Inhibitory Control Deficits in Anxious Individuals: Research Status and Controversies from an Attentional Control Theory Perspective

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Abstract

According to attentional control theory, anxiety impairs individuals' inhibitory control function. Although this hypothesis has received support from substantial behavioral and neurophysiological evidence, considerable controversy surrounds the core question of whether high-anxiety individuals increase or decrease top-down attentional control resources to perform inhibitory control tasks. This situation stems from multiple factors. The theoretical explanations themselves possess clear limitations; the presence of numerous extraneous variables in empirical studies has led to relatively low reliability and validity of existing research findings. Future research could resolve this controversy by investigating the relationships among anxiety levels, attentional control levels, and inhibitory control.

Full Text

Research Status and Controversies Regarding Inhibitory Control Deficits in Anxious Individuals: A Perspective from Attentional Control Theory

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Abstract

According to attentional control theory, anxiety impairs individuals' inhibitory control function. Although this hypothesis has been supported by substantial

behavioral and neurophysiological evidence, considerable controversy persists regarding a core question: Do high-anxiety individuals increase or decrease top-down attentional control resources to complete inhibitory control tasks? This controversy arises from multiple factors. The theoretical explanations themselves exhibit clear deficiencies, and the presence of various extraneous variables in empirical studies has resulted in low reliability and validity of existing findings. Future research could resolve this controversy by exploring the relationships among anxiety level, attentional control level, and inhibitory control.

Keywords: anxiety; inhibitory control deficit; attentional control theory; attentional control

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Anxiety represents an unpleasant emotional experience or psychological state that individuals undergo. As a fundamental emotion emerging through human evolution, moderate anxiety serves adaptive functions; however, high anxiety significantly impairs cognitive abilities (Bishop, 2007; Eysenck, Nazanin, Rita, & Calvo, 2007). Experimental studies have demonstrated that both trait anxiety and test anxiety negatively affect cognitive performance (Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011; Von der Embse, Jester, Roy, & Post, 2018). These detrimental effects manifest not only as attentional biases toward threatening stimuli (e.g., threatening faces and words) in high-anxiety individuals (Mogg & Bradley, 2018; Yair, Dominique, Lee, Bakermans-Kranenberg, & Ijzendoorn, 2007), but also as deficits in inhibitory control over non-threatening stimuli or behaviors (Berggren & Derakshan, 2013a; Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011; Eysenck et al., 2007). This issue is particularly prominent in educational contexts, where Von der Embse et al. (2018) reviewed studies since 1988 on the relationship between test anxiety and various academic performance measures, including standardized tests and college entrance examinations, finding a significant negative correlation between test anxiety and academic achievement. Consequently, researchers have increasingly focused on the mechanisms through which anxiety undermines cognitive abilities.

Both early theories such as cognitive interference theory and processing efficiency theory, as well as the more recent attentional control theory, posit that anxiety impairs individuals' inhibitory control capacity (Eysenck et al., 2007; Von der Embse et al., 2018). However, it is important to note that attentional control theory restricts its applicability specifically to trait anxiety and test anxiety. Inhibitory control function—an individual' s capacity to control attention, behavior, thoughts, and/or emotions to override strong internal predispositions or external temptations in favor of more appropriate or necessary actions—represents a core component of the central executive system (Diamond, 2013). Effective inhibitory control forms the foundation for completing cognitive tasks such as attention and memory processes, making research on how anxiety affects inhibitory function particularly valuable. Nevertheless, substantial controversies exist between relevant theories and empirical studies, significantly hindering progress in this area (Berggren & Derakshan, 2013a; Bishop, 2009).

This paper therefore provides a comprehensive review of recent research on anxiety' s impact on inhibitory function, summarizing and analyzing potential sources of these controversies.

2. Theoretical Explanations of Inhibitory Control Deficits in Anxious Individuals: Two Opposing Perspectives

Researchers integrated cognitive interference theory and processing efficiency theory in 2007 to propose attentional control theory, which has gained widespread acceptance as an explanation for the relationship between anxiety and inhibitory control (Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011; Eysenck et al., 2007). This theory hypothesizes that anxiety weakens attentional control within the central executive system, thereby impairing cognitive performance. The central executive system is not a unidimensional functional structure but rather a comprehensive system composed of distinct yet closely related components. It is believed to contain at least three relatively independent components: inhibition, shifting, and updating (Nigg, 2000). According to attentional control theory, the core components of inhibition and shifting primarily require attentional control, whereas updating mainly relies on memory functions. Consequently, anxiety primarily impairs individuals' inhibition and shifting functions, with growing evidence suggesting that anxiety is more strongly associated with impaired inhibition (Olatunji, Cisler, & Deacon, 2010; Reinholdt-Dunne, Mogg, & Bradley, 2013).

Inhibitory control depends on the normal functioning of the attentional control system, which comprises a stable system of both goal-driven top-down processes and stimulus-driven bottom-up processes (Corbetta & Shulman, 2002). Attentional control theory posits that under normal circumstances, this system maintains dynamic equilibrium. However, high-anxiety individuals exhibit lower system balance, making them more susceptible to interference from both internal distracting stimuli (worrisome thoughts) and external irrelevant information. Worrisome thoughts reduce the efficiency of the top-down goal control system in high-anxiety individuals, while threatening external stimuli disproportionately affect them, resulting in attentional bias toward threat. This further disrupts the dynamic balance of their attentional control system by interfering with bottom-up attentional processes (Eysenck et al., 2007). Additionally, attentional control theory adopts the processing efficiency theory' s perspective that anxiety first impairs processing efficiency rather than performance effectiveness. The "processing efficiency" concept, originally proposed by processing efficiency theory and subsequently embraced by attentional control theory, distinguishes between performance effectiveness—the quality of task completion, typically measured by accuracy—and processing efficiency—the relationship between performance effectiveness and effort expended. In behavioral studies, processing efficiency is typically measured by reaction time, while in neurophysiological research, it can be indexed by neural markers reflecting the degree of top-down attentional resource engagement (Eysenck et al., 2007). Because anx-

ious individuals are more motivated to achieve task goals, they often expend greater attentional control resources. Consequently, compared to low-anxiety individuals, high-anxiety individuals show reduced processing efficiency when completing inhibitory control tasks, yet their performance effectiveness remains unaffected. However, attentional control theory further specifies that performance effectiveness is not permanently immune to anxiety' s effects; when tasks demand high attentional control resources, high-anxiety individuals cannot compensate through additional top-down resource allocation or effort, resulting in impaired performance effectiveness as well (Eysenck et al., 2007).

Despite the theoretical plausibility of these hypotheses and substantial empirical support, critics have challenged attentional control theory' s core assumption that high-anxiety individuals allocate additional top-down attentional control resources to complete inhibitory control tasks (Bishop, 2009). While Bishop agrees that high-anxiety individuals exhibit attentional control deficits, she disputes the theory' s assumption that they maintain unaffected performance effectiveness by sacrificing processing efficiency. Bishop adopted and extended Lavie' s perceptual load theory (Lavie, Hirst, De Fockert, & Viding, 2004), arguing that under high perceptual load conditions, attentional resources are fully occupied by the current task, preventing interference from irrelevant information in both high- and low-anxiety individuals. Under low perceptual load conditions, however, attentional resources are not fully utilized, making individuals susceptible to irrelevant information interference. Due to their inherent attentional control deficits, high-anxiety individuals are consequently more vulnerable to such interference (Bishop, 2007; Bishop, 2009; Bishop, Rob, & Lawrence, 2007). Based on this framework, Bishop acknowledges that attentional control deficits constitute an important cause of inhibitory control impairments in high-anxiety individuals, but argues that these individuals do not exhibit increased attentional control resource investment during inhibitory control tasks. Instead, high-anxiety individuals experience difficulty with top-down attentional control resource engagement and do not maintain performance effectiveness by sacrificing processing efficiency (Bishop, 2009).

Although attentional control theory has faced opposition from some researchers, its proponents have continuously attempted to integrate these theoretical controversies. They argue that the hypothesis regarding high-anxiety individuals'increased top-down attentional control resource allocation is conditional: it holds only when task difficulty is appropriate and high-anxiety individuals are willing and able to allocate additional top-down resources (Berggren & Derakshan, 2013a). If tasks are too simple, high-anxiety individuals may lack motivation to allocate additional resources, resulting in insufficient top-down engagement. Conversely, when task difficulty is excessive or when high-anxiety individuals operate in threatening environments with severely limited available attentional control resources, they may still exhibit insufficient top-down engagement despite increased motivation (Berggren & Derakshan, 2013a). While this hypothesis is theoretically reasonable, it lacks strong empirical support, and relevant studies remain highly controversial.

3. Empirical Studies on Inhibitory Control Deficits in Anxious Individuals

To investigate whether and how anxiety impairs inhibitory control abilities and to test attentional control theory' s hypotheses, researchers have employed multiple methodological approaches. In studies targeting trait anxiety, anxiety measurement has consistently utilized the trait anxiety subscale of the State–Trait Anxiety Inventory (STAI), whereas test anxiety studies have predominantly employed the Test Anxiety Inventory (TAI). Although numerous paradigms exist for measuring inhibitory control, most studies have selected only a single experimental paradigm. Each measurement paradigm assesses only partial aspects of inhibitory control, yet all inhibitory functions consume attentional control resources, and existing research indicates that anxiety's effects do not differ across various inhibitory control functions (Berggren & Derakshan, 2013a; Eysenck et al., 2007). Inhibitory control functions can be summarized as comprising at least two closely related yet cognitively distinct components: resistance to distractor interference and prepotent response inhibition (Friedman & Miyake, 2004). Therefore, we will separately elaborate on how anxiety affects these two inhibitory control abilities.

3.1 Behavioral Studies

Behavioral research on anxiety' s impact on inhibitory control has primarily focused on testing a core hypothesis of attentional control theory: compared to low-anxiety individuals, high-anxiety individuals expend greater attentional control resources to achieve task goals, such that anxiety first affects processing efficiency rather than performance effectiveness when completing inhibitory control tasks (Derakshan & Eysenck, 2009; Eysenck et al., 2007). The logic of behavioral studies is as follows: both distractor interference inhibition and prepotent response inhibition tasks include at least two conditions—a relatively simple control condition requiring minimal attentional control resource consumption, and a more difficult inhibitory control condition requiring substantial resource expenditure. According to attentional control theory, high- and low-anxiety individuals should not differ significantly in reaction time or accuracy during control conditions. However, when completing inhibitory control tasks, high-anxiety individuals should exhibit significantly longer reaction times than low-anxiety individuals due to their strategy of sacrificing processing efficiency to maintain performance effectiveness, while showing no significant differences in accuracy.

3.1.1 Anxiety Impairs Distractor Interference Inhibition Distractor interference inhibition refers to the ability to resist or resolve interference from task-irrelevant information in the external environment, with the Eriksen Flanker task being the most classic representative paradigm (Eriksen & Eriksen, 1974). Researchers using the Flanker task to investigate trait anxiety' s impact on distractor interference inhibition have found that high trait-anxiety

individuals show larger interference effects in reaction time, primarily due to increased reaction times during incompatible trials. However, these studies did not conduct differential analyses of accuracy between high and low trait-anxiety groups (Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010). Another study using a modified Flanker task replicated this finding of larger interference effects in high trait-anxiety individuals, again attributable to increased reaction times during incompatible trials, while finding no significant accuracy differences between groups (Berggren & Derakshan, 2013b). These results partially support attentional control theory' s hypothesis that anxiety primarily affects processing efficiency rather than performance effectiveness. Nevertheless, not all behavioral findings support this hypothesis. One study using the Flanker task to examine test-anxious individuals' distractor interference inhibition found no significant reaction time differences between high and low test-anxiety groups in a non-threatening context (Zhang, Zhou, & Zou, 2015).

3.1.2 Anxiety Impairs Prepotent Response Inhibition Prepotent response inhibition refers to the ability to intentionally suppress dominant, automatic, or prepotent responses, commonly measured using the antisaccade task, color-word Stroop task, and Go/Nogo task (Friedman & Miyake, 2004; Hallett, 1978; Nigg, 2000).

Research using the antisaccade task has demonstrated that high trait-anxiety individuals exhibit significantly longer reaction times when completing antisaccade trials (which require attentional control resource consumption) compared to low trait-anxiety individuals, while showing no significant reaction time differences during prosaccade trials (which require minimal attentional control). Importantly, no significant accuracy differences emerged between high and low trait-anxiety groups for either trial type (Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009). This pattern supports attentional control theory's hypothesis that anxiety primarily affects processing efficiency rather than performance effectiveness. However, studies using the Go/Nogo task to examine trait anxiety' s impact on prepotent response inhibition have found no significant differences between high and low trait-anxiety individuals in either processing efficiency (indexed by Go trial reaction time) or performance effectiveness (indexed by Go trial accuracy or Nogo trial error rates) (Righi, Mecacci, & Viggiano, 2009; Sehlmeyer et al., 2010). Conversely, a study using the color-word Stroop task found no reaction time differences between high and low trait-anxiety individuals, but observed higher error rates in high trait-anxiety individuals during incompatible trials (Basten, Stelzel, & Fiebach, 2011).

3.2 Neural Mechanism Studies

The logic underlying neural mechanism research on anxiety' s impact on inhibitory control is as follows: during control conditions, tasks are simple and do not consume excessive attentional control resources, so high- and low-anxiety individuals should not differ significantly in brain activity within regions re-

sponsible for attentional control resource allocation. During inhibitory control tasks, however, the increased difficulty demands substantial attentional control resources, and due to high-anxiety individuals' attentional control deficits, their brain activity in attention-related regions should differ significantly from that of low-anxiety individuals. Nevertheless, existing research remains controversial regarding whether activity in attention-related brain regions increases or decreases during inhibitory control task completion (Berggren & Derakshan, 2013a).

3.2.1 Anxiety Impairs Distractor Interference Inhibition According to attentional control theory, although high-anxiety individuals exhibit attentional control deficits, they compensate by expending greater attentional resources to improve task performance. Therefore, when completing inhibitory control tasks, high-anxiety individuals should show enhanced activity in brain regions responsible for attentional control resource allocation compared to low-anxiety individuals. Research using the Flanker task has found that high trait-anxiety individuals exhibit larger N2 waves in frontal regions during distractor interference inhibition tasks compared to low trait-anxiety individuals (Qi et al., 2014). The N2 wave, a negative component occurring 200-350 ms post-stimulus, is considered an important index of response inhibition control or conflict monitoring (Folstein & Van Petten, 2008; Yeung, Botvinick, & Cohen, 2004). Thus, high-anxiety individuals appear to expend greater attentional control resources to complete inhibitory control tasks. However, not all neurophysiological findings support attentional control theory. One study combining the Flanker paradigm with emotional cues found that following threatening face presentation, only low trait-anxiety groups showed significant N2 amplitude differences between compatible and incompatible conditions. Moreover, high trait-anxiety individuals exhibited significantly reduced N2 amplitude differences (incompatible minus compatible), reflecting diminished conflict monitoring capacity—indicating impaired distractor interference inhibition without increased attentional control resource engagement (Dennis & Chen, 2009). Bishop, using a letter search task, found that compared to neutral face cues, threatening face presentation produced significantly increased amygdala activation but decreased prefrontal activation in high versus low trait-anxiety individuals, an effect observed only under low perceptual load, not high load (Bishop et al., 2007). Furthermore, to avoid emotional stimulus interference, Bishop had participants complete only the letter search task and found that under low load conditions, trait anxiety scores were significantly negatively correlated with dorsal prefrontal activation strength (incompatible minus compatible) (Bishop, 2009). This not only supports the applicability of perceptual load theory to research on inhibitory control deficits in high-anxiety individuals but also suggests that high-anxiety individuals' attentional control deficits may result from insufficient top-down attentional resource engagement, contradicting attentional control theory' s assumptions. However, it should be noted that in Bishop' s study, the low-load task may have been too simple, potentially creating inhibitory control tasks with minimal con-

flict that did not require substantial attentional control resource consumption (Bishop, 2009). This is particularly problematic because attentional control theory specifically posits that high-anxiety individuals only allocate additional top-down attentional control resources when current tasks demand substantial attentional control resources (Eysenck et al., 2007), rendering these findings even more controversial.

3.2.2 Anxiety Impairs Prepotent Response Inhibition Researchers have examined EEG activity during prepotent response inhibition in trait-anxious individuals using the Go/Nogo task. Results indicate that high trait-anxiety individuals exhibit larger N2 amplitudes in frontal regions during Nogo trials compared to low trait-anxiety individuals, suggesting that high trait-anxiety individuals require greater attentional control resource expenditure to complete the task (Righi et al., 2009; Sehlmeyer et al., 2010). Additionally, a study using the Stop-Signal paradigm found that high trait-anxiety individuals showed greater alpha wave desynchronization in frontal regions compared to low trait-anxiety individuals. Since alpha wave activity strength is inversely related to cortical activity in corresponding brain regions, this indicates that high-anxiety individuals allocate more attentional control resources to suppress prepotent responses (Savostyanov et al., 2009). To directly investigate activity in the dorsolateral prefrontal cortex (DLPFC)—the brain region responsible for attentional resource regulation during inhibitory control—researchers combined functional magnetic resonance imaging (fMRI) with the color-word Stroop task. They found that compared to low trait-anxiety individuals, high trait-anxiety individuals showed significantly increased DLPFC activation during incompatible trials. Additionally, high trait-anxiety individuals exhibited lower functional connectivity between the DLPFC and other regions in the inhibitory control network, including the inferior frontal junction area (IFJ), dorsal anterior cingulate cortex (dACC), and left fusiform gyrus (Basten et al., 2011). The DLPFC is considered a core control region for attentional control (Aw, Cohen, Stenger, & Carter, 2000), and its increased activation during inhibitory control tasks suggests that high trait-anxiety individuals adopt a strategy of increasing top-down attentional control resources to compensate for attentional control deficits. However, research using the antisaccade paradigm found that high trait-anxiety individuals showed reduced ERP activity in frontal and central regions immediately before the presentation of to-be-inhibited targets. Since pre-target ERP activity in the antisaccade task reflects neural indices of top-down attentional control resource engagement for inhibition, high trait-anxiety individuals appear to exhibit insufficient top-down resource engagement during inhibitory tasks (Ansari & Derakshan, 2011), contradicting attentional control theory' s hypotheses.

4. Controversies in Existing Research

Multiple factors have prevented researchers from reaching consensus on whether high-anxiety individuals increase or decrease top-down attentional control re-

sources to complete inhibitory control tasks. Overall, these controversies stem from two main sources: obvious deficiencies in theoretical assumptions that contain logical loopholes, and inadequate control of extraneous variables in empirical research that prevents proper validation of theoretical hypotheses.

4.1 Theoretical Controversies

Theoretical controversies primarily manifest as loopholes in existing theories' explanations of the mechanisms underlying inhibitory control deficits in high-anxiety individuals.

First, current theoretical assumptions are based on the premise that high anxiety impairs attentional control, which in turn causes inhibitory control dysfunction. This framework implicitly treats high anxiety as the cause and impaired attentional control as the effect. However, this premise lacks strong empirical support. Although existing research demonstrates that high-anxiety individuals exhibit reduced attentional control, these findings only establish a correlational relationship between anxiety and attentional control capacity. Conversely, attentional control constitutes an important resource for emotion regulation, and low attentional control may itself be a significant cause of anxiety (Gagne, Osullivan, Schmidt, Spann, & Goldsmith, 2017; Ochsner & Gross, 2005; Opitz, Gross, & Urry, 2012). Experimental research has shown that individuals with low attentional control exhibit significant increases in anxiety levels (indexed by electrodermal activity) following the Trier Social Stress Test (TSST), whereas changes in anxiety levels did not significantly alter attentional control capacity (Birk, Opitz, & Urry, 2017). Furthermore, some researchers have identified low attentional control during childhood as a significant risk factor for generalized anxiety disorder nine years later (Zainal & Newman, 2018). Additionally, working memory updating training (dual n-back) has been shown to improve attentional control levels (indexed by theta/beta ratio) and inhibitory control capacity (indexed by Flanker task reaction time) in trait-anxious individuals while simultaneously reducing their trait anxiety levels (Sari, Koster, Pourtois, & Derakshan, 2016). Since working memory updating training essentially constitutes attentional control training (Shipstead, Lindsey, Marshall, & Engle, 2014), these findings suggest that low attentional control may be an important cause of anxiety, warranting further investigation into the applicability of current theoretical assumptions.

Second, controversy persists regarding whether anxiety' s trait or state characteristics consume attentional control resources. Although both attentional control theory proponents and Bishop argue that trait anxiety rather than state anxiety is associated with attentional control resource allocation, with supporting empirical evidence (Bishop, 2007; Eysenck et al., 2007), laboratory research faces difficulty accurately determining the respective contributions of trait and state anxiety to attentional control changes. For instance, when using the Flanker task to examine distractor interference inhibition deficits, experimentally induced state anxiety changes did not affect inhibitory control levels

(Pacheco-Unguetti et al., 2010). Bishop' s research demonstrated that trait anxiety scores correlated with prefrontal activation during inhibitory control tasks, whereas state anxiety scores correlated with amygdala activation (Bishop et al., 2007). However, from a laboratory research perspective, it is challenging to precisely determine the contributions of trait and state anxiety because high trait-anxiety individuals often exhibit elevated state anxiety during task performance, particularly in evaluative contexts. Therefore, both trait and state characteristics of anxiety may jointly influence attentional control levels.

4.2 Empirical Controversies

Empirical research suffers from low reliability and validity due to multiple confounding extraneous variables.

First, different experimental paradigms involve substantially different cognitive processes. The complexity of inhibitory control has led most researchers to examine only single inhibitory control capacities. Although existing theories and research have not specified whether anxiety differentially affects various inhibitory control abilities, this may constitute an important source of controversy. On one hand, cognitive process differences between distractor interference inhibition and prepotent response inhibition may contribute to divergent results (Brydges, Anderson, Reid, & Fox, 2013; Brydges et al., 2012; Velzen, Chris, Wit, & Heuvel, 2014). For example, the Flanker task (measuring distractor interference inhibition) and the Go/Nogo task (measuring prepotent response inhibition) involve significantly different cognitive processes (Brydges et al., 2012; Giuseppe et al., 2010). The Go/Nogo task involves a process of stopping all responses, whereas the Flanker task requires inhibiting irrelevant information interference before making a correct response. In terms of task difficulty, distractor interference inhibition tasks consume relatively more attentional control resources (Brydges et al., 2012). On the other hand, even tasks measuring the same inhibitory control component differ in cognitive processes. For instance, although both Go/Nogo and Stop-Signal tasks measure prepotent response inhibition, they correspond to action stopping and action cancellation, respectively, reflecting middle and late stages of inhibitory control (Sebastian et al., 2013). Thus, while different inhibitory control measurement paradigms reflect inhibitory control capacity, they cannot be considered completely equivalent to complete inhibitory control ability, undoubtedly increasing research controversies.

Second, the validity of processing efficiency and performance effectiveness measures used in inhibitory control research remains controversial. In behavioral studies, reaction time typically serves as the processing efficiency index and accuracy as the performance effectiveness index. However, some researchers argue that reaction time is only an indirect measure of processing efficiency, which may explain why many behavioral studies fail to find significant reaction time differences between high- and low-anxiety individuals—though this alone cannot fully account for contradictory findings across studies (Eysenck & Derakshan, 2011). The validity issues with reaction time and accuracy as indices may constitute

another important factor. For example, in Go/Nogo tasks, many participants achieve 100% accuracy on Go trials, which overlooks individual differences in decision criteria used to distinguish Go from Nogo stimuli during task completion. Some participants may adopt relatively conservative strategies, while others may sacrifice accuracy for shorter reaction times. To address this limitation, some researchers have introduced signal detection theory' s d as a performance effectiveness index and the ratio of d to Go trial reaction time for correct trials as a processing efficiency index when examining trait anxiety' s impact on prepotent response inhibition using the Go/Nogo paradigm. Results indicated that trait anxiety impaired both processing efficiency and performance effectiveness (Edwards, Edwards, & Lyvers, 2017). In neurophysiological research, the validity of processing efficiency indices is similarly debated. In Flanker tasks, the N2 component typically serves as an index of inhibitory control processes, yet some researchers argue that typical N2 components are absent in classic Flanker tasks with equiprobable congruent and incongruent trials, suggesting that previously observed N2 components may actually reflect frontal P3 components (Kałamała, Szewczyk, Senderecka, & Wodniecka, 2018). Moreover, whether the N2 component reflects conflict monitoring or inhibitory control remains controversial (Groom & Cragg, 2015). Therefore, findings from studies using the N2 component to investigate the neural mechanisms of inhibitory control deficits in anxious individuals require further verification.

Third, task difficulty and cognitive load may be important factors influencing experimental results. On one hand, according to attentional control theory, if tasks are too simple, high-anxiety individuals may lack motivation to allocate additional top-down attentional control resources, resulting in insufficient resource engagement (Berggren & Derakshan, 2013a). On the other hand, when available attentional resources are sufficient, inhibitory control deficits in high-anxiety individuals may not be apparent. Only when task difficulty increases or attentional resources are occupied by other tasks—making available attentional control resources inadequate to meet current demands—does anxiety' s detrimental effect on inhibitory control become evident (Eysenck et al., 2007). Researchers have investigated this issue using dual-task paradigms, finding that anxiety' s impact on processing efficiency is non-significant or small under low cognitive load, but emerges or increases significantly under high cognitive load (Berggren, Koster, & Derakshan, 2012; Najmi, Amir, Frosio, & Ayers, 2015). For example, in Qi et al.' s (2014) study, participants completed a Flanker task concurrently with either high- or low-load working memory tasks. Results revealed that only under high working memory load did high trait-anxiety individuals exhibit larger interference effects in both reaction time and N2 amplitude compared to low trait-anxiety individuals. Finally, as attentional control theory notes, when inhibitory control tasks demand extremely high attentional control resources or when available resources are very limited, we must consider that attentional control resources are inherently finite, and high-anxiety individuals may be unable to complete inhibitory control tasks through increased top-down resource allocation. However, in actual research, it is difficult to control all

variables within a single study, which undoubtedly reduces research reliability.

Fourth, individuals'motivational levels and working memory capacity may be important confounding variables (Diamond, 2013; Kouneiher, Charron, & Koechlin, 2009). According to attentional control theory, although high-anxiety individuals' attentional control resources are depleted, they expend greater effort to improve task performance, particularly when task difficulty is sufficient or goals are clear. Therefore, this hypothesis assumes that high-anxiety individuals possess the motivation to expend greater effort to achieve goals. When motivation is low, high-anxiety individuals may not allocate additional effort (Edwards et al., 2017). Some studies have even found that high-anxiety individuals may 倾向于 complete tasks more quickly, resulting in shorter reaction times (Basten et al., 2011). In specific contexts, such as examination settings or under time constraints, low-anxiety individuals may also exhibit high motivational levels. Consequently, significant reaction time differences between high- and low-anxiety individuals may not be observed. Thus, individual motivational level variations may confound research findings. Additionally, individual working memory capacity may be another important factor causing divergent results across studies, as successful inhibitory control depends on adequate working memory capacity (Diamond, 2013), and individuals with high working memory capacity have been shown to possess better inhibitory control abilities (Unsworth, Schrock, & Engle, 2004). Experimental research has demonstrated that high working memory capacity can counteract trait anxiety' s negative impact on prepotent response inhibition (Wright, Dobson, & Sears, 2014). Therefore, individuals with high working memory capacity possess superior inhibitory control abilities and can easily manage inhibitory control tasks, making the impairing effects of high anxiety on their inhibitory control less apparent.

Despite continuous theoretical development and emerging empirical research on anxiety-related inhibitory control deficits, researchers have yet to reach consensus on this issue. By summarizing the latest research findings and analyzing potential causes from both theoretical and empirical perspectives, this paper proposes viable directions for future research.

Regarding theoretical controversies, intervention studies with high-anxiety individuals may provide a promising approach to resolving current dilemmas. First, the focal point of disagreement between the two opposing theoretical perspectives concerns the activity status of prefrontal and other attention control-related brain regions during inhibitory control task completion. Intervention methods that can directly alter brain region activity, such as transcranial electrical stimulation, may offer an effective solution by enhancing or reducing activity in relevant brain regions to investigate relationships between regional activity and processing efficiency/performance effectiveness during inhibitory control tasks (Ironside et al., 2017; Miler, Meron, Baldwin, & Garner, 2018). Second, employing established attentional control training methods such as mindfulness training and working memory training with high-anxiety individuals while monitoring changes in attentional control and anxiety levels may help clarify the

relationship between anxiety and attentional control deficits (Leone de Voogd, Wiers, Zwitser, & Salemink, 2016; Sari et al., 2016; Xiu, Wu, Chang, & Zhou, 2018). Monitoring relationships among attentional control level, trait anxiety, and state anxiety may help determine whether anxiety' s trait or state characteristics influence attentional control levels.

Regarding controversies in existing empirical findings, there is no single optimal solution, as a major source of controversy stems from the inherent complexity of both anxiety and inhibitory control. Therefore, future research should pay particular attention to controlling extraneous variables, which is fundamental to ensuring good reliability and validity. Simultaneously, analyzing and investigating factors that may confound research findings can enhance our understanding of anxiety and inhibitory control. First, divergent results across different inhibitory control measurement paradigms may indicate that anxious individuals exhibit differential impairment across inhibitory control components. Identifying these differential impairments could enable more targeted interventions for inhibitory control deficits (Maraver, Bajo, & Gomez-Ariza, 2016). Second, developing more effective measures of processing efficiency and performance effectiveness is essential for advancing inhibitory control research; if measurement indices lack validity, research findings cannot be adequately assured. Third, investigating how task difficulty and cognitive load affect inhibitory control in high-anxiety individuals can enhance understanding of the mechanisms underlying anxiety-related inhibitory control deficits and improve theoretical explanations. Based on the assumption that high-anxiety individuals inherently possess insufficient attentional control, dual-task paradigms should reveal more pronounced inhibitory control deficits under high working memory load—findings that would conversely support the hypothesis that insufficient available attentional control resources cause inhibitory control deficits in high-anxiety individuals. Finally, a significant cause of controversy in existing research is the neglect of individual differences. Therefore, investigating how individual motivation and working memory capacity moderate inhibitory control deficits in high-anxiety individuals will benefit understanding of the underlying mechanisms.

Ansari, T. L., & Derakshan, N. (2011). The neural correlates of impaired inhibitory control in anxiety. *Neuropsychologia, 49*(5), 1146-1153.

Aw, M. D., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, 288*(5472), 1835-1838.

Basten, U., Stelzel, C., & Fiebach, C. J. (2011). Trait anxiety modulates the neural efficiency of inhibitory control. *Journal of Cognitive Neuroscience, 23*(10), 3132-3145.

Berggren, N., & Derakshan, N. (2013a). Attentional control deficits in trait anxiety: Why you see them and why you don' t. *Biological Psychology, 92*(3), 440-446.

Berggren, N., & Derakshan, N. (2013b). The role of consciousness in attentional control differences in trait anxiety. *Cognition and Emotion, 27*(5), 923-931.

Berggren, N., Koster, E. H. W., & Derakshan, N. (2012). The effect of cognitive load in emotional attention and trait anxiety: An eye movement study. *Journal of Cognitive Psychology, 24*(1),

Birk, J. L., Opitz, P. C., & Urry, H. L. (2017). Distractibility as a precursor to anxiety: Preexisting attentional control deficits predict subsequent autonomic arousal during anxiety. *Biological Psychology, 122*, 59-68.

Bishop, S. J. (2007). Neurocognitive mechanisms of anxiety: An integrative account. *Trends in Cognitive Sciences, 11*(7), 307-316.

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12*(1), 92–98..

Bishop, S. J., Rob, J., & Lawrence, A. D. (2007). Neural processing of fearful faces: Effects of anxiety are gated by perceptual capacity limitations. *Cerebral Cortex, 17*(7), 1595–1603.

Brydges, C. R., Anderson, M., Reid, C., & Fox, A. M. (2013). Maturation of cognitive control: Delineating response inhibition and interference suppression. *PloS One, 8*(7).

Brydges, C. R., Clunies-Ross, K., Clohessy, M., Lo, Z. L., Nguyen, A., Rousset, C., et al. (2012). Dissociable components of cognitive control: An event-related potential (erp) study of response inhibition and interference suppression. *PloS One, 7*(3), e34482.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*(3), 201-215.

Dennis, T. A., & Chen, C. C. (2009). Trait anxiety and conflict monitoring following threat: An ERP study. *Psychophysiology, 46*(1), 122-131.

Derakshan, N., Ansari, T. L., Hansard, M., Shoker, L., & Eysenck, M. W. (2009). Anxiety, inhibition, efficiency, and effectiveness: An investigation using the antisaccade task. *Experimental Psychology, 56*(1), 48-55.

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist, 14*(2), 168-176.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135-168.

Edwards, M. S., Edwards, E. J., & Lyvers, M. (2017). Cognitive trait anxiety, stress and effort interact to predict inhibitory control. *Cognition and Emotion, 31*(4), 671-686.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143-149.

Eysenck, M. W., & Derakshan, N. (2011). New perspectives in attentional control theory. *Personality and Individual Differences, 50*(7), 955-960.

Eysenck, M. W., Nazanin, D., Rita, S., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336-353.

Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the erp: A review. *Psychophysiology, 45*(1), 152-170.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*(1),

Gagne, J. R., Osullivan, D. L., Schmidt, N. L., Spann, C. A., & Goldsmith, H. H. (2017). The shared etiology of attentional control and anxiety: An adolescent twin study. *Journal of Research on Adolescence, 27*(1), 122-138.

Giuseppe, B., Goldberg, T. E., Thomas, W., Saumitra, D., Philip, K., Brad, Z., et al. (2010). Brain regions underlying response inhibition and interference monitoring and suppression. *European Journal of Neuroscience, 23*(6), 1658-1664.

Groom, M. J., & Cragg, L. (2015). Differential modulation of the N2 and P3 event-related potentials by response conflict and inhibition. *Brain & Cognition, 97*, 1-9.

Hallett, P. (1978). Primary and secondary saccades to goals defined by instructions. *Vision Research, 18*(10), 1279-1296.

Ironside, M., Browning, M., Ansari, T., Harvey, C., Sekyi-Djan, M., Bishop, S., et al. (2017). Prefrontal cortex regulates amygdala response to threat in trait anxiety. *BioRxiv*, 215699.

Kałamała, P., Szewczyk, J., Senderecka, M., & Wodniecka, Z. (2018). Flanker task with equiprobable congruent and incongruent conditions does not elicit the conflict N2. *Psychophysiology, 55*(2), e12980.

Kouneiher, F., Charron, S., & Koechlin, E. (2009). Motivation and cognitive control in the human prefrontal cortex. *Nature Neuroscience, 12*(7), 939-945.

Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General, 133*(3), 339-354.

Leone de Voogd, E., Wiers, R. W., Zwitser, R. J., & Salemink, E. (2016). Emotional working memory training as an online intervention for adolescent anxiety and depression: A randomised controlled trial. *Australian Journal of Psychology, 68*(3), 228-238.

Maraver, M. J., Bajo, M. T., & Gomez-Ariza, C. J. (2016). Training on working memory and inhibitory control in young adults. *Frontiers in Human Neuroscience, 10*(e0142169), 588.

Miler, J. A., Meron, D., Baldwin, D. S., & Garner, M. (2018). The effect of prefrontal transcranial direct current stimulation on attention network function in healthy volunteers. *Neuromodulation, 21*(4), 355-361.

Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: Cognitive-motivational framework and treatment. *Trends in Cognitive Sciences, 22*(3), 225-240.

Najmi, S., Amir, N., Frosio, K. E., & Ayers, C. (2015). The effects of cognitive load on attention control in subclinical anxiety and generalised anxiety disorder. *Cognition and Emotion, 29*(7), 1210-

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*(2),

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences, 9*(5), 242-249.

Olatunji, B. O., Cisler, J. M., & Deacon, B. J. (2010). Efficacy of cognitive behavioral therapy for anxiety disorders: A review of meta-analytic findings. *Psychiatric Clinics, 33*(3), 557-577.

Opitz, P. C., Gross, J. J., & Urry, H. L. (2012). Selection, optimization, and compensation in the domain of emotion regulation: Applications to adolescence, older age, and major depressive disorder. *Social and Personality Psychology Compass, 6*(2), 142-155.

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. *Psychological science, 21*(2), 298-304.

Qi, S., Zeng, Q., Luo, Y., Duan, H., Ding, C., Hu, W., et al. (2014). Impact of working memory load on cognitive control in trait anxiety: An ERP study. *PloS 0ne, 9*(11), e111791.

Reinholdt-Dunne, M. L., Mogg, K., & Bradley, B. P. (2013). Attention control: Relationships between self-report and behavioural measures, and symptoms of anxiety and depression. *Cognition and Emotion, 27*(3), 430-440.

Righi, S., Mecacci, L., & Viggiano, M. P. (2009). Anxiety, cognitive self-evaluation and performance: Erp correlates. *Journal of Anxiety Disorders, 23*(8), 1132-1138.

Sari, B. A., Koster, E. H., Pourtois, G., & Derakshan, N. (2016). Training working memory to improve attentional control in anxiety: A proof-of-principle study using behavioral and electrophysiological measures. *Biological Psychology, 121*, 203-212.

Savostyanov, A. N., Tsai, A. C., Liou, M., Levin, E. A., Lee, J.-D., Yurganov, A. V., et al. (2009). Eeg-correlates of trait anxiety in the stop-signal paradigm. *Neuroscience Letters, 449*(2), 112-116.

Sebastian, A., Pohl, M. F., Klöppel, S., Feige, B., Lange, T., Stahl, C., et al. (2013). Disentangling common and specific neural subprocesses of response inhibition. *NeuroImage, 64*(1), 601-615.

Sehlmeyer, C., Konrad, C., Zwitserlood, P., Arolt, V., Falkenstein, M., & Beste, C. (2010). Erp indices for response inhibition are related to anxiety-related personality traits. *Neuropsychologia, 48*(9),

Shipstead, Z., Lindsey, D. R. B., Marshall, R. L., & Engle, R. W. (2014). The mechanisms of working memory capacity: Primary memory, secondary memory, and attention control. *Journal of Memory & Language, 72*(1), 116-141.

Unsworth, N., Schrock, J. C., & Engle, R. W. (2004). Working memory capacity and the antisaccade task: Individual differences in voluntary saccade control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(6), 1302-1321.

Velzen, L. S., Van, Chris, V., Wit, S. J., De, & Heuvel, O. A., Van Den. (2014). Response inhibition and interference control in obsessive-compulsive spectrum disorders. *Frontiers in Human Neuroscience, 8*, 419.

Von der Embse, N., Jester, D., Roy, D., & Post, J. (2018). Test anxiety effects, predictors, and correlates: A 30-year meta-analytic review. *Journal of Affective Disorders, 227*, 483-493.

Wright, C. A., Dobson, K. S., & Sears, C. R. (2014). Does a high working memory capacity attenuate the negative impact of trait anxiety on attentional control? Evidence from the antisaccade task. *Journal of Cognitive Psychology, 26*(4), 400-412.

Xiu, L., Wu, J., Chang, L., & Zhou, R. (2018). Working memory training improves emotion regulation ability. *Scientific Reports, 8*(1), 15012.

Yair, B. H., Dominique, L., Lee, P., Bakermans-Kranenburg, M. J., & Ijzendoorn, M. H., Van. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*(1), 1-24.

Yeung, N., Botvinick, M. M., & Cohen, J. D. (2004). The neural basis of error detection: Conflict monitoring and the error-related negativity. *Psychological Review, 111*(4), 931-959.

Zainal, N. H., & Newman, M. G. (2018). Executive function and other cognitive deficits are distal risk factors of generalized anxiety disorder 9 years later. *Psychological Medicine , 48*(12), 2045-

Zhang, H., Zhou, R., & Zou, J. (2015). Modulation of executive attention by threat stimulus in test-anxious students. *Frontiers in Psychology, 6*, 1486.

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