The Relationship between Working Memory and Depressive Symptoms in Adolescents and Relevant Interventions

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Abstract. Major depressive disorder can have a serious negative impact on the cognitive functioning of adolescents, while most existing research focused on the biological, genetic and social factors of major depressive disorder. Working memory is a system related to the manipulation of short-term memory and is part of what constitutes human cognition. The current study reviewed the recent studies exploring the relationship between working memory and major depressive disorder in adolescents and related applications for treatment. As a result, in general, the ability of working memory was negatively associated with major depression, accompanied by negative correlations between it with various relevant factors and depressive symptoms. Also, intervening the working memory could alleviate major depression in adolescents. This paper only provided a generalized discussion regarding the relationship between working memory and depressive symptoms, while the interactions and specific associations of internal systems of working memory with depressive symptoms are expected to be confirmed in the future research. This review can contribute to future research on the relationship between specific working memory systems and mood disorders from a cognitive psychology perspective. It can also provide some suggestions to the design of prevention and intervention programs for depression at schools.

Keywords: Major Depressive Disorder; working memory; adolescence.

1. Introduction

All Major Depressive Disorder (MDD) is diagnosed when a person experiences at least 14 days of severely depressed mood, low self-esteem and loss of interest and pleasure [1]. Patients with major depressive disorder have altered mental and physical states, including the quality of sleep, appetite, concentration and energy level of patients. In the past, a series of substantial advances have been made in the study of adult patients with MDD, while relatively less attention has been paid to adolescent patients. As the emphasis on mental illness has gradually increased, the number of confirmed cases of adolescents with major depressive disorder has increased in recent decades. Major depressive disorder among adolescents has become one of the psychological disorders with the highest suicide rate globally [2]. Therefore, an increasing number of people have realized the importance of understanding of and treatment for major depressive disorder among adolescents.

Most of the previous research on MDD focused on genetic inheritance, environmental influences, stress model, and hormones. A twin study on the genetic epidemiology of MDD indicated that MDD is significantly heritable and also can be influenced by individual environmental factors [3]. Saveanu and Nemeroff studied the influence of hormones on people's moods and concluded that norepinephrine alternations and dopamine alterations could influence mood operations. Low levels of noradrenaline and dopamine may cause individuals to have a more depressed mood in the face of stress [4]. Slavich and Irwin's study on stress showed the association between social-environmental stress and depression from biological and sociological perspectives [5]. In addition, researchers have also investigated MDD from a cognitive psychology perspective, aiming to conclude the connection between a person's cognitive functioning and psychological disorders. A team of Canadian researchers found that people's cognitive dysfunction and MDD interact: that is, cognitive dysfunction may lead to MDD, and meanwhile, MDD would make cognition dysfunctional [6].

Working memory is a crucial concept in cognitive psychology, evolving from the concept of short-term memory. Working memory is a brain system which can temporarily store and operate the information for cognitive tasks including learning, comprehension and reasoning. Besides, in 1992,

Baddeley pointed out that the model of working memory consists of three subcomponents including the central executive, the visuospatial sketch pad and the phonological loop. The visuospatial sketch pad system manipulates the images and the phonological loop processes the speech information. The information stored and processed by these two slave systems will be coordinated in the central executive [7]. In 2010, Baddeley added the fourth subcomponent of the working memory system: the episodic buffer, which is also a slave system, associated with episodic long-term memory. The new theoretical model of working memory has been widely used in applied psychology and neuroscience [8].

Adolescence (10-19 years old) is an extremely significant period of cognitive development, during which the abilities of deductive reasoning and decision making are developing, and the cognitive capacity is expanding, and working memory is developed during this process. Adolescents have the ability to think abstractly, therefore, their perception of themselves, their ideas about the future, and their understanding of the people around them are affected by this abstractive way of thinking [9]. Meanwhile, teenagers' hormone levels are elevated and they become more emotional, and such changes can present many challenges. Therefore, the proportion of adolescents with major depressive disorder keeps rising, and major depressive disorder has become the most diagnosed psychological disorder among adolescents [2]. In fact, common signs and symptoms of major depressive disorder in adolescent patients are approximately similar to those of adult patients, but there can be some discrepancies [10].

Numerous studies examining major depressive disorder from a cognitive perspective have targeted adults as the subjects, and research on adolescent cognitive development and MDD is less common. Moreover, among the studies related to the interactions between adolescent cognition and MDD, more studies have emphasized the interactions between perception or attention abilities and MDD, while fewer studies investigated the working memory in cognition of adolescent MDD patients. However, working memory capacity is directly related to one's memory storage and memory retrieval, and one's memory processing may affect emotional processing and lead to psychological disorders, so working memory should also be of concern when discussing major depressive disorder from a cognitive psychological perspective. This article explored and analyzed the changes that occur in the working memory of adolescents with major depressive disorder, as well as the possible associated factors. The findings may contribute to the cognitive psychological investigation and treatment of working memory on major depressive disorder among adolescents.

2. The Impacts of Working Memory on Depression

2.1 The General Relationship between Working Memory and Depression

First, the difficulties to process image information in working memory can contribute to depressive symptoms. An individual may become less able to process information when he is depressed, and at the same time, the poorer working memory that results from this situation may cause him to doubt and become frustrated with himself. The research designed by Royuela-Colomer aimed to compare the emotional working memory of teenagers and adults with major depressive disorder with that of healthy individuals. The emotional n-back test was used to examine the emotional working memory by reaction time (RT), and questionnaires of depression inventory were conducted. The n-back test made participants choose the emotional stimuli which was matched with the previous one. The results of this research indicated that in a high load of working memory, for the DS (depressive symptoms) adolescents, the RTs for all three faces were faster than the HC (healthy control) adolescents. Moreover, in a low load of working memory, for the adolescents in both two groups, the RTs were the fastest for happy faces. Also, compared to adults, adolescents were more likely to be attracted by positive information (happy faces). Unlike healthy adolescents, adolescents with MDD might lack the bias toward positive materials (happy faces) with a high load of working memory tasks. Their study illustrated adolescents with MDD may not have a normal working memory capacity for processing positive image information as healthy individuals [11].

Besides, image processing of facial expressions is a crucial part of information transfer between people because facial expressions can convey people's emotions and thus facilitate interpersonal communication. If there is a problem with the ability to perceive facial expressions, people may have difficulty in normal interpersonal communication and thus become depressed. A study focused on the influence of facial expressions with specific traits on attentional control of adolescents with MDD using working memory [12]. The participants consisted of adolescents with MDD and healthy controls (HC). Various questionnaires were used to measure depression severity, and the visual n-back task was used to access the data of the reaction to the facial expression. The research found that the performance patterns of two groups were different from each other with discrepant emotional stimuli. Besides, the HC performance on neutral face distractors was better than the MDD performance. Compared to healthy controls, the distinction between performance on positive and neutral stimuli was larger in the MDD group, while the MDD group had worse performance on neutral stimuli than positive stimuli. Furthermore, there was no remarkable discrepancy on the performances between the healthy controls and MDD groups on negative stimuli. It is believed that the MDD patients' working memory processing differs from that of healthy individuals.

Moreover, whether the interaction between depressive symptoms and the working memory system has continuity is also worth exploring. A twin study was conducted to investigate the continuous relations between central executive function and major depressive disorder [13]. The sample consisted of 439 twin pairs in the same sex assessed at ages of 12, 17 and 23 years. Nine EF tasks, inhibition tasks, updating tasks, set shifting tasks and the CES-D measure were set for the participants to collect the data. The results of this study supported that depression manifestations are correlated to the central executive function negatively, and this relation has been existing continuously. However, the depressive symptoms of older age (age 23) were less related to executive function than the younger age. Also, the residual correlation between depressive symptoms and executive function at the younger age (age17) could provide the prediction for depression in the older age (age 23). It has been examined that the depressive symptoms are negatively correlated continuously to the executive function capability, working memory updating and other cognitive skills such as mental set shifting tasks.

2.2 Atypical Working Memory Updating and Depressive Symptoms

The working memory updating is an essential function of working memory to update the received information, and it could interact with each other. Wagner and Alloy's research was designed to find the correlation among the central executive, trait rumination, and depressive symptoms in adolescents [14]. The participants consisted of 486 early adolescents, and multiple questionnaires were applied to collect information about rumination and depression history and symptoms. The TEA-Ch task, Sky Research Dual task and Digit Span subtest of WISC-IV for children were used to access the working memory information. The results showed that trait rumination is positively correlated with depressive symptoms. Girls had higher scores both on rumination and depressive symptoms than boys, and age was significantly correlated with sustained attention and working memory. Trait rumination could not predict the capability of other functions of the central executive in working memory. Their study dominantly revealed a positive correlation between rumination and MDD among the adolescent population, as well as its gender and age differences. The greater the capacity for working memory updating, the less frequent and less extensive the trait rumination will be.

In the early stages of cognition, people receive information, which is then transmitted to the memory system for processing. Receiving information is extremely important for human cognitive processes, so it is worth discussing whether the early perception stages are correlated with depressed mood. The eye-tracking research on updating capability in working memory aimed to study the influence of emotional stimuli on working memory during high/low cognitive load in adolescents with dysphoric symptomatology [15]. The participants of this research were adolescents without dysphoric symptomatology (NDS group) and adolescents with dysphoric symptomatology (DS group). CDI and STAI-AC questionnaires were used to evaluate depressive symptoms and trait

anxiety, and the impact of emotional information on working memory would be examined by the eye tracking test. The latency analysis and accuracy analysis were adopted on the data. The results showed that during the high load of working memory, the latency was highest for happy faces in the DS group and the latency was highest for angry faces in the NDS group, which means adolescents with DS were less able to update information about positive emotional stimuli. During the low load of working memory, the latency was highest for angry faces in the DS group and the latency was highest for neutral faces in the NDS group, which means adolescents with DS were less able to update information about negative emotional stimuli. The findings indicated that the working memory processing could be altered by the dysphoric symptoms in the early perception stage in adolescents.

Besides, Spatial Working Memory (SWM) is also an important component of working memory, and its association with depressive symptoms can also reflect the relationship between the working memory system and depression. Vance and Winther's research aimed to investigate the interactivity between depression manifestations, inattentiveness and the ability of spatial working memory (SWM) in adolescents with and without persistent depressive disorders and MDD [16]. The participants consisted of young people with persistent depressive disorder (DD), MDD and comorbidity of MDD and DD. The various questionnaires and tests were used to collect data about mood, irritability, attention and working memory. After data analysis, the results illustrated that Inattention is positively correlated to depressed mood, which means depression could predict inattention. The poorer SWM would lead to increased inattention in depressed participants, besides, this impairment could be worse with higher severity of depression. For adolescents with MDD, the SWM, inattention and depressed mood have been confirmed to interact in a triad.

3. The Effectiveness of Working Memory Training

As mentioned above, there was a relationship between working memory and depressive symptoms and they can interact with each other, so it can be conjectured that the depressive mood of patients can be alleviated by training the working memory. Numerous studies have attempted to treat adolescents with MDD from a cognitive psychological perspective using training that targets working memory. A study found that adaptive training for working memory skills of adolescents could lessen anxiety and lowered susceptibility to depression. The study was designed to investigate the efficacy of adaptive training of working memory on anxiety and depressive symptoms in teenagers [17]. The participants were randomly divided into the training group or control group. Multiple questionnaires and scales were used to evaluate the depressive symptoms, and the adaptive n‐back training task was used for training pupils in certain time periods (1 to 20 days). The results of the study clearly reflected an increase in working memory performance and a decrease as the duration and frequency of n-back training increased in comparison to the control group. Meanwhile, the anxiety symptoms and depression manifestations decreased considerably as more n-back training was adopted for pupils. Moreover, the reduction in anxiety and depression was sustained at follow-up one month, which means the influence of n-back working memory training is lasting. These findings supported that the training for working memory could be beneficial for adolescents with depressive or anxious symptoms.

Nevertheless, effective working memory training is not universal and easily attainable because it requires a high level of interactivity as well as a long training time. In a shorter-duration study exploring the effectiveness of emotional training of working memory on the reduction of depressive symptoms, the online intervention did not reach the envisioned outcomes [18]. The research aimed to examine the direct influences of online intervention training on the capacity of working memory, and the effects on depressive symptoms. The randomized participants were assigned to two groups: EmoWM and Placebo. The computerized version of Self Ordered Pointing Task was used to access the WM capacity, the response to Cyberball was used to evaluate the stress activity, and the scale and questionnaires were adopted to collect the data about emotional functioning and depressive symptoms. The emotional WM training would be adopted by the EmoWM group while the placebo drugs would

be applied to the Placebo group. The results implied that there was no significant direct efficacy of online emotional WM intervention on WM capacity and depressive symptoms. The results also didn't support that online training would lead to a reduction in anxiety symptoms and depression. Such results may be due to the fact that this study was completely online, so the interactivity between trainees and trainers was not tight. In addition, the number of subjects in this study was relatively large (n=168), so it was less specific and targeted for individual training.

4. Conclusion

In conclusion, by reviewing and summarizing the previous studies, this article elucidates the interactions between working memory and major depressive disorder in adolescents, in terms of overall association, updating capacity, and training effectiveness. First, for adolescent patients, the capacity of working memory was negatively correlated with depressive symptoms, and this correlation persists into early adulthood. Moreover, the processing of visual image information in people with depressive symptoms is significantly discrepant from that in healthy individuals, as evidenced by the distinct responses to image information from different emotional stimuli. Second, atypical working memory updating has been shown to be associated with major depressive disorder in adolescent patients. The frequency and degree of trait rumination were shown to be negatively correlated with working memory capacity and positively correlated with depressive symptoms. Furthermore, under both high and low loads of working memory, adolescents with MDD have an altered competence to update information than the norm. Third, training for working memory has been shown to alleviate symptoms of major depressive symptoms and anxiety in adolescents to some extent. However, such training for working memory requires longer training time and higher practicality rather than online short-term training to have the hypothesized effect.

This article summarized the link between working memory and major depressive disorder and possible treatment pathways for adolescents in general. However, the relevance of various systems in working memory to depressive symptoms is currently unclear, and there are conflicting and controversial findings in many recent studies. Future research should explore and investigate the link between the functioning and inter-coordination of systems in working memory and depressive symptoms. In addition, training for working memory to alleviate depressive symptoms has not been systematically investigated, and the specific requirements and effects of training have not been conclusive. Therefore, future studies will be expected to conclude well-established training requirements and training methods. This review can provide some guidance to future interventions and practices for at-risk adolescents.

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