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A short review of working memory and attention in depression

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ABSTRACT

Depression is a state of disturbance in emotions, behaviour, and cognition. The representations of this common mental disorder were characterised by a few types, including postpartum depression, psychotic depression, bipolar disorder in depressive episodes, major depressive disorder (MDD), and persistence depressive disorder. These multiple types of depression are significantly being studied in order to reveal their relational effects on cognitive function, especially in working memory and attention skills. This mini-review article was intended to summarise the findings on the relation of depression effects to cognitive function from a neuronal network and neuroscience perspective.

Keywords: depression; working memory; attention; cognitive function

1. INTRODUCTION

Major depressive disorder (MDD) was categorised as the world's leading mental disorder, which led to thousands of suicidal cases (World Health Organization, 2023). In the United States alone, 44 thousand suicidal cases were reported per year, and 30 to 70 percent of the cases were highly related to depression (American Foundation for Suicidal Prevention, 2016). Depression is a mental disorder that is on the rise and has quietly morphed into a public health crisis. The burden of mental depression is widely accepted as a major burden on the economy, mental health, family institutions, and social life. Statistically, almost 800,000 suicidal cases have been recorded all over the world, which makes depression one of the contributing factors to those statistics. Considering that, depression is considered a worrisome disorder aside from any physical chronic diseases (i.e., stroke, heart problems, cancer). Besides, the risk of relapse is high; patients may experience a relapse within two years of their first depression attack, and they may have more than one relapse throughout their lifetime (Hammar & Årdal, 2009; Mueller et al., 1999).

Many researchers and neuropsychiatrists agree that impairment of cognitive function is common in mental disorders, especially depression. This is because the neural mechanism related to inhibiting stimuli in working memory is known to be impaired in depressed patients (Chen et al., 2015). Cognitive functions are mental processes that allow us to pay attention, remember information, and learn. They are the foundation of our ability to focus, solve problems, and acquire new knowledge (Lam et al., 2014). However, these cognitive functions are impaired in people with depression due to emotional instability (Balbuena et al., 2016; Thompson et al., 2012). Emotional instability here refers to the symptom of feeling heavy sadness and a sudden loss of life enjoyment. It differs from the sadness experienced by healthy individuals in that depressive symptoms last for more than two weeks and impair daily functioning, leading to feelings of worthlessness and suicidal thoughts. Additionally, it is thought that emotional instability in depression is caused by an impairment in the inhibition domain of cognition. This means that people with depression have difficulty filtering out irrelevant information from their working memory quickly, compared to people without depression symptoms (Gohier et al., 2009).

An inhibitory system in cognition is required to filter out irrelevant information for placement in the limited working memory space, and any deficit in this mechanism results in the emotional attachments of people with depression to unwanted stimuli (Gohier et al., 2009; Hasher & Zacks, 1988). Unwanted stimuli can vary depending on the individual, but examples include negative thinking or dwelling on past events. The inhibitory system plays a

crucial role in cognitive processing, but much is still unknown about this relationship. To our knowledge, there is no short and comprehensive review study that discusses specific cognitive functions in depression from a neuroscience perspective. Therefore, this mini-review article aims to discuss two essential cognitive functions that are impaired in people with depression: working memory and attention.

2. METHOD

A literature search was made on the PubMed and Scopus databases on depression studies related to working memory and attention. The search terms included “depression”, “attention”, “working memory”, “attention skill in depression” and “working memory in depression”. There was no restriction on the publication year, as this mini-review only aims to provide an overview of the fundamental state of both cognitive functions. In fact, older literature, especially from the prominent pioneers of cognitive studies, for example, working memory theory by Baddeley, has to be included, considering the proposed theories are still relevant and accepted by many clinicians and researchers to this day. Thus, no restriction on the year was set for this mini-review study.

3. DISCUSSION

3.1 Working Memory

Working memory functions as the temporary or short-term storage of any information that can be manipulated for mental tasks, and it can be replaced or deleted when needed (Mi et al., 2017). However, certain information in working memory can correspond to long-term memory when there is persistent neuronal encoding of working memory information into long-term memory, which usually occurs through repetition and long-term exposure to the same information or stimuli. Additionally, researchers agree that working memory is essential for cognitive function. If working memory is impaired, it can directly lead to problems with other cognitive functions, such as the allocation of attention and learning (Christopher & MacDonald, 2005; Mi et al., 2017). This is because working memory is necessary for initiating and carrying out any task. In fact, without working memory, we would not be able to learn new

things. A simple example of working memory is following the instructions in a racing video game. As we play the game, we learn the instructions and rules, and we use this information to control the speed of the car, avoid distractions, and reach the finish line. Working memory holds this information in our brains throughout the game session. At the same time, we must pay attention to the game to ensure that we reach the finish line and avoid distractions. This only works when our working memory is functioning properly.

In 1992, Baddeley proposed a theoretical model of working memory that comprises the central executive as the central system and two buffers (i.e., a visuospatial sketchpad and a phonological loop) (Baddeley, 1992). Later, he made a revision to the new theoretical model by adding an emotional/pleasure detector and an episodic buffer as the third buffer in the new working memory model (Baddeley, 2013; Chen et al., 2015). Studies have shown that depressed people have a deficit in inhibitory functioning, which limits their cognition to filter out unwanted stimuli or stimulation. A deficiency in inhibitory function leads them to easily attach emotionally to information that might be negative to them. This is supported by a study done by Joormann & Gotlib (2010), whereby they presented two types of stimuli (negative and positive words) to a group of depressed patients for a brief period of time, and later they assessed them on the Stenberg working memory test to evaluate the effects of the presented stimulus on them (Joormann & Gotlib, 2010). It revealed that the negative stimulus has more effects on depressed groups compared to control groups.

The working memory activates a multitude of brain regions. In healthy individuals with normal working memory, the activation region was found to be activated at the prefrontal cortex, parietal cortex, anterior cingulate cortex, and reticular activating system (Chen et al., 2015). Certain researchers have linked the deficit in functional activation at the dorsolateral prefrontal cortex (DPC), with psychiatric disorders such as schizophrenia and depression. However, it was shown by Barch et al. (2003) that DPC deficit was more obvious in schizophrenics by using functional magnetic resonance imaging (fMRI) compared to depression (Barch et al., 2003). The DPC is associated with the main brain areas for both memory and attention. Furthermore, the area of DPC has been acknowledged as having the most consistent impaired brain regions in depression (Pizzagalli & Roberts, 2022); hence, recent studies have focused on DPC improvement to alleviate depression symptoms. For instance, an fMRI neurofeedback targeted to normalise the connectivity activity of DPC with cingulate areas showed improvement in depression symptoms (Taylor et al., 2022). Another study specifically targeting DPC as the treatment area was recently performed in 2023, whereby the studies exhibited significant changes in DPC activity before and after taking depression medication that improved at least 40 percent of depression symptoms (Lee et al., 2023).

When comparing the working memory performance of depressed patients and schizophrenic patients, both groups of patients performed similarly on simple working memory tasks (Noort et al., 2016). However, on complex working memory tasks, schizophrenic patients performed significantly worse than depressed patients. This suggests that working memory deficits may be more severe in schizophrenia. Even though depressed patients had better working memory than schizophrenic patients, they still performed significantly worse than healthy individuals on both simple and complex working memory tasks. This suggests that working memory impairment in depression can have a significant impact on the lives of affected patients, depending on its severity (Bearden et al., 2011). Subsequently, the impacted working memory may also signify the poor functional state of cognition played by prefrontal function, such as in performing tasks (Barch et al., 2003; Merriam et al., 1999). Hypoactivation of working memory performance was being recorded in the depression state of bipolar II depression, whereby the N-back memory task performance was evaluated while being administered with fMRI, and the results revealed a significant deficit compared to healthy subjects (Brooks et al., 2015). There was significantly less activation discovered in the left hemispheric regions of the middle frontal gyrus (Brodmann area 11), superior frontal gyrus (BA 10), inferior parietal lobule (BA 40), bilateral occipital regions, and middle temporal gyrus (BA 39), which leads to the conclusion that depression in bipolar II was significantly associated with poor connections in the frontoparietal area that involved working memory function, explaining the emotional mood swings and poor task performance.

Depression patients may also be affected by inhibitory failure. This failure was observed in depressed patients' reactivity to positive information during an emotional working memory N-back test (Wante et al., 2018). In that study, a group of depressed patients were required to complete a working memory task while being shown a variety of emotional faces: positive (happy), negative (angry), and neutral. Interestingly, it was found that depressed patients had slower reaction times and made more errors when shown with happy faces, as compared to the healthy group. This indicated that the depression patient failed to have an emotional bias towards positive stimulation, suggesting a contributing factor to the poor working memory and overall cognitive function.

Working memory is supported by three main executive functions: inhibition, shifting, and updating, which are essential for cognitive development (Miyake et al., 2000). In general, inhibition or inhibitory components allow the mental ability to suppress irrelevant information when it is necessary, while shifting means the mental state ability to switch directions in different tasks, for example, doing two tasks at the same time. The updating component works by monitoring incoming information, encoding it into

existing working memory, and updating those existing memories by revising them so that old information becomes the latest information (Miyake et al., 2000).

Zhang et al. in 2018 found on the instability of emotional state in depression by studying the working memory of depressed patients towards emotional stimulus (i.e., positive, negative, and neutral stimulus). The study integrated event-related potential (ERP) and the N-back test as their methodological research (Zhang et al., 2018). The ERP findings discovered that affected patients had smaller occipital P1 for positive material, which suggests impaired sensitivity at the early encoding stage. The other two ERP components, P2 and parietal late positive potential (LPP), were found to be larger in the depressed group regardless of stimulation, mirroring the inefficiency of the matching and maintaining process (Zhang et al., 2018). Thus, the inefficiency of both processes leads to poor updating of working memory in depression.

Even though numerous studies have been conducted in working memory studies in depression, those findings were not yet being considered as comprehensive as it did not cover the whole component of working memory and also the exact mechanism of “how” and “why” the working memory being affected while having depression. Despite the variety of findings and the fact that no conclusive conclusions can be drawn, this information may still help those with depression to have a better understanding of their mental condition.

3.2 Attention

Attention skills are functionally interrelated with other cognitive domains, and without attention, no information can be encoded into the working memory and learning process. Attention can be evaluated based on speed processing, automatic processing attention, and selective attention (Dalgleish & Watts, 1990; Hammar & Årdal, 2009).

A systematic meta-analysis review was performed by Rock et al. (2014) on depression data. In that study, a significant moderate cognitive deficit was identified in memory, executive function, and attention among target groups compared to control subjects. This refers to the results that shown Cohen's *d* ranging from -0.52 to -0.61 in executive function and memory deficit. However, non-significant small or moderate impairment in memory was shown to range from -0.22 to -0.54 as the Cohen's *d* range. He further concluded that the cognitive impairment in depression may be associated with poor psychosocial functioning (Rock et al., 2014).

Bias attention was theoretically derived from cognitive evaluation in depression, as stated by Mogg, Bradley, and Williams in 1995. Attention bias was evaluated among three groups of subjects (anxious, depressed, and healthy

normal groups) in order to assess the role of awareness (Mogg et al., 1995). Moggs and his team (1995) evaluated all three groups by presenting a list of word pairs visually with a dot probe following each word pair. The attention of subjects was identified based on their attention to the spatial position of the words and their responses to the dot probe. As expected, the findings revealed an attention bias in the depressed and anxious groups towards supraliminal negative words compared to the control group. Meanwhile, the anxious group showed less vigilance for supraliminal anxiety-relevant words than the depressed group, and subliminally shifted attention to the spatial location of negative words. This means that both anxiety and depression showed attention shifts to negative words compared to healthy normal subjects, and it supports Moggs' original hypothesis that preconscious processes are related to anxiety-related bias. Selective or biased attention may be influenced by a person's emotional and personal relevance, as depressed patients tend to focus on negative stimuli rather than positive ones.

The exact neural mechanism of negative bias selection in giving attention is unfortunately unknown. However, it might be related to the emotional appraisal and regulation system, as suggested by Feng et al. (2015). It has been assumed that the initial appraisal of emotion on certain negative events builds up a cycle of emotional appraising and reappraising in depressed patients. Besides, major depression may also be influenced by the emotion context insensitivity hypothesis, which determines the flattened emotional reactivity to types of stimuli (negative or positive). In most depression cases, the reduction of insensitivity was greater for positive stimuli, or, in other words, depression has greater sensitivity towards negativity (Feng et al., 2015).

Contrast findings of attentional bias were found by Edvinsson et al. (2017), whereby they found no significant difference in emotional interference score between women with postpartum depression, antenatal depression, and the control group (Edvinsson et al., 2017). All the subjects were assessed by an emotional Stroop task, and the reaction time for each valence of obstetric words was identified at the end of the session. The findings revealed shorter reaction times to positive ($p = .028$) and negative ($p = .022$) stimuli among postpartum depression compared to neutral valence. Based on these findings, Edvinsson et al. (2017) concluded that shorter reaction times to emotional stimuli compared to neutral stimuli in postpartum depression may signify emotional numbing.

4. CONCLUSION

As demonstrated in this mini-review article, the cognitive functions of working memory and attention in depression differ from those in healthy individuals, which explains the possible reasons for the abnormal depressive sadness experienced by patients. Emerging understanding of the neural mechanisms and processing underlying impaired working memory and attention in depression suggests that these deficits are highly related to abnormal brain region activity, specifically in the dorsolateral prefrontal cortex. Additionally, inhibitory failure and biased attention towards negative stimuli in daily life may also significantly affect depressed patients. The mechanisms of all of these abnormalities are highly related to the way the brain works, which is not yet fully understood due to the complexity of brain function. However, these findings provide reliable evidence of the cognitive differences between depressed patients and other populations. It is fascinating to consider that there is much more to learn about the brain-related causes of cognitive impairment in depression.

Availability of data and material

All materials/literatures used in this mini review are available from the Scopus and WoS database.

Author contribution

Development and conceptualization: SAA, TB, FR; Methodology: SAA, TH, FR, NAF and FM; Writing review and editing: SAA, TH, FR, NAF, FM, and HN.

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Conflict of interest

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