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Effect of Working Memory Load on Anxiety-Related Attention Deficits in Executive Attention Tasks Performance: A Review

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Elevated anxiety negatively affects cognitive performance on executive functions tasks, especially, inhibitory control tasks. The Performance Efficiency Theory and the Attention Control Theory (ACT) have proposed frameworks for explaining the relationship between anxiety and executive control. In the framework, ACT has proposed a few predictions regarding the relationship between anxiety and inhibitory control and set-shifting. In recent literature, some experiments have tested those predictions. Findings that emerged through this research have proposed mixed results. Some studies have supported the existing framework and some have reported results that challenge the existing framework. This review discussed the methodology and results of these studies and proposed further extension of ACT. Along with this, suggestions for future research have been discussed.

Keywords: Anxiety, Executive control, Attention Control Theory, Processing Efficiency Theory, Cognitive load

Anxiety is a highly prevalent psychological abnormality in the modern age (Bandelow & Michaelis, 2015). It is the ambiguous apprehension and worry of negative emotions and threatful stimulations (Humphreys & Revelle, 1984). This repetitive apprehension occupies the working memory resources of anxious individuals and leads to a reduction in their performance on cognitive tasks because these tasks also rely on the same working memory resource pool for their successful execution (Abushalbaq et al., 2021; Eysenck et al., 2007; Eysenck & Calvo, 1992). Eysenck and Calvo, (1992) reviewed contemporary literature which discusses anxiety-related cognitive deficits and, proposed the '*Performance Efficiency Theory*', which predicted that individuals with elevated anxiety worry about probable threatening consequences. This theory assumes that worry is the cognitive component of anxiety and recruit's central executive and transient storage of the visuospatial sketchpad and the phonological loop components of working memory (Baddeley, 1986). Based on these assumptions, it was predicted that elevated anxiety would impair the performance of the central executive mildly, which might be managed by the increased effort of the individual. Still, adding substantial extra load through changes in instruction or the addition of secondary task/s would surely impair the individual's performance on the central executive task. Further testing of these predictions, refined the PET and led to the emergence of the *Attentional Control Theory* (ACT) (Eysenck et al., 2007). Based on a

review of studies tested predictions of PET, ACT assumed that anxiety-related deficits are largely limited to attention control, specifically, inhibitory control (IC) and set-shifting control components of central executive functions. According to ACT, (1) heightened anxiety reduces goal-directed attention control and increases stimuli-driven attention control; (2) anxious individuals are more prone to distraction from threatful distractors than neutral distractors; (3) an increase in task demands of central executive would further hamper the poor inhibitory control associated with high anxiety. Eysenck et al., (2011) shed light on performers' motivation and suggest that individuals can eliminate the anxiety-driven dominancy of bottom-up attention control and exercise goal-directed attention control, in case of high motivation associated with high task demand and clear instructions. These theories discussed the complexity of anxiety and executive control's relation in the context of task demand.

This review revolves around a subset of executive functions (i.e., inhibitory control, distractor processing, and attention bias). Reportedly, it is affected by elevated anxiety or in individuals with anxiety disorders and high-trait anxiety (Eysenck & Calvo, 1992; Robinson et al., 2013; Shields et al., 2016; Singh et al., 2023). Executive attention is crucial to our daily as well as specific behavior and its deficit can cause potential harms, e.g., accidents in daily behavior and learning deficits (Alfonso & Lonigan, 2021). In the context of task demand, empirical pieces of evidence supported the ACT which is that an increase in task demand can further deteriorate executive attention performance, specifically, IC, which was already diminished due to manifestations of anxiety in the form of generalized anxiety disorder, social anxiety, maths anxiety, or state anxiety heightened due to exposure to threatful stimuli, such as the threat of electric shock, unpleasant pictures or sound. On the other hand, some studies have reported the null effect of additional CCL. And, contrary to this, some recent studies have reported that an increase in concurrent cognitive load (CCL) through a secondary task or the primary task itself, can reduce the effect of anxiety and increase IC performance (Spangler & Friedman, 2017; Delchau et al., 2020). This review has been proposed to underline the factors responsible for mixed results.The manifestations of anxiety have been recorded in different forms and, hence, have been named uniquely due to their unique nature, such as trait anxiety, state anxiety, social anxiety, test anxiety, etc. However, Eysenck and Calvo (1992) and multiple others have claimed that the trait and state anxiety are similar and can be used interchangeably. Later claims of the distinct nature of different types of anxiety (Pacheco-Unguetti, et. al., 2010), led us to consider each kind of anxiety as a distinct category. Any individual experiences anxiety in daily routine interactions for six months or more, hence this condition is recognized as a generalized anxiety disorder (GAD). Similarly, individuals high on situation-specific trait anxiety and experience threats to their ego in some specific situations, e.g., social forum, performance stage, or examination hall, are labeled as suffering from heightened test anxiety and social anxiety. Long-term practice of these unique adaptation styles led to their different reactions to anxiety-provoking stimulation. These styles, affect an individual's working memory performance differently, hence, loading working memory load, affects anxiety-driven cognitive deficits differently. Perhaps this is the reason behind the recent testing of cognitive deficit attenuation through load resulted in non-linear findings.

Trait Anxiety and Distractor Interference

Trait anxiety is an individual's disposition, which is characterized by their vulnerability to heightened anxious apprehension and

worry, in exposure to places where there is the possibility of threat to their physical or mental state of being. In support of PET, (Qi et al., 2014), reported that participants with high trait anxiety performed equally well on congruent and incongruent trials of flanker tasks in low-load conditions. This might have resulted due to the use of the adaptive strategy i.e., enhanced effort. The affordance of participants for adaptive strategy was reduced due to a lack of WM resources in high-load conditions, which have been indulged in expenses of additional cognitive load-inducing tasks (Qi et al., 2014). In another attempt, the distractor was an angry face which is in general much salient to the human being in comparison to neutral flankers, hence greater interference was recorded in the high trait anxiety group in low load conditions (Basanovic et al., 2018). Here it seems that participants didn't use adaptive strategy and were found to process distractors that can carry threat-related information. This difference between groups regarding distractor processing and IC associated with trait anxiety was not affected by additional cognitive load. Here, not affected IC indicates possibilities that either load increase was sub-optimal to bring any change in inhibition control performance or the domain of increased load might differ from anxiety-linked inhibitory control. Here, we found that a similar amount of load can affect the inhibitory control performance in the case of a neutral distractor but is not able to affect distractor inhibition performance in the case of an emotionally negative distractor. It strengthens the notion that anxiety makes individuals more vulnerable to threatful distraction (Eysenck & Calvo, 1992). Combined observation suggests that a smaller increase in cognitive load, as done in discussed studies can affect attentional inhibitory control but only in emotionally neutral tasks, in negative emotion tasks, anxiety was found additionally suspicious for angry faces, which might need relatively larger manipulation of cognitive load for bringing change in trait anxiety-related attentional IC deficit.

State Anxiety and Distractor Interference

State anxiety is the elevation of anxiety by the presence of threatening stimulation and can be observed in healthy individuals. Elevated state anxiety through exposure to the threat of shock or negative stimuli among healthy individuals can also negatively affect attention performance, similar to social and test anxiety, as we have seen above discussion. Similarly, a high working memory load during attention tasks can modulate an anxiogenic detrimental effect on attention task performance. An initial potent indication of this notion was presented by, Vytal et al. (2012), who reported impaired verbal working memory task performance with an increase in anxiety. And, with an increase in CCL, a reduction in anxiety-related deficiency of IC was also reported. Later, Spangler and Friedman (2017) again reported the state anxiety-related deficit in IC, assessed through flanker tasks can also be modulated by the increase in CCL. This experiment exploited 4 different levels of working memory load and induced state anxiety among healthy participants via noise blast. This presented interesting and comprehensive findings that an initial mild increase in CCL enhanced the inhibitory control performance; further, a greater increase in CCL deteriorated the IC performance. The authors claimed a negative quadratic relationship between working memory load and state anxiety-related IC deficit. In a subsequent attempt, Ward et al. (2020) induced state anxiety among healthy participants via the threat of electric shock and manipulated load through lateral change detection task and assessed distractor filtering. Results revealed that elevated state anxiety was not able to affect the inhibition control for processing of neutral distractors irrespective of load. The null effect of anxiety and load was observed

probably due to an insufficient increase in anxiety and load, in comparison to other studies that reported affected distractor processing. The ACT and PET claimed greater attention bias for negative than positive, than neutral distractors (Eysenck et al., 1992; Eysenck et al., 2007). Vytal et al. (2016) used an n-back task (n=1,2,3), and even the 3-back load was insufficient to inhibit threatful distractor processing. This finding supported the notion of greater vulnerability among individuals with anxiety disorder than healthy controls. Empirical observations and theoretical directions suggest that for the assessment of attentional bias for neutral distractors, further studies should measure trait anxiety along with manipulation of state anxiety, and elevation in state anxiety and load should also be significantly higher than compared to Ward et al. (2020).

Social Anxiety and Distractor Interference

Social anxiety is a situation-specific personality trait. It is similar to trait anxiety but also shares similarities with state anxiety. In its nature and manifestation, it differs from trait anxiety, as in high trait anxiety, individuals are vulnerable to high-state anxiety in generally threatful situations but in high social anxiety individuals' anxious responses emerge only when they apprehend negative evaluation of their social image. Few studies have reported attentional processing-related differences between social and other types of anxiety. Mansell et al. (2002) reported that high trait anxiety is related to hypervigilance to threat cues and high social anxiety is largely related to avoidance of threat cues and increased self-focus. In general, socially anxious individuals have been reported with attention-related deficits, such as enhanced or reduced attention bias. Further, we would discuss the modulation of these deficits with manipulation in CCL. Judah et al. (2013) tested attention bias for emotional face through the dot-probe task with n-back (n=0,1,2) task on high and low socially anxious groups (HAS & LSA). The HSA group showed controlled avoidance of threatening faces in low load and increased CCL weakened the control and late attention bias was observed in HSA subjects. Boal et al. (2018) tested attention bias for threat distractors in the HSA and LSA groups in different WML. The slight bias of avoidance was present among HSA and attraction among LSA, which was found unaffected in high load conditions. The lack of load's effect on bias was probably observed due to insufficient load in the higher load conditions. Delchau et al. (2020) reported the absence of disengagement bias among anxious subjects in low or higher-load conditions. Engagement bias was present in the high anxiety group and it was found to be affected by high CCL. In the no-load condition, social anxiety was significantly positively correlated (r=.26) with engagement bias. An increase in concurrent cognitive load eliminated the otherwise present engagement bias. This was contrary to Boal et al. (2018), perhaps due to greater load in high-load conditions. Recently, Liang (2021) used the Anti-saccade task to assess and compare attention bias for faces (viz. happy, neutral, angry) with CCL manipulation through n-back task among HSA and LSA groups. Increased cognitive load improved IC performance, observed through shorter saccade latencies but reduced overall efficiency due to increased saccade error rate, as predicted by ACT.

Test Anxiety and Distractor Interference

Another manifestation of anxiety is Test anxiety. It is also the situation-specific personality trait, i.e., anxiety-related responses emerge in the environment, which can evaluate the individual's performance. Anxiety-related attention deficits have also been noted in high-test anxiety (HTA) groups compared to low-test anxiety (LTA). Wei et al. (2021) tested IC through flanker task in

high and low load conditions, during threat and no-threat conditions among HTA and LTA individuals. For a deeper understanding of attention-related deficits in test anxiety individuals, Wei et al. (2021) also recorded the neural activity of subjects' brains through EEG during the flanker task. Results supported the ACT and heightened recruitment of attentional resources or effort was recorded among HTAs in low load-no threat conditions for incongruent trials for optimizing performance equal to LTAs. It indicates greater inhibitory cost among HTAs, even in low load and no threat conditions. In high load and threatful conditions, this compensatory strategy of increased effort was not found effective, and the results showed poor behavioral task performance in both congruent and incongruent trials, hence poorer IC performance. In another attempt, Hu et al. (2023) reported results were in coherence with predictions of PET, viz., distraction was greater in test-related distractors compared to test-unrelated distractors in faster trials among HTAs across all load conditions. In slower trials, a distraction from either type of distractor was absent across load conditions. The absence of changes in distraction or IC during slower or faster trials with variation in CCL trials was observed perhaps due to insufficient load in high load conditions. And, change in IC's performance i.e., distraction was evident with change in trial duration (i.e., faster & slower trials) was perhaps the result of increased effort by anxious individuals as suggested in the prediction of ACT which states that anxious individuals use adaptive mechanism and increase effort to overcome the IC deficit caused by high anxiety.

Generalized Anxiety Disorder and Distractor Interference

Few studies have assessed the attentional bias among individuals who have prolonged elevated trait anxiety which reached the clinical level, referred to as Generalised Anxiety Disorder (GAD), and tested whether manipulation in CCL can affect these attentional biases. MacNamara and Proudfit (2014) compared healthy controls with a group diagnosed with GAD on their attention control performance. The GAD group showed larger attention biases for unpleasant distractors in high-load conditions. In another attempt, Najmi et al. (2015) employed the Flanker task to assess the difference in neutral distractor processing between the GAD and the healthy group in high and low load conditions. The GAD group showed significantly smaller interference in high-load conditions only. It indicates that GAD-suffering individuals experienced enhanced attentional control but only in high-load conditions. Similarly, Vytal et al. (2016) took a step ahead and induced state anxiety in a group of healthy and GAD subjects and instructed them to perform a WM task (visual n-back task; n=1,2,3) and assessed the distraction caused by the threat of shock on WM task performance. The GAD group was unable to inhibit the interference during threat trials in highest CCL condition and poorer performance was observed whereas healthy participants' inhibition enhanced in highest CCL condition during threat trials and enhanced WM task performance was recorded compared to safe trials In all three studies, we found two distinct lines of results, viz., one showed enhanced inhibition and better performance with an increase in load among GAD subjects (Najmi et al., 2015) and the second showed inhibition and overall performance reduction in GAD subjects in CCL (MacNamara et al., 2014; Vytal et al., 2016). We observed that the distractor type (i.e., negative and neutral distractors) played a detrimental role in two results lines and confirmed the PET and ACT prediction. Results supported the notion that long-term anxiety makes individuals more vulnerable to bias towards negative distractors in comparison to healthy individuals.

Discussion

The discussion in reviewed studies largely revolved around Attention Control Theory, Performance Efficiency Theory. Few studies have supported theories thoroughly in empirical findings whereas some have reported discrepancies and indicated further branches of these theories. Trait anxiety individuals have shown adaptation to anxiety-related attention impairment. Qi et al. (2014) supported the adaptation notion in low CCL and, reported lower distraction from neutral distractors but an increase in CCL caused greater interference, hence a reduction in inhibitory control performance. According to PET and ANT predictions, individuals high in trait anxiety develop an enhanced vulnerability to distract from threatful distractors. Basanovic et al. (2018) findings supported the notion and reported greater distraction among HTA in threatful distractor trials. The inability of high CCL to change distraction caused by angry faces among high and low trait anxiety subjects, indicate towards insufficient CCL, which was also in support of a prediction which state that overloading central executive would increase the anxiety-related IC deficit.

Across CCL multiple levels, state anxiety-related attention deviation in healthy subjects had reported mixed results. In support of predictions of ACT and PET regarding vulnerability and overloading central executive, Vytal et al. (2016) reported that an increase in CCL caused a greater level of increase in anxiety-related inhibition impairment among GAD subjects with high state anxiety, who were much more vulnerable to threatful distractors than healthy subjects. On the other hand, where vulnerability was low, results contrary to overloading prediction were reported by Vytal et al. (2012).

In studies that assessed attention bias due to social anxiety and its modulation with cognitive load, Judah et al. (2013) in coherence with ACT' vulnerability prediction reported that high CCL increased the subject's response time in trials containing emotional distractors. This indicated an increase in attention bias. For further elaboration on the present bias, Boal et al. (2018) measured both biases separately but did not report any effect of load. Later, their methodology was criticized for high load conditions which was not enough load to create a competition between the WM task (load-inducing) and selective attention task. Further, Delchau et al. (2020) manipulated load effectively and reported that anxiety-related attention bias was limited only to engagement bias and no disengagement bias was recorded. An increase in load eliminated the bias present in low load which was again a finding showed discrepancy to the ACT's overloading central executive prediction. And, Liang (2021), the latest study assessed distraction due to emotional distractor in the form of inhibitory control and reported an interesting finding that an increase in load reduced the subject's dwelling time on distractor, but increased the error rate in performance. Normal accuracy and slowed response time exemplify the prediction of ACT that subjects increased their effort as a compensatory mechanism evident by slowed response time and high accuracy but failed in effectively enhancing the performance. Prediction of ACT which state that anxiety reduces efficiency but not effectiveness, was also evident in Liang (2021). Overall, all the studies, that had large range manipulation of cognitive load reported that load has significantly affected anxiety-related attention deficits.

Individuals with elevated test anxiety have shown deterioration in their inhibition control performance when concurrent task load increased, hence increase in distractor processing has been observed (Wie et al., 2021). Later, Hu et al. (2023) again tested individuals with elevated test anxiety in

varying cognitive load conditions. Results supported PET, as the median split analysis of reaction times showed accurate but longer reaction times due to higher load and scarcity of cognitive resources only in slow trials whereas in fast trials compromised accuracy was recorded. Overall, results showed that high cognitive load can affect hypervigilance and IC among HTA subjects. The absence of a reduction in distractor processing suggests the inclusion of high-load trials with a greater load in future studies.

Comprehensive observation of recent literature suggests that the majority of studies are in line with predictions of PET and ACT, and claimed that an increase in CCL significantly increase the deleterious effect of elevated anxiety on the IC performance. Studies that reported no effect of load, have largely employed relatively low load in high-load conditions. Findings from a few studies have challenged the existing notion and showed a significant positive effect of high concurrent cognitive load on anxiety-related deficiency in inhibitory control performance or reduced distraction. Najmi et al. (2015), reported the anxiety-related deficit in inhibitory control to inhibit the processing of neutral incongruent flankers as a distractor in the low-load condition in the GAD group and this deficit was attenuated with an increase in CCL. Similarly, Vytal et al. (2012) reported a reduction in state anxiety-related deficit in inhibitory control for inhibiting the processing of electric shock threat, with high CCL condition, among healthy subjects. And Delchau et al. (2020), also reported that the engagement bias was present among subjects with high social anxiety in low-load conditions, and the bias was eliminated with an increase in CCL. These studies indicate an extension of ACT, i.e., high CCL of optimum level can narrow and focalize attention to the attention task and leave no resources for anxiety-related cognitive activities, such as worry and distractor processing.

The review suggests that for limiting the focus to attention task and seizing of distractor processing, the amount of load should be much higher in the presence of a threatful distractor than a neutral distractor. Both PET and ACT agree that anxious individuals used to be more vulnerable to threatful distractors than neutral detractors. Based on this assumption, a proposed new branch of ACT might vitalize the role of motivation in exercising attention control, as it suggests that greater load and clear instruction for load-inducing tasks and attention tasks, and lack of vulnerability to anxious distraction, shifts individuals' motivation towards attention task and to exercise IC on task and prevent distraction processing for increasing performance (Eysenck et al., 2011). Further, these studies showing a positive effect of load should be replicated to clearly understand this newly emerged pattern of positive impact of load.

Future Suggestions

This review proposes some suggestions for future studies for a better understanding of the effect of CCL on the IC performance of subjects with high anxiety. First, manipulation of load should be done in a parametric fashion, and the amount of load in high conditions should be greater enough. Second, a few studies should also incorporate different types of WML and compare the effect of each on the inhibition of distractor processing of different types of distractors (i.e., neutral, positive, and negative). Third, studies should test hypotheses on a relatively larger sample size. Fourth, testing of CCL interaction and the distractor's saliency to the subject is crucial to the proposed addition of ACT. Further, this testing should also be in an ecologically more valid setting, such as, educational, clinical and driving or piloting contexts. So that, findings can help in

designing careful interventions and implications.

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