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Attention Processes Underlying Risk and Resilience in Behaviorally Inhibited Children

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Abstract
Purpose of Review We briefly review the literature on behavioral inhibition (BI) in childhood and its associated social and emotional outcomes. We review the interplay of automatic and controlled attention processes in BI children and outline the relations between childhood BI and two components of effortful control (EC): response inhibition and attention switching.
Recent Findings Contemporary research in cognitive and behavioral neuroscience indicates that components of EC differentially impact developmental risk for BI children. Response inhibition may inflate the risk of anxiety issues by promoting the inefficient deployment of attentional resources in social contexts, while attention shifting may serve as a protective factor by supporting dynamic social information processing.
Summary The attentional processes subsumed under EC have diverse implications for the developmental trajectory of BI. Further research is necessary to identify the exact mechanisms by which the components of EC affect the manifestation of BI across development, and how this knowledge can guide early intervention efforts.

Keywords Behavioral inhibition · Executive attention · Effortful control · Response inhibition · Attention shifting · Affective flexibility

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Introduction

Behavioral inhibition (BI) is an early-appearing temperament characterized by heightened physiological and emotional reactions to novel social and non-social stimuli [1, 2]. Young children who are high in BI are reluctant to approach novelty and display high levels of attention, or hyper-vigilance, to unfamiliar people, objects, and environments. There is a good deal of developmental continuity in this temperament, with BI in toddlerhood associated with social reticence in the preschool years, a specific form of social withdrawal characterized by high levels of anxious and onlooking behaviors in unfamiliar social situations [3]. In turn, social reticence is associated with heightened social withdrawal and parent- and self-reported shyness across later childhood and adolescence. Over the past 40 years, a good deal of research has examined the impact of BI in early childhood and shyness in later childhood and adolescence on various indices of adjustment and well-being. These studies reveal that early BI and later shyness are associated with a host of difficulties in domains as diverse as peer relationships [4], teacher-child relationships [5], and academic achievement [6]. Further, nearly 50% of individuals expressing high levels of BI in early childhood develop an anxiety disorder over their lifetime, reflecting a fourfold increase in risk relative to children with no history of BI [7–9].

Despite a wealth of evidence indicating mean level increases in risk for children with a history of BI, two important observations are critical for guiding current theory and research. First, there are distinct developmental trajectories of shyness that include patterns of both *continuity and change*. Although longitudinal studies using observational [10] and parent-report [11•] measures demonstrate an overall decline in social reticence and shyness over childhood, there are a wide range of individual differences superimposed on this

general developmental trend. Importantly, children who remain high and stable in their shyness are at particular risk relative to those who start out high but show a steady decline or those who were never high [7, 10, 12–14]. Second, there is a good deal of inter-individual variability in the concurrent and longitudinal mapping of BI or shyness onto developmental outcomes. That is, not all children with a temperamental history of BI or childhood shyness are at risk for poor social/emotional outcomes. Together, these findings present a critical challenge to developmental psychologists to identify specific mechanisms that promote continuity (vs change) over time and that potentiate (vs mitigate) risk for shy children.

We focus the current review on the relations between BI and shyness and the development and implementation of specific executive control processes. We believe that these cognitive processes, and their underlying neural bases, are critical to understanding the specific self-regulatory challenges faced by children with a history of BI. In turn, we believe that targeting these self-regulatory processes can optimize children's social information processing abilities and the quality of their relationships with teachers, parents, and peers, factors known to support resilience among shy children [15]. We recently outlined a dual-processing model to synthesize existing behavioral, cognitive, and neuroscience findings on BI and developmental risk [16•]. In summary, we argued that at its core, BI reflects an inborn information processing bias in which attention is directed, quickly and automatically, toward novel and potentially threatening stimuli. Using ideas from temperament theory, cognitive science, and developmental cognitive neuroscience, we proposed that these early-appearing and automatic attention biases influence the development and implementation of more controlled cognitive processes including response inhibition, error monitoring, and attention shifting. We proposed three models (top-down model of control, risk potentiation model of control, and overgeneralized control model) to account for the joint influences of automatic and controlled processing on the variable developmental outcomes of children with a history of BI. Based on a detailed literature review, Henderson et al. concluded that the top-down model, in which higher levels of executive control down-regulate the attention, emotion, and information processing biases of shy children, had limited support. Rather, we noted that greater neural engagement during performance of specific cognitive control tasks (response inhibition, error monitoring) conferred additional risk for children with a history of BI, and speculated that for shy children, these processes detract from the ability to flexibly shift attention and as such support extended and elaborative processing of threatening and self-relevant cues (consistent with a risk potentiation model). Further, we noted several physiological and neuroimaging findings suggesting that children with a history of BI engage specific cognitive control abilities inefficiently (consistent with the overgeneralized control model), which may limit cognitive and behavioral flexibility. In the remainder of the current review, we focus on the most recent research on BI/shyness that provides additional empirical support for the risk potentiation and overgeneralized control models.

Automatic Processing

In his model of BI, Kagan linked the BI phenotype to cross-species neural and autonomic circuits underlying fear potentiation and conditioning [17, 18]. Consistent with these models, concurrent and longitudinal studies demonstrate associations between BI, social reticence, and enhanced behavioral and physiological orienting towards motivationally significant non-social [19] and social [20–22] cues. Early in development, this heightened orienting appears specific to novel and threat-relevant stimuli, but with age, this sensitivity may generalize to both negatively and positively valenced stimuli [23]. fMRI studies implicate the amygdala and striatum as key subcortical structures underlying this heightened salience sensitivity in children with a history of BI. Importantly, several of these fMRI studies reveal longitudinal effects of early childhood BI on automatic processing biases through adolescence and early adulthood, suggesting that these early biases have lasting effects on the neural networks underlying automatic processing of stimulus salience [21, 24–26]. Further, the extent of these biases significantly moderates developmental risk for children with a history of BI. For example, White et al. reported that early BI predicted parent-reported anxiety in middle childhood, but only when children displayed an attention bias to threat or no bias at all, assessed behaviorally [27]. In contrast, BI was unrelated to later anxiety for children who displayed an attention bias away from threat. At a neural level, Hardee et al. reported that in young adults, greater amygdala-insula connectivity during an attention bias task was associated with more self-reported internalizing symptoms, but only for participants with a history of childhood BI [28]. Exaggerated salience sensitivity in early development may contribute to the development of biased causal attributions and estimates of the probability and cost of both positive and negative social cues and experiences in later childhood and adolescence [21, 29].

Controlled Processing

In her influential model of temperament, Rothbart described the critical role of emerging executive processes in supporting the transfer of control over infants' and children's attention, behavior, and emotion from parents to children themselves [30, 31]. Factor analyses on parent-report assessments of temperament reveal a constellation of traits including inhibitory

control, attention focusing, and perceptual sensitivity, collectively referred to as effortful control (EC) [32]. In contrast to the reactive and automatic nature of the orienting biases reviewed above, EC describes a proactive, voluntary, and willful mode of processing that depends upon later developing neural networks governing executive attention [16•, 33].

Based on theoretical models equating EC with self-regulation, several studies have tested top-down models of control in which it is expected that EC is inversely related to reactive aspects of temperament. However, in the study of BI/shyness specifically, there is limited support for this top-down model of control. Study findings are mixed with some reports of negative relations (i.e., high shyness associated with low EC) [6, 34], some reports of positive relations (i.e., high shyness associated with high EC) [6, 35, 36], and some reports of no association [11•]. Informed in part by increased knowledge of the neural systems governing specific emotion-cognition interactions [37], we are now in a position to move beyond questions addressing global top-down models of control (e.g., is high EC related to better developmental outcomes?) to address more specific questions about which EC processes support optimal regulation for which types of children.

One framework through which to interpret the interaction of automatic and controlled processing as it applies to BI is attentional control theory (ACT) [38], a theoretical extension of Eysenck and Calvo's processing efficiency theory [39]. ACT holds that anxiety introduces competition between stimulus-driven (i.e., automatic) and goal-directed (i.e., controlled) attention systems. Specifically, anxiety-related hypervigilance biases attention towards detailed stimulus processing and monitoring for threatening or social-evaluative contextual cues while biasing attention away from goal-directed cues. To compensate for the attentional pull or costs of hypervigilance, controlled processing systems must accordingly recruit more resources to simply maintain goal-directed attention and action. In sum, anxiety makes the deployment of concentrated attention less *fluid and efficient*, as more resources must be engaged in order to maintain a similar level of performance. Given that the attentional pull of salient environmental cues may be particularly pronounced for BI children, the threshold of cognitive resources necessary to maintain goal-directed attention and action may be elevated.

Several recent studies suggest that *response inhibition* and *attention shifting* may be EC components that are particularly relevant for understanding trajectories of change and individual differences in relative risk among shy children. It is interesting that despite being moderately positively correlated (at least when assessed by parent report), response inhibition and attention shifting influence shyness in opposite directions, with high response inhibition enhancing risk and high attention shifting mitigating risk for children with a history of BI and shyness, as detailed below. In the context of ACT, *attention shifting* may be particularly important for regulating information processing, arousal, and emotion for children high in BI/shyness and reflect the relative speed and efficiency with which shy children can overcome the automatic pulls over attention and thereby increasing the efficiency with which goal-directed attention and action are achieved [11•, 16•]. In contrast, for BI/shy children, high levels of *response inhibition* may prolong monitoring of contextual cues, thereby decreasing the efficiency with which goal-directed attention is reinstated, in turn limiting flexibility in attention, cognition, and emotion and conferring additional risk. Figure 1 presents a schematic drawing of the hypothesized associations between threat processing, the relative strength of a child's attention shifting vs response inhibition abilities, and the (in)efficiency of goal-directed attention for BI children. Over development, the inability to flexibly shift attention away from salient contextual cues and the tendency to excessively monitor these cues may contribute to the development of anxious cognitions through the prolonged analysis of threat and a ruminative style of thinking [40]—and ultimately undermine self-regulatory efforts for shy children. Below, we provide brief summaries of the most recent research specifically relating attention shifting and response inhibition to trajectories of change and relative risk for BI/shy children that we believe support this hypothetical model.

BI and Response Inhibition

Response inhibition involves responding to contextual cues signaling the need to suppress a dominant response in favor of a subdominant response and is typically assessed using either parent reports or direct assessments on flanker or go-no/go tasks requiring the inhibition of a dominant motor response (i.e., stopping oneself from performing an action). There are mixed findings regarding the nature of the association between response inhibition and shyness in children. For example, some studies report that BI/shyness is associated with enhanced performance on response inhibition tasks [41], some report worse performance for children high in BI/shyness [42], while others report no association [5]. It is noteworthy that the majority of findings showing positive associations between response inhibition and shyness are based on parent reports [11•] suggesting that these estimates may be inflated due to the phenotypic overlap in the expression of shyness and response inhibition as compliance-like behaviors. That is, watchful and vigilant behaviors may be interpreted as well-developed response inhibition skills, when they actually reflect fearful inhibition. Therefore, to understand the nature of this association, we believe it is critical to use standardized laboratory assessments of response inhibition and to incorporate both behavioral and physiological/neural performance measures.

In both early [43, 44•] and middle [45] childhood, shyness is unrelated to behavioral performance on response inhibition

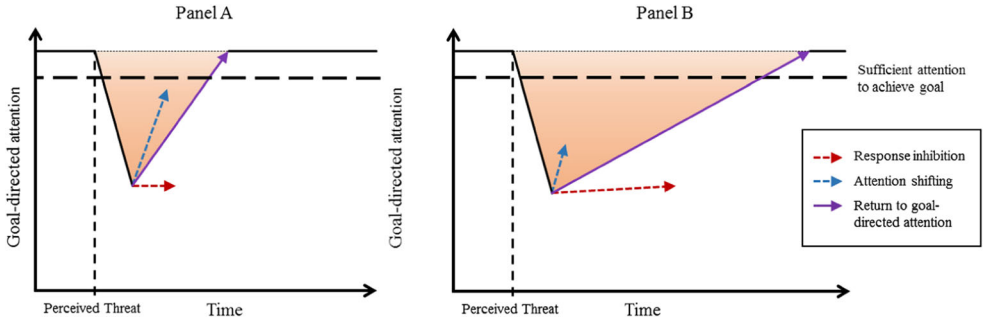

Fig. 1 The proposed influences of attention shifting and response inhibition on the efficiency of goal-directed attention and action for BI children. **a** An optimal processing model for BI children in which despite initial attention capture by threat cues, strong attention shifting abilities and normative response inhibition abilities result in a relatively efficient (indicated by smaller shaded area) return to goal-directed attention and action. In contrast, **b** depicts a suboptimal processing model in which the initial attention capture by threat is prolonged and maintained by strong response inhibition skills and weak attention shifting abilities resulting in an inefficient (indicated by larger shaded area) return to goal-directed attention and action

laboratory tasks. However, White et al. showed that preschoolers' performance on response inhibition tasks *moderated* the relation between observed BI and later anxiety symptoms [43]. Consistent with the risk-potentiation model proposed by Henderson et al., high levels of BI in toddlerhood were associated with elevated anxiety symptoms at age 5, but only among children who performed relatively well on response inhibition tasks in the lab [16•]. In middle childhood, Henderson similarly reported that behavioral performance on a flanker task was unrelated to shyness, but the amplitude of the N2, an event-related potential elicited when processing incongruent stimuli, moderated the relation between shyness and emotional functioning [45]. Specifically, self-reported shyness predicted higher social anxiety and more negative attribution styles, but only for children with relatively large N2 amplitudes. The N2 has a fronto-central distribution consistent with source localization to the anterior cingulate cortex [46], a critical node in the executive attention network. Importantly, these relatively large amplitude responses did *not* translate into enhanced behavioral performance. Similarly, Fu, Taber-Thomas, and Perez-Edgar reported heightened activation of the dorsolateral prefrontal cortex (dlPFC) among BI versus non-BI children while performing a dot-probe task, and this activation was again unrelated to task performance [47•]. Together, these findings suggest that for shy children, neural engagement of the executive attention system may be a compensatory, but relatively inefficient, strategy used in novel and social-evaluative contexts to maintain normal performance in the face of anxiety. These findings also underscore the importance of including both behavioral and physiological/neuroimaging indices to identify how individual differences in temperament manifest in the activation and efficient implementation of attentional resources.

Wolfe and Bell reported similar findings in a study with preschool-aged children [44•]. They recorded continuous EEG at baseline and during the performance of a series of response inhibition tasks in the lab. Again, parent reports of shyness were unrelated to behavioral performance on the tasks; however, shyness was associated with patterns of change in EEG power during task performance. Specifically, shy children, regardless of task performance, showed a significant baseline-to-task increase in medial frontal and parietal power whereas for non-shy children, only those who performed well on EF tasks showed these task-related changes in power. Again, these findings showed that activation of prefrontal regions of the executive attention network simply maintained, rather than enhanced, the behavioral performance of shy children. Wolfe and Bell speculated that the task-related increases in frontal power could reflect the "cognitive busyness" associated with self-consciousness or task irrelevant self-focused attention elicited by performing in a novel context [44•]. Again, activation of the executive attention network, for shy children, may reflect a compensatory, but inefficient, allocation of neural resources in an attempt to overcome the more habitual pull of attention toward salient contextual cues (as depicted in Fig. 1b).

Tang et al. used a three-stimulus continuous performance, auditory oddball task to examine the associations between shyness and event-related potentials to standard, target, and novel stimuli [12]. In the task, EEG was recorded continuously, and children were instructed to make a button press when they heard a low-frequency target tone (10% frequency) in a stream of standard (80% frequency) and novel (10% frequency) tones. Children's self-reported shyness was associated with shorter response latencies and larger amplitudes P300 ERPs to target and standard tones, but not to the novel tones. Again, though, greater neural activation was not associated with enhanced performance, leading Tang et al. to speculate that this increased cortical arousal was a result of hypervigilance motivated by performance anxiety [12], an interpretation similar to ACT and the 'cognitive busyness' mechanism implicated by Wolfe and Bell to explain their findings with younger children [44•]. Finally, the amplitude of frontal P300 to standard tones mediated the association between conflicted

shyness (i.e., high sociability and high shyness) and neuroticism, suggesting that this tendency towards exaggerated neural responses, or neural inefficiency, potentiates social/emotional risk for shy individuals by supporting extended processing of self-focused cognitions.

BI and Attention Shifting

Attention shifting, another subcomponent of EC, involves flexibly redirecting one's attention between mental sets and operations in response to changing situational demands [48]. The timely shifting of one's attention away from the task-irrelevant dimensions of a stimulus toward appropriate dimensions constitutes efficient attention switching. In contrast to response inhibition, the relation between BI and attention shifting is negative (i.e., high BI/shyness is associated with poor attention shifting) in both children [49, 50] and adults [51]. Eggum-Wilkens et al. reported that higher levels of parent-reported attention shifting at age 3 were concurrently associated with lower levels of parent-reported shyness and that children high in shyness remained lower on attention shifting across early childhood [11•]. Further, while high levels of response inhibition may promote avoidant social behavior, attention shifting may serve as a protective factor against the development of internalizing problems; among BI children, those high in attention shifting displayed fewer anxiety symptoms relative to those low in attention shifting [43]. As discussed above in the context of ACT, the ability to shift attention away from scanning salient contextual cues may be critical for dampening the adverse effects of anxiety on flexible, goal-directed behavior for children high in BI/shyness (as depicted in Fig. 1a).

Attention shifting with regard to emotionally salient social stimuli appears to be particularly relevant to BI. Affective stimuli have privileged access to attentional resources, entering conscious awareness more readily [52–54]. This is particularly true for individuals higher in trait anxiety, among whom attention biases to negative social stimuli (e.g., angry/fearful faces) are prevalent [55]. These biases, in addition to negative biases in the interpretation of ambiguous emotional expressions, are common among BI children [29, 56]. This dispositional preoccupation with emotion may have significant repercussions on attention shifting in social situations. Reeck and Egner found that shifting attention away from the affective dimension of emotionally expressive faces to a non-affective dimension (gender) required greater effort as indexed by slower reaction times and greater activation of neural executive attention systems (e.g., vlPFC, dlPFC, and ACC) relative to shifting attention toward the affective dimension [57]. Shifting attention away from emotional processing may be particularly effortful for BI children given their inherent attention biases. This would diminish the neural and cognitive resources available for engaging in dynamic, flexible, and reciprocal interactions with peers potentially setting off a cascade of negative social experiences for BI children. Eggum-Wilkens et al. hypothesized that attention shifting relates to the quality of children's social interactions by making them attractive and rewarding playmates [11•]. In this regard, the ability to readily engage and disengage from emotional information, referred to as affective flexibility [58], may be a central determinant of the developmental trajectory of BI.

Group differences in affective flexibility have been explored in several populations with characteristics related to BI. Marcus et al. presented preadolescents (ages 11–14) with arrays of four expressive faces and tasked them with identifying two pairs that shared some discriminating characteristic (size, identity, or emotion) [59•]. To match both pairs correctly in 'flexible' trials, participants were required to consider a given face along both its emotional and non-emotional dimensions, thereby engaging affective flexibility. In 'non-flexible' trials, no face was involved in both matches and thus not engaging affective flexibility. Marcus et al. found that higher levels of trait anxiety were associated with slower reaction times (RTs) on flexible trials but not on inflexible trials [59•]. This suggests that anxiety specifically affected participants' abilities to switch to and engage flexibly with the emotional aspects of the stimuli. Similar deficits in affective flexibility have been found in adults with anxious and depressive symptomatology [60] and ruminative tendencies [61, 62]. Future studies with children, incorporating a longitudinal design, will be essential to fully explore the impact of affective flexibility on the association between early BI and later social and psychological outcomes.

Implications for Prevention/Intervention

Conventional wisdom dictates that higher levels of effortful control (broadly defined) are universally advantageous for children and ought to be encouraged by parents and educators. However, in light of the negative developmental outcomes associated with response inhibition and BI, promoting control processes unitarily may unintentionally exacerbate the problems experienced by BI children by honing their habitual and well-developed tendencies to engage in detailed processing and monitoring of salient and self-relevant cues in their environments. Rather, interventions need to reflect individual differences, addressing specific areas of EC in need of improvement. Among children with BI, interventions ought to cultivate the *activational* aspects of EC as a means of surmounting their inhibitory inclinations. The counterpart to response inhibition, activational control, refers to the ability to willfully engage in a behavior despite one's affective inclination to avoid it [63] and is negatively related to shyness across the lifespan [11•, 64]. Given effective strategies for overcoming their inhibitory motivations, BI children may better engage

with their peers from a young age, thereby discouraging social withdrawal [65].

Another potential target for intervention in BI children is attention shifting. Building upon ideas from ACT, attention switching may moderate the detrimental effects of biases to social threat when socializing in early childhood. Attentional control moderates the association between anxiety and biases towards threatening facial expressions, with higher levels of attention shifting facilitating easier disengagement for both anxious children [66] and adults [40]. By enabling BI children to more readily divert their attention from sources of social stress, they can engage their peers in a more dynamic, goal-directed fashion and rely less on avoidant coping responses. Interventions targeting attention shifting (or even more specifically affective flexibility) may provide the groundwork for effective emotion regulation and flexible social problem solving in early childhood.

Another means of improving BI children's social functioning may be introducing coping mechanisms for reducing the 'cognitive busyness' experienced in novel and social evaluative contexts. In this regard, mindful awareness practices could be promising candidates. Mindful awareness (also known as mindfulness) is characterized by the regulation of attention to the present moment and commitment to conscious disengagement from intrusive mental events [67]. School-based mindfulness intervention programs have been shown to increase teacher- and parent-reported EF [68], attention and social skills [69], and to reduce stress responses such as rumination, intrusive thoughts, and emotional arousal [70]. Beyond protracted training programs administered at the group level, Nadler et al. found short sessions of mindfulness administered in small groups to be effective in increasing calmness in 7- to 9-year-old children [71]. This suggests that mindful awareness training targeting children high in BI could be a promising avenue for intervention in early childhood.

Conclusions

In conclusion, BI is a temperament that increases risk for social and emotional maladjustment across the lifespan. By incorporating studies of BI in relation to specific executive control processes, we can better identify the neural and attentional mechanisms to promote versus mitigate this developmental risk. We highlight two important control processes, response inhibition and attention shifting, that differentially impact developmental risk for BI children. Given the automatic processing biases inherent to BI, strong response inhibition skills may engage executive attention networks in an overgeneralized or inefficient way which is evidenced behaviorally by inefficient information processing and inflexible behavior in novel social contexts which can exacerbate anxiety over time. In contrast, attention shifting may facilitate more flexible and efficient goal-directed behavior in BI children. As such, prevention and intervention efforts targeting attention shifting and affective flexibility may support reciprocal and competent interactions with peers, optimizing the social and emotional development of children with a history BI.

Compliance with Ethical Standards

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Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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