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A review on cognitive load, anxiety and emotional context dynamics of working memory performance

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Abstract: *Anxiety is a physiological and psychological state with physical, behavioral and cognitive manifestations. Anxiety can deteriorate cognitive performance (Derakshan & Eysenck, 2009). High anxiety has often been seen to have a negative impact on the working memory of the individual (Eysenck & Calvo, 1992). Anxiety often affects the performance on tasks that require attentional control. More specifically it has been reported as affecting the working memory of an individual. The review on the role of emotional context in cognitive performance of the individual has shown that it influences the cognitive output linked performance (Osaka et al.,2013). Studies on emotional context have also reported the impact of negative context on anxiety where negative context leads to performance decline. Anxiety has also been reported to reduce the performance when the working memory is loaded (Berggren et al., 2012). It has been seen that under the conditions of high cognitive load, working memory resources are often depleted and anxiety combined with high cognitive load leads to a performance decline (Shackman et al., 2006). Again, the present day focus is on quality performance and morale maintenance during performance. It also seems important to study the developmental changes in working memory.*

Key Words: *Working memory, n-back, cognitive load, anxiety, Emotional context, Cognitive Performance.*

1. INTRODUCTION:

Working memory has emerged as a system that holds task relevant information in the brain during the performance of the cognitive task (Baddeley& Hitch, 1974, Daneman & Carpenter, 1980) as well as manipulates certain higher order complex tasks (Owens et al., 2014).

Traditionally, working memory has been understood as the process by which information is maintained or stored for a brief period of time, typically between 3 and 10 seconds, but longer than in other circumstances (Banich et al., 2009). The term came into use after Miller (1956) who suggested for the first time that our working memory capacity is limited and could store up to seven plus/minus two digits of information.

It has also been understood as the hypothesized memory system that holds the input while an interpretation of it is worked out (Reber et al., 1985). The main function of working memory entails coping with the complex tasks of everyday decision making and other higher cognitive activity and behaviour (Lin, 2012).

Baddeley & Hitch (1974) gave a basic model of working memory which assumes that the central executive also known as the "super system" operates in combination with the two secondary systems which are 1.) Phonological loop often concerned with the storage of sound and auditory information and 2.) Visuospatial Sketchpad concerned with the visual and spatial information (Baddeley & Hitch, 1974). Herein, the central executive system is also known as the attentional control system (Morrison & Chein, 2011).

Baddeley (2000) added a fourth component i.e. "episodic buffer" to the existing model of working memory. This component was stipulated to hold all the representations that integrate the visual, spatial and the phonological information.

Baddeley (2000) also suggested the Hedonic Detector Hypothesis which proposes that this system is capable of picking up positive and negative associations from an object which is in the episodic buffer of the working memory.

Working memory capacity indicates the ability to maintain task relevant information when a number of distracting information sets operate simultaneously (Morrison & Chein, 2011). It also reflects the capacity of higher order cognitive processes and functioning such as complex decision making, comprehension and creative problem solving. It has been seen that the larger the working memory capacity, the greater the higher order cognition as well as working memory performance. Greater academic achievement has also been found associated with larger working memory capacity (Morrison &Chein, 2011).

Eysenck & Calvo (1992) gave the Processing Efficiency theory which describes the relation between the effectiveness of the performance and the investment of the resources. The main prediction of this theory is that anxiety affects processing efficiency more strongly than it affects performance effectiveness because the attentional resources that are reduced due to worry are somewhere compensated for by increased effort in the case of performance effectiveness (Calvo, 1985).

Further, Attentional control theory by Eysenck et al., (2007) explains the effect of anxiety on cognitive performance. This theory represents a major development of processing efficiency theory. The assumptions of attentional control theory lay on the fact that the effects of anxiety on attentional processes are essentially important to understand how anxiety affects performance. This theory suggests that an increase in anxiety leads to an increased distribution of attention to threat related stimuli thereby reducing the attentional focus on the on-going task (Eysenck et al., 2007).

Not only has working memory been found to develop throughout childhood, it has also been found to influence all kinds of cognitive activities (Marcovitch et al., 2010).

Eysenck (1992) described anxiety as an aversive state that occurs in situations in which level of perceived threat to the individual is high and the individual often develops certain strategies to reduce anxiety and achieve the goals (Eysenck et al., 2007). Anxiety can be both distracting and disruptive (Vytal et al., 2013).

Further, anxiety has been found to interfere with learning as anxious students seem to be distracted by irrelevant or incidental aspects of task at hand and they have trouble focusing on significant details of that task (e.g. Nadeem et al., 2012). Likewise, it has been found to be true for adults (e.g. Eysenck et al., 2007) specifically with reference to the working memory tasks and tasks that require attentional control. Early school leaving and failure to enter college or universities has also been associated with it (Lee et al., 2009).

At the same time, anxiety also seems to serve an adaptive function and has been seen as a typical marker for development e.g. in school setting anxiety is experienced by students when they are being evaluated as in giving a test or making a speech (Huberty, 2009).

Cognitive load in general refers to the load on working memory. Cognitive load theory proposes that as the capacity of working memory is limited, individuals may face information overload which, if not managed properly, can hamper the performance (Sweller, 1988).

Cognitive load influences the working memory processes because working memory is believed to be involved in a variety of tasks (Duncan & Humphreys, 1989), therefore, the level of perceptual load in a particular task has been identified as a powerful determinant of distraction. According to Load theory (Lavie, 2005), irrelevant stimuli can only be perceived if there is a sufficient perceptual capacity left over from task processing (Foster, 2013).

The n-back task introduced by Wayne K. Kirchner in 1958 and it involves the presentation of “rapidly continuously changing information” and measures very short term retention. The n-back task involves the presentation of a continuous sequence of stimuli and the subject is required to recall the stimuli in a specified number back in a number sequence e.g. on asking the n-1, the subject has to recall the stimuli immediately presented before the current stimuli, at the n- 2, the subject has to recall the stimuli presented two items before of the present stimuli. The difficulty of the task increases with the increasing number of n. Moreover, this task has higher face validity as a measure of working memory (Lin, 2012).

Working memory, as already described, is said to be one of the major processes that allows an individual to focus on tasks and to keep an eye on the goals in hand (Shallice & Burgess, 1996). A load on working memory is seen to be disrupting one’s ability to maintain certain task goals and also increases the likelihood of distraction by irrelevant stimuli (Berggren et al., 2012).

Morrison & Chein, (2011) gave neurological evidence on how emotional context is related to performance under higher working memory load conditions and suggested that human amygdala could be involved in higher order cognitive functions like the executive control function of the working memory.

Studies have often showed that positive and negative emotions influence cognitive task performance e.g. words that contain an emotional relevance are often remembered well than words that have a neutral relevance, therefore, it is the emotionally relevant stimuli that often contain emotional information that are found to affect the working memory of the individuals (Osaka et al.,2013).

Negative stimuli are often known to hamper an individual's performance e.g. it has been found that in the presence of negative stimuli an individual often faces interference in variety of tasks (Schimmack,2005). Studies have also shown that the presence of negative and positive words often lead to a higher reaction time among the participants (Gotoh, 2008).

Neuroimaging studies of healthy adults on working memory have been associated with the activation in the frontal and the parietal cortices and particular focus has been on the prefrontal cortex (Owen et al., 2005). The prefrontal cortex has been found to be an important part of the working memory capacity. Studies have focused on two different parts of the prefrontal cortex region of the brain; one part of the prefrontal cortical region i.e. the dorsolateral prefrontal cortex plays an important role in the manipulative functions in the working memory (Fletcher & Henson, 2001) and the ventrolateral prefrontal cortex region is known to play a role in the encoding, maintenance and inhibition (Postle et al., 2000).

Gathercole et al., (2004) explained that working memory skills are linked to the test performance of children in schools. Similarly, Alloway et al., (2009) opined that very low working memory capacity is often linked to poor educational outcomes. According to Eysenck (1979), every performance that involves anxiety is often linked to temporary reduction in the working memory capacity. Shackman et al., (2006) reported that anxiety consumes working memory resources and thus decreases the performance.

All the working memory training programs aim at increasing the working memory capacity of the individuals and one of the most extensively studied brain training exercise aiming at the working memory capacity is the n-back task. The n-back task involves observing a constant stream of items (e.g., letters) and determining whether each item matches the stimulus presented n stimuli back (Reber et al., 1985; Morrison & Chein, 2011).

A particular form of anxiety that often occurs during situations that involve an individual's performance being evaluated in social, work and academic settings is referred to as evaluation anxiety (Northern, 2010). Deffenbacher (1980) explained evaluation anxiety as comprising of both affective as well as cognitive components.

A study by Humpherys and Revelle (1984) revealed that when an individual worries, it obstructs the attention of an individual this result in avoiding of the task by the individual, which further results in the individual allocating fewer resources to the task. Hence, it impairs the performance.

Whereas anxiety has been shown to reduce the working of prefrontal cortical regions (both dorsolateral and ventral regions), studies that have examined working memory have found the activation of the dorsolateral prefrontal cortex to be greater under high working memory load than under low working memory load (Gazzaley & Nobre, 2012).

Calvo & Eysenck (1996) in their study found that text comprehension was impaired by the simultaneous presentation of meaningful speech for high anxious but not for low anxious individuals thereby depicting the assumption that anxiety often impairs the inhibition function.

The performances of high anxious individuals are more vulnerable and can be weakened by task irrelevant distractors than that of low anxious individuals where emotional stimuli are used (e.g. Fox et al., 2005).

On the other hand, the enabling of sensory processing as well as increasing activation of the defense mechanisms under certain conditions that evoke threatening stimuli has been reported as part of the adaptive role of anxiety (Cornwell et al., 2007).

There are many studies that have shown how emotions contribute to the working memory performance, but still there is a debate on how these effect the cognitive control during such tasks. Recently, researchers have started to explore the role that working memory plays in the emotional processing (Mikels et al., 2008). Schmeichel et al., (2008) in their studies have reported that individuals with higher working memory capacity could suppress emotional facial expressions when viewing emotionally charged stimuli. Where age related differences are involved in the working memory tasks, Mammarella et al., (2013) have observed an increase in the working memory task when emotional stimuli are used.

The stimulation of emotions as opined by LeDoux (1996) results from the activation of information that is stored in the emotional memory system. Damasio (2004) gave the Somatic Marker Hypothesis which postulates how certain emotional processes shape our behavior more specifically our decision making processes.

The study by Osaka et al., (2013) have shown the temporal characteristics of emotional effect on working memory task by measuring brain activation on the reading span task. The study indicated that emotional biased and neutral reading span tasks activated prefrontal areas, including DLPFC and ACC, the neural substrates of working memory. From the study it was found that the negative reading span tasks resulted in the activation of the right amygdala than the neutral reading span tasks.

Gray et al., (2002) have shown that when positive affect is induced it leads to an increase in the verbal working memory performance; in contrast when negative affect is induced it leads to an increase in the spatial working memory performance.

Anxiety laden worrying consequently overpowers high load task performance, as supported by Eysenck et al., (2007), that high cognitive load tasks may be more vulnerable to anxiety laden disturbances, whereas certain studies have shown

an opposite effect of anxiety on working memory under the condition of cognitive load e.g. Vytal et al., (2013) in their study reported an opposite effect of anxiety on the verbal working memory capacity as working memory is reduced by anxiety under low cognitive load and under the conditions of high cognitive load, the verbal working memory has an opposite effect as it reduces anxiety, therefore, such studies have led to the importance of studying the role of cognitive load in emotion-cognition interaction.

An important study on the impact of anxiety on the non-verbal working memory processes have provided certain findings that have been associated with the role of cognitive load and its association between anxiety and cognition (Vytal et al., 2012). Using the n- back task having a different difficulty levels the authors of the study found that the performance was hampered by anxiety only when the task was easy or moderately challenging (Vytal et al., 2013).

Lavie (2005) highlighted that in the tasks that involve high cognitive load, the impact of distractors on such tasks would be great. Bishop (2008) opined that anxiety lays a great emphasis on the tasks that put a lower demand on the processing resources whereas tasks that put a higher demand on processing resources reduce the harmful effects of anxiety.

Studies on the visuospatial and verbal working memory tasks have shown that as the individual grows up with age there are related improvements in the task performance, however the task processing demands varies at different rates (Gathercole & Alloway, 2004).

Age related changes in the maintenance of information of the working memory task have shown that up to 8 years of age there is an improvement which gets more gradual at the age of 11 to 12 years (Gathercole, 1992).

The study by Cowan (2001) has shown that the prefrontal cortex may be load dependent therefore, it can be said that activation in this region may be related to the amount of the information that has to be memorized.

Studies by Owen et al., (2005) have shown through the use of neuroimaging techniques that n-back tasks usually involve the loads between 1 back and 3 back. Experimenters who have studied n-back technique on children have found that loads of 2 and 3 back have often led to unsatisfactory performance among children of young age (Lin, 2012).

2. CONCLUSION :

An explanation for the poor performance in high anxious individuals is explained by the Interference Theory, which postulates that high anxious persons spend more time attending to task irrelevant information (e.g., worry about test performance and consequences of poor test performance, comparing one's ability or performance to that of others, etc.), and these task irrelevant information causes individuals to devote less time to the task at hand thus, resulting in poor performance (Wine, 1980).

In the above backdrop, from the educational aspect, the visible differences in the cognitive performance of the individuals are of extreme concern to parents, teachers as well as students nowadays. With an increased concern on focus and concentration, emotional context has assumed importance especially with regard to cognitive performance.

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