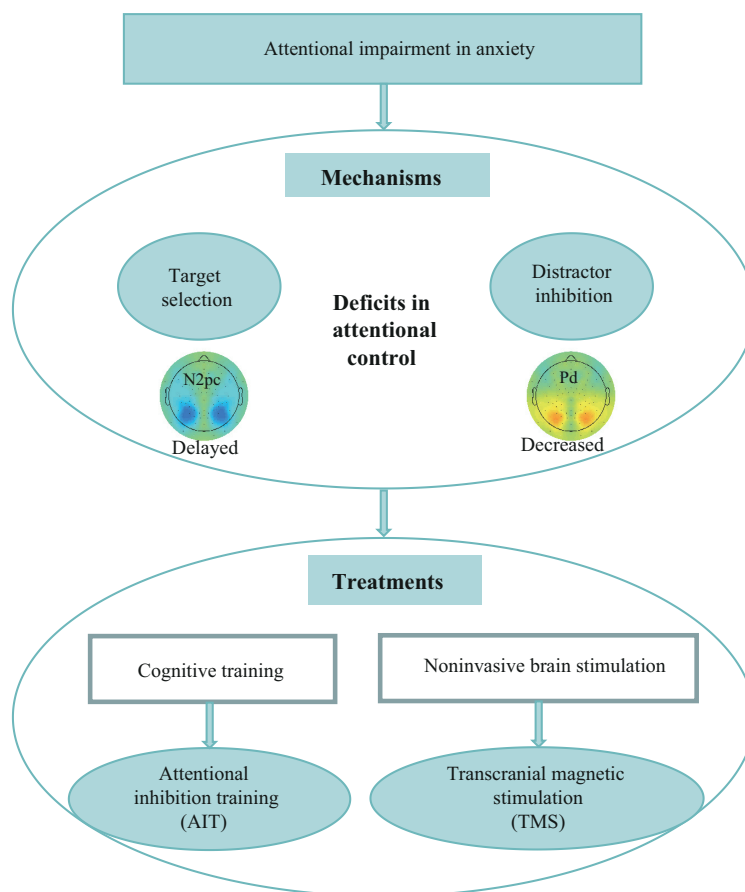# Neurological Insights into Attentional Deficits in High Trait Anxiety: a Commentary on Hu *et al.*'s Paper in *Cerebral Cortex* (2023)[*]

MA Hao-Yun[1,2], LIANG Jian-Hui[2], LIU Dong-Qiang[1]**

([1])*Research Center of Brain and Cognitive Neuroscience, Liaoning Normal University, Dalian 116029, China;*

[2])*Shenzhen−Hong Kong Institute of Brain Science, Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China)*

Graphical abstract

Abstract　In a recent publication, Hu *et al.* (2023) have reported that individuals with high trait anxiety exhibit attentional deficits characterized by reduced inhibition of distractors and delayed attentional selection of targets, indicating impaired top-down attentional control. This commentary underscores their significant contributions to the cognitive theory of anxiety. Based on their findings, we propose a novel training approach called attentional inhibition training (AIT), aimed at improving top-down attentional control to alleviate symptoms of anxiety. Furthermore, we explore the potential application of non-invasive transcranial magnetic stimulation (TMS) for rapidly enhancing attentional control function.

Anxiety disorders are prevalent mental health conditions. High-level anxiety has long been associated with increased attention to negative stimuli[1]. Recent studies show that highly anxious individuals are more prone to distraction from irrelevant stimuli, even when they are non-emotional stimuli, such as geometric shapes. This suggests a general impairment in attentional processes that is not specific to emotional stimuli[2-3]. However, the neural mechanisms underlying this general attentional impairment in anxiety remain unclear. A recent study published in *Cerebral Cortex* by Hu *et al.*[4] provides direct neurophysiological evidence supporting the notion that high trait anxiety impairs top-down attentional control, including less effective inhibition of distractors and slower selection of target stimuli.

Understanding the impact of anxiety on both bottom-up and top-down attentional processes is crucial to comprehending the mechanism underlying anxiety-related attention deficits. Previous studies have provided evidence for impairments associated with anxiety in bottom-up attentional processing. In a visual search task, Hu *et al.*[4] examined the attentional processing of neutral geometric stimuli using neurophysiological indicators of attentional selection and inhibition, namely N2pc and Pd components of event-related potential (ERP). The authors found that decreased inhibition of distractors was associated with increased levels of trait anxiety, however, trait anxiety did not affect bottom-up attentional capture. Additionally, high trait anxiety resulted in delayed target selection due to impaired top-down control over attention. This finding suggests that individuals with high trait anxiety exhibit general deficits in top-down attentional control, *i. e.*, poorer distractor inhibition and slower target selection.

1　Mechanisms underlying attentional impairment associated with anxiety

This research makes significant contributions to our understanding of attentional impairment mechanisms in high anxiety through three key aspects. Firstly, anxiety-related theories propose that anxiety may enhance bottom-up attention while diminishing top-down attentional control, particularly inhibitory function[1, 5]. For example, an fMRI study has indicated reduced prefrontal attentional control among highly anxious individuals[6]. In this study, the authors present pioneering neurophysiological evidence for impaired inhibition function in high anxiety. Thus far, corresponding evidence has supported the impact of anxiety on both bottom-up and top-down attention[3-4] (Figure 1). Bottom-up and top-down processing are fundamental components of attention[7], with the former referring to automatic attentional capture by salient stimuli and the latter emphasizing active control of attention guided by personal goals, expectations, and prior knowledge. High anxiety increases individuals' susceptibility to salient stimuli such as threatening or distinct color stimuli, which is reflected in enhanced bottom-up attentional capture[8]. Additionally, anxiety affects the top-down attentional control system involved in active selection of task-relevant targets and inhibition of task-irrelevant distractors[6, 9]. This study provides neural evidence that anxiety impairs both target selection and distractor inhibition within the top-down attentional control system.
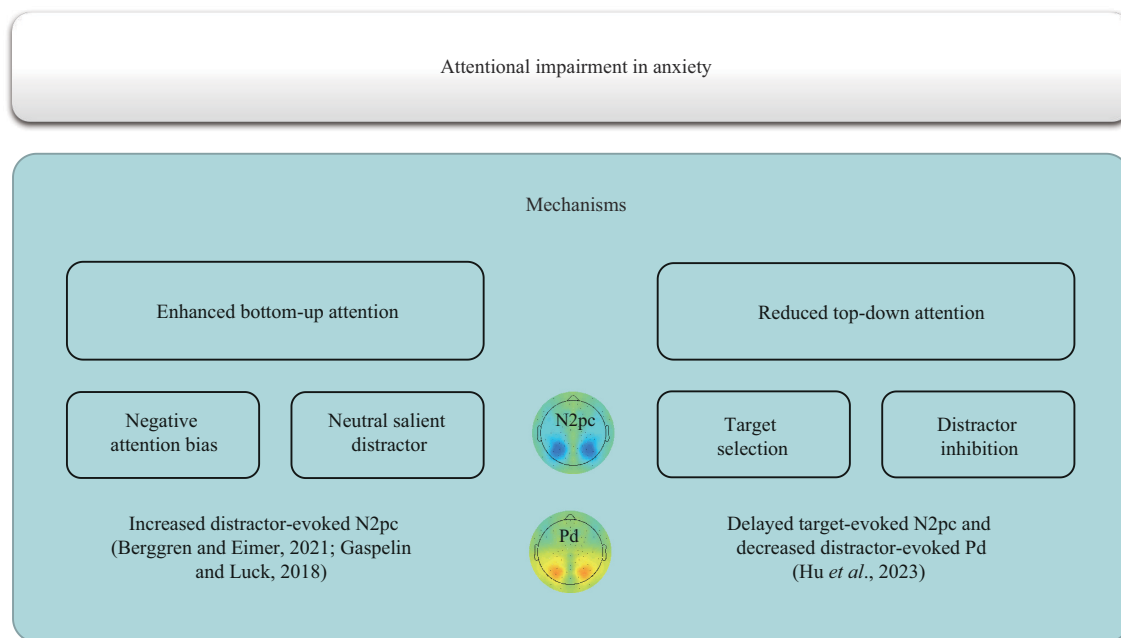
Fig. 1 Mechanisms of attentional impairment associated with anxiety

Secondly, Hu et al.[4] found that individuals with high levels of anxiety exhibited impaired attentional inhibition when faced with unpredictable stimuli, indicating that anxiety disrupts the adaptability of attentional inhibition. Previous research has demonstrated that predictable stimuli facilitate the development of rejection templates, which enhance distractor inhibition. However, for unpredictable stimuli, the establishment of rejection templates is not possible[10-11]. Gaspar and McDonald[12] employed predictable distractors with a fixed feature and did not observe the effect of anxiety on the inhibition of distractors. Combined with the above studies, it suggests that individuals with high anxiety can effectively inhibit distractors within the confines of a rejection template but struggle outside this template due to compromised flexibility in attentional inhibition.

Thirdly, the finding that attentional control is primarily influenced by trait anxiety rather than state anxiety implies that impaired attention function predominantly arises from enduring tendencies towards anxiety. Trait anxiety refers to a persistent and stable inclination to experience anxiety, while state anxiety denotes a transient manifestation of anxiousness and tension in the present context. In Bishop's fMRI study[6], it was similarly observed that

frontal attentional control is impacted by trait anxiety rather than state anxiety. This also aligns with previous research indicating that chronic anxiety affects various facets of cognitive control[13-14]. These findings underscore the notion that long-term anxiety exerts an influence on general cognitive function, whereas short-term states of anxiety have limited immediate effects.

2 A new cognitive training method to improve attentional control

Gradual alterations in cognitive function are closely associated with the progression of anxiety disorders[15]. Cognitive training for the treatment of anxiety disorders is grounded on reciprocal relationships between anxiety and cognition. In the past, it was believed that anxious individuals have negative emotional bias, so the attention-bias modification (ABM) training has been used as the mainstream cognitive training to alleviate anxiety[1].

Recent behavioral and neurological studies have revealed that anxiety not only affects emotional bias but also impairs an individual's general attentional control[2-4, 12]. Previous studies have employed the attention control training (ACT) in post-traumatic stress disorder (PTSD) patients to enhance attentional control functions and alleviate PTSD symptoms[16-18].

ACT uses the dot-probe paradigm for training, aiming to enhance patients' suppression of threatening stimuli. Additionally, ACT have also been applied to adolescents with anxiety disorders[19]. It is crucial to note that both ABM and ACT primarily focus on emotion-related attention training to improve attention function toward negative stimuli. Hu et al.[4] revealed a general deficit in attentional control functions in high anxiety, particularly attention inhibition functions. This finding has served as a catalyst for our proposal of a novel cognitive training method aimed at alleviating anxiety through the enhancement of top-down attentional control. Termed as attentional inhibition training (AIT), this innovative approach employs unpredictable neutral distractors, such as color salient stimuli, within the visual search paradigm to effectively train individuals in active inhibition. Consequently, AIT facilitates the restoration of individual attentional control function and holds promise for alleviating symptoms of anxiety.

In addition, non-invasive brain stimulation techniques such as transcranial magnetic stimulation (TMS) [20] and transcranial electrical stimulation (TES) [21] can be employed to modulate the brain regions responsible for attentional inhibition. Yıldız et al. [22] found that applying TMS to the right dorsolateral prefrontal cortex (rDLPFC) can enhance attentional control functions in depression. Lega et al. [20] indicated that the right frontal eye field (rFEF) plays a crucial role in filtering out distractors. The above studies provide evidence for the brain regions related to attentional control functions. It highlights the potential for more effective TMS interventions focused on enhancing distractor inhibition, thereby offering a prompt and efficacious approach to enhance attentional inhibition function and alleviate anxiety symptoms.

3 Conclusion

Previous studies have suggested that the dorsolateral prefrontal cortex (DLPFC), frontal eye field (FEF), and lateral intraparietal area (LIP) are implicated in attentional inhibition function[6, 23-24]. However, the precise brain region underlying attentional inhibition remains unclear. In addition, the study of the neural circuit mechanism of the effect of attention inhibition on anxiety is of great significance for understanding the pathogenesis of anxiety.

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高特质焦虑个体注意缺陷的神经学见解[*]
——对胡等在《大脑皮层》发表文章（2023）的评论

马灏云[1,2)]　　梁建惠[2)]　　刘东强[1)**]

（[1)] 辽宁师范大学脑与认知神经科学研究中心，大连 116029；

[2)] 中国科学院深圳先进技术研究院深港脑科学创新研究院，深圳 518055）

摘要　Hu 等（2023）发表文章探讨了高特质焦虑个体在抑制干扰和目标选择延迟方面所遇到的挑战，表明其对注意自上而下控制能力受损，尤其在不可预测的情况下，这种注意抑制适应性受到了影响。本文强调了 Hu 等发现高特质焦虑个体注意缺陷机制的重要性。基于他们的工作，本文提出了一种新颖的训练方法——注意抑制训练（AIT），旨在增强自上而下的注意控制，以缓解焦虑症状。此外，文章还探讨了利用无创经颅磁刺激（TMS）快速增强注意功能的应用。文章还强调，这一方法的有效性有赖于未来研究精确定位控制注意的脑区。

关键词　焦虑，注意缺陷，注意抑制，认知训练，神经机制

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