of social referencing becomes indirect (Feinman et al., 1992). Inconsistent with previous findings with infants, Aktar, Majdandzic, de Vente, and Bögels (2014)

demonstrated that for toddlers (30 months old) categorized as high in behavioral inhibition, fear/avoidance responses were not predicted by parental trait or state anxiety. However, they did find that infants who were highly inhibited at 12 months were more likely to show fearful and avoidant responses in a maternal social referencing task at 30 months. This effect was not found for fathers. Thus, paternal social referencing appears to be independent of early behavioral inhibition, despite research implicating the important role of fathers in the development of child anxiety (e.g., Bögels & Perotti, 2011; Bögels & Phares, 2008).

The Influence of Behavioral Inhibition on the Strength of the CS-US Link

Differences in sensitivity to conditioning may mediate the effects of behavioral inhibition on fear and anxiety acquisition. There is some support (e.g., Kendler, Neale, Kessler, Heath, & Eaves, 1992) for a genetically based vulnerability to phobias that is mediated by fear conditioning (e.g., Hettema, Annas, Neale, Kendler, & Fredrikson, 2003) and personality variables such as trait anxiety. Studies have found that trait anxiety influences the speed and strength of conditioning, with more rapid and stronger aversive conditioning shown by individuals high in trait anxiety (e.g., Zinbarg & Mohlman, 1998). This may explain the role of high trait anxiety, and therefore also BIS sensitivity, as a vulnerability factor in phobia and anxiety acquisition.

The BIS may also interact with indirect pathways to fear by, for example, increasing US salience or threat expectancies, which serve to strengthen the CS-US link (Field & Purkis, 2011). Indeed, children who are categorized as high in behavioral inhibition have been found to show enhanced reactivity to stressors (Smoller et al., 2005). Compared to children categorized as low on behavioral inhibition, highly behaviorally inhibited children may experience an aversive US as more salient because of greater sensitivity to aversive events, leading to a stronger CS-US link and a larger learned fear response. Researchers have argued that the greater incidence of aversive life events or adverse family environments, such as parental divorce, found among clinically anxious children is not directly responsible for fear or anxiety acquisition. Rather, the impact of such negative events is worsened by vulnerability factors like behavioral inhibition (see the chapter "Behavioural Inhibition and the Prevention of Internalising Distress in Early Childhood" by Rapee and Bayer) (Spence & Dadds, 1996).

One mechanism via which the BIS may enhance reactivity to stressors is by increasing attentional bias toward threat-related stimuli given that high BIS sensitivity/trait anxiety is related to greater devotion of attentional resources to anxiogenic cues (see Gray & McNaughton, 2003). Research shows that BIS overactivity is associated with earlier and more frequent detection of aversive stimuli (Poy, Eixarch, & Avila, 2004) and BIS sensitivity is related to negative emotional processing (Gomez & Gomez, 2002). Theoretically, high BIS sensitivity is likely to

increase attention to negative USs, which in turn increase either the number of CS-US pairings or the salience of the US during learning.

Properties of the CS may also interact with behavioral inhibition to strengthen the CS-US link. In one study, Dubi, Rapee, Emerton, and Schniering (2008) explored whether fear relevance influenced the magnitude of the learning effect. They presented toddlers with one fear-relevant stimulus (e.g., a toy snake) and one fear-irrelevant stimulus (e.g., a flower) in the presence of either positive or negative expressions from the toddler's mother. They replicated De Rosnay et al.'s (2006) finding that children were more likely to react to the stimuli with fear after observing their mothers reacting negatively, regardless of fear relevance. However, highly behaviorally inhibited children showed no differences in learning compared to non-vulnerable children. It is possible that the differences in findings may have been due to the lack of highly behaviorally inhibited children in the sample or the fact that animal fear learning was studied rather than social anxiety.

Field and Purkis' model also emphasizes the importance of the child's prior learning experiences in strengthening the CS-US link. Specific parental rearing styles are likely to influence a child's learning history, expectancies, and coping strategies and may place a child at greater risk of clinically significant fear or anxiety. Parenting styles, defined as attitudes expressed toward the child across different situations, and parenting behaviors, which are expressed toward the child in specific situations, are thought to provide an emotional climate for the parent-child relationship (Baumrind, 1967). Critically, children who have high levels of behavioral inhibition are more likely to experience negative or hostile parenting (Hane, Cheah, Rubin, & Fox, 2008; Hirshfeld, Biederman, Brody, Faraone, & Rosenbaum, 1997), overinvolved or intrusive parenting (Degnan, Henderson, Fox, & Rubin, 2008; Hudson, Dodd, & Bovopoulos, 2011; Rapee, 2002; Rubin, Burgess, & Hastings, 2002), critical parenting characterized by dissatisfaction (e.g., Hirshfeld et al., 1997), overprotective parenting (Johnson et al., 2016), low levels of encouragement, positive reinforcement or autonomy promotion (Murray et al., 2008), and greater levels of control and derision (Rubin et al., 2002) that may contribute toward child anxiety (Murray et al., 2009).

The relation between these parenting styles/behaviors and the stability of behavioral inhibition over time is likely to have an effect on fear and anxiety acquisition through shaping the child's learning histories, expectancies, and coping (see Fig. 1). For instance, parents who allow their child autonomy and appropriate levels of independence are likely to provide their child with more opportunities to be exposed to novelty, which may present children with greater opportunities for positive or neutral learning with stimuli. Prior positive or neutral learning can inhibit subsequent negative fear-related learning (Askew et al., 2016; Golkar & Olsson, 2016) by creating neutral or positive expectancies about the outcome of a learning event with the stimulus. Moreover, autonomy and exposure to novel experiences may enhance children's coping and adaptive skills when faced with ambiguous or anxiety-eliciting situations, promoting a sense of competence and mastery and therefore leading to a gradual decrease in behavioral inhibition (e.g., Muris, van Brakel, Arntz, & Schouten, 2011).

The Influence of Post-Learning Processes on the Strength of the Learned Response

As identified above, a number of post-learning processes may also contribute to the strength of the response. One such factor is individual coping styles in that operant conditioning processes may contribute to the strengthening of the response by reinforcing avoidance strategies. One of the outputs of the BIS is the inhibition of ongoing behavior (Gray & McNaughton, 2003), and avoidance behavior may be viewed as an extreme form of inhibition (Field, 2006a). During development, children categorized as highly behaviorally inhibited are more likely to experience social rejection and are more likely to avoid social stressors and respond to rejection with avoidant coping (e.g., Fox et al., 2005). Therefore, higher levels of BIS sensitivity (or trait anxiety) in children would be associated with greater motivation to avoid novel stimuli associated with threat and consequently would lead to inhibition of approach behavior and greater avoidance behavior. The avoidance is likely to be negatively reinforced by reducing levels of anxiety as a result of less exposure (see Weems & Stickle, 2005) and also by caregivers through inadvertent approval of avoidance behaviors.

If behavioral avoidance limits the variability of children's learning histories, they will have fewer opportunities for positive encounters with stimuli. Learning theory predicts that subsequent aversive experiences with a stimulus would therefore have greater negative impact because learning for stimulus-threat outcome contingencies is uninhibited (Field, 2006c). Taken together, based on Field and Purkis' model (Fig. 1), poor coping skills, such as avoidance behaviors, are likely to inflate the aversiveness of the US and subsequently enhance the CR.

Research has also shown that infant development is improved if highly behaviorally inhibited children are provided with opportunities to socialize with others, for example, by being placed in nonparental caregiving environments (e.g., Almas et al., 2011; Furman, Rahe, & Hartup, 1979). In support, Laird, Pettit, and Mize (1994) found that interacting with other children, combined with mother-child conversations about the child's peers, was associated with enhanced child competence.

Conclusion

Behavioral inhibition interacts with associative fear learning processes to facilitate fear learning. Temperament is thought to moderate the effects of both direct (contact with a direct aversive event) and indirect (via transmission of information or vicarious learning) associative learning episodes. This chapter has outlined the influence of behavioral inhibition and the behavioral inhibition system on relevant associative learning models of anxiety, with an emphasis on the influence of behavioral inhibition on the strength of the CS-US link and the influence of post-learning processes

on the strength of the learned response. This is an important addition to our understanding of how temperament factors such as behavioral inhibition and BIS sensitivity moderate the effects of negative learning experiences and contribute to fear learning in children. Increasing understanding of the interaction between temperament and environmental factors during fear learning has the potential to improve early identification of children who are particularly vulnerable to developing fears and phobias. Preventative interventions could be specifically targeted at these children, as well as more effective treatments should develop fear and anxiety.

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