Effect of working memory training on mental disorders

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Abstract

This article reviewed data about the impact of working memory training on improving mental health. It was proved that one of the most salient effects of mental disorders is deficit in many domains of cognition which affect their quality of life and adaptative behaviors of persons with mental anomalies. A large body of studies have demonstrated an obvious association between working memory (WM) and cognitive functioning. Consequently, there is a strong psychological trend that pledged for WM training as a potential promising therapy for improving cognitive abilities in mental disorders. In this way, the present review analyses the literature on WM training in some mental disorders. Additionally, we intend to highlight the advantages and the efficacy of this tool in Schizophrenia, Depression and Neurodevelopmental Disorders. The review of the previous results uncovered significant and encouraging outcomes in many cognitive processes in addition to improvement in everyday life of patients. We concluded, that WM training can be recommended to lessen particularly cognitive alteration and generally pathological symptoms in mental illness.

Keywords: working memory training; mental disorders; Schizophrenia; Depression; Neurodevelopmental Disorders.

Introduction

Working memory is a complex cognitive process that is responsible for temporary storage and processing of information (Baddeley & Hitch, 1974; Baddeley, 2010; Cowan, 2005, 2008). This central cognitive structure predicts performance in many tasks such as reading (El-Mir, 2016, 2017, 2020, 2022). It was also corroborated that is deficient in many mental disorders like Autism Spectrum Disorder (ASD) (Guennach & El-Mir, 2019), depression (Dahbi & El-Mir, 2020). Additionally, its fuctioning is also affected by emotional processes (El-Mir, 2018; Bousbaiat & El-Mir, 2021). Besides Working memory training affectes positively ASD patients (Sedjari & El-Mir, 2021), and Schizofrenics (El-Haddadi, & El-Mir, 2022).

Mental disorders nosology considered that cognitive alterations are salient effects of mental disorders. Cognitive impairments are the core of the functional disability associated with these illnesses, sometime es more important than the clinical symptoms (Millan et al., 2012; Soumet- Leman et al., 2016). Thus, a growing body of research focused on cognitive remediation as a powerful aid in the treatment of several psychological disorders (e.g. Chapaman et al, 2013; Kühn et al., 2014). In fact, this therapy was originally designed for brain injured patients to improve their impaired cognitive abilities. Two approaches can be distinguished in this intervention (Soumet-Leman et al., 2016); stimulation approach that aims to directly enhance the deficit function and compensation approach to develop preserved functions in order to alleviate deficiencies. Cognitive training targets specific skills such as attention, verbal memory and working memory (e.g. Shapiro et al., 2011), planning and mental flexibility (e.g. Amedo & Todd, 2011). But most recently, there has been a great interest in WM training as a compensatory intervention in psychiatric disorders since they have been related to WM dysfunction in many studies (e.g. D'Esposito et al., 1995). Moreover, the training of WM may lead to a general improvement (Owen et al., 2010) because of its key role in cognitive functioning (e.g. Engel et al., 1999; Gaonac'h & Fradet, 2003; Guichart-Gomez, 2003; Roulois, 2011). More precisely, WM training focused on expanding working memory capacity (WMC) (Verhaefhen et al., 2004; Klingberg et al., 2005; Westerberg et al., 2007) and that enhance many cognitive processes given that WMC is a determining factor in executing various cognitive tasks (Engle et al., 1999; Kan et al., 2004; Sehmiedek et al., 2010; Rosenberg et al., 2020).

Regarding the central nervous system brain, Wanmaker (2015) noted the absence of an obvious pattern relating to neurobiological networks underlying WM training. Actually, the results of studies exploring associations between WM training and brain regions are inconsistent which may be due to many factors namely training conditions (Wanmaker, 2015), participant motivation towards the task (Jaeggi & al., 2011), age (Schimiedek et al, 2009), gender (Neubauer & Fink, 2010), task difficulty (Jolles et al., 2010) and duration of training (e.g. Basak et al., 2008). Additionally, several neuroimaging studies reported activation changes after working memory training in frontoparietal areas (Buschkuehl et al.,2012; Ansari, 2015; Duda & Sweet, 2020; Dziemian et al., 2021) that are steadily activated during working memory tasks (Wager & Smith, 2003; Owen et al., 2005; Salmi et al., 2018; Emch et al., 2019) and suspected to be implicated in the occurrence of some mental disorders like Depression, Attention-Deficit Hyperactivity (ADHD) and schizophrenia (D'Esposito et al., 1995).

The following is a brief outline related to the effects of WM training in some most burdensome mental disorders that are Schizophrenia, Depressive and Neurodevelopmental Disorders.

Firstly, it should be noted that the concept of WM training dates back to the seventies, precisely with the work of Kohl et al. (1976) aimed to have a better understanding of the memorization impairments in schizophrenic subjects. They have shown that encouraging patients to use effective memorization strategies might normalize their performance (Passereux & Bazin, 2009).

1. Working memory training in Schizophrenia

In fact, the core symptoms of schizophrenia might be related to the WM disabilities (Forbes et al., 2009). In the meta-analysis of studies comparing WM function in subjects with schizophrenia and healthy ones, those researchers have reported large deficits in the three domains of WM (phonological, visuospatial and central executive). The impairment of the WM has been associated with other cognitive processes that are defective in this psychopathology such as memory, attention, and planning (Silver et al., 2003) and other executive functions such as inhibitory control and mental flexibility (McCab, 2010).

Almost 95% of schizophrenic patients suffer from cognitive deficits, 65% show impaired cognitive flexibility, 75% show deficiency in planning tasks and 65% show disabilities in WM (Morice & Delahunty, 1996). In addition, antipsychotic medications are not sufficient in enhancement of cognitive impairment in schizophrenia (e.g. Fett et al., 2011; Fisher et al., 2009; Green, 1996; Mellissa et al., 2009). Thus, developing an effective treatment for cognitive deficits in this mental disorder is considering as one of the most important challenges for 21st century (Mellissa et al., 2009).

Given that WM have been correlated to cognition (Vauth, 2004), WM training would be an effective aid in the treatment of Schizophrenia in light of several studies have proved the positive influence of the WM training on other cognitive domains such as attention (Tang & Posner, 2009), processing speed (Dux et al., 2009) and perception (Mahnck et al., 2006) and also of the fact that the neural responses to repetitive practice are normal in this mental illness (Fisher et al. 2009).

A very large number of studies have been conducted in order to explore the effects of WM training in Schizophrenia patients, but despite the heterogeneity of the results, they seem encouraging. For instance, Hubacher et al. (2013) used a computerized program (Brain Stim) in 15 subjects with schizophrenia who were compared with 14 control patients taking – Treatment As Usual-. Participants were instructed to train four times a week for 45 minutes during 4 weeks. Post neuropsychological evaluation showed that patients who performed the training increased in verbal WM. Whereas, the meta-analysis of WM training by Melby-Lervag and Hulme (2013) revealed notable short- and long-term amelioration in visuospatial WM but a small short improvement in verbal WM outcomes. Other studies reported the transferability of the benefits from WM training to other cognitive domains. Fisher et al., (2009) assigned 50 hours of computerized auditory training or a control program with computer games to schizophrenic subjects, the exercises of the active training present increasingly difficult auditory- verbal WM and verbal learning tasks. As a result, the experimental group showed reliable significant improvement in global cognitive, verbal WM, verbal learning and memory and also in auditory psychosocial performance. These results are in line with Mellisa et al. (2009). As well, the meta-analysis by Wykes et al. (2011) found notable gains on cognitive impairment and also on social and occupational functioning. In the same context, Hargreaves et al. (2015) recruited stable patients with schizophrenia and related psychosis to complete 8 weeks of WM training, they observed an immediate significant amelioration in episodic memory and delayed improvement in logical memory tasks.

Over well and as reported by Isaac and Januel (2016), CR can show neuroplastic effects in schizophrenia by reorganization of neural networks. They also affirmed that this therapy leads to improvement in various cortical and subcortical activation. Despite the heterogeneity of CRT approaches, these non-pharmacological interventions induce functional, structural, and connectivity changes in patients with schizophrenia (Matsuda et al., 2018). But, to specify the efficacy of WM training on neural structures, numerous neuroimaging studies based on button bottom-up approach have been carried out endorsed the neural mechanisms related with WM training. Large number of Studies have confirmed activation in the neural network associated with WM, namely the middle, superior and inferior frontal gyri and the superior and inferior parietal lobes (Leung & Alain, 2011; Owen et al., 2005; Rottschy et al., 2012). Additionally, Li and colleagues (2015) have directed meta-analysis including six studies and using activation likelihood estimation (ALE). They reported activation in five regions namely the Right Superior frontal gyrus, the right praecuneus, the left angular gyrus, the right inferior frontal gyrus and the right fusiform gyrus. Also, in Ramsey and colleagues (2017), functional MRI analysis have indicated neuroplastic changes mainly in Dorsolateral prefrontal cortex (DLPFC) in all patients with schizophrenia who benefited of 48 Hours of training using 21 computerized tasks demanding working memory and selected from the psychological Software Services, CogRehab program, Brain train's educational software and variants of N-back tasks.

2. Working memory training in Depression

Regarding Depressive Disorders, researchers highlight the prevalence of cognitive disabilities in patients with Depression and their significant influence on autonomy and psycho-social functioning in addition to somatic symptoms and mood changes. Deficits are noted in several domains (Eliott, 2002), but they primarily affect executive functions, attention and memory (Vidailhet, 2010). Depressed patients frequently complain about memory difficulties that affect their capacity to function in daily life (Soumet-Leman et al., 2016). It has been suggested that the cause of those specific symptoms might be associated to the dysfunction of WM (Chapman & Chapman, 1973, 1978; Ouimet et al., 2009; Nikolin et al., 2021) since they all depend on this system (Ilkwska & Engle, 2010) and due to this dysfunction, depressed individuals select and maintain negative material in their WM that leads to the continuation of a negative mood (Isen, 1984; Siemer, 2005). In fact, several studies have reported deficiencies in WM in depressed patients during the performance of a task, they have significantly worse performance than healthy peers across all WM tasks (e.g. Harvevey et al., 2004; Rose & Ebmeier, 2006; Snyder, 2013; Snyder & Lhankin, 2018; Soumet-Leman, 2016)

Considering the relationship between the deficit of the WM and the cognitive impairment in Depression disorders and the association between difficulties in controlling the content of WM and rumination and also the role of its capacity in suppressing intrusions (Wanmaker & Franken, 2014), WM training seems be an effective intervention to mitigate the cognitive deficits as well as the other clinic symptoms of Depression. In fact, many studies have evaluated the effects of the cognitive remediation in Depressive Disorders. The first was that of Elgamal et al., (2007). However, few reviews were carried out using WM training to decrease the symptoms of this psychopathology. Some of them have reported positive results, yet others have not shown similar conclusions. One of these reviews that of Beloe and Derakshan (2018) who aimed to explore the effects of an adaptive WM training on anxiety and Depression in adolescents. An adaptive N-back task training was assigned to a group of 128 volunteer adolescents compared to a control group of 126 teenagers executing the non-adaptive version of the dual N-back training. Participants had to complete 5 days training per week during 4 weeks. The outcome measures showed a significant improvement of WM performance and a considerable decrease in scores of the Revised Children's Anxiety Depression Scale (RCADS) in the experimental group directly following intervention and at 1 -month follow-up. Wanmaker et al. (2014) also examined the impact of a gamified WM training on Depression, anxiety, and rumination symptoms in dysphoric students. Participants executed 5 WM tasks, 3 times a week during 3 weeks. They were randomly divided into an experimental group and placebo training one which were compared with a healthy control group. They used Span board task adapted from Prins et al. (2011) to measure WM capacity, the Beck Depression Inventory – II (BDI –II) to evaluate the level of depression, the State Trait Anxiety Inventory (STAI) to measure anxiety traits and the Ruminative Response Scale (RRS) to assess the frequency of rumination behavior. Data analysis has shown a higher increase in WMC in the experimental group comparing to both placebo training and healthy groups, whereas it was reported any transfer of this improvement to symptoms of Depression, anxiety, and rumination. The study of Wanmaker (2014) is partially in line with this result, he proposed a training based on Dual N-back task (Jaeggi et al., 2007) and the Symmetry Span (Kane et al., 2004) to 49 depressed individuals. Patients executed the tasks 6 times a week during 4 weeks. In parallel, 49 other participants got a placebo training. The same tests were administered before and after the intervention; the Internal Shift Task Digit Span and Reading Span were used to measure WMC while the severity of Depression symptoms, rumination and anxiety were measured respectively by the Beck Depression Inventory (BDI- II), the Ruminative Response Scale (RRS) and the Stat-Trait Anxiety Inventory. The outcome of the study indicated the absence of positive effects of WM training on cognitive deficits as well as on the level of Depression which is in concordance with the conclusion of Leone de voogd et al. (2016). Those researchers examined the influence of an emotional WM training, that aimed to augment WMC by using emotionally charged stimuli (Mammarella, 2014) on 168 adolescents aged between 11 and 18. They were randomised over an active or placebo emotional WM training and have been trained two times a week during 4 weeks. The results didn't report any significant increase in WMC nor in anxiety and depressive symptoms.

Despite the conclusions of studies that reported the absence of positive impact due to the WM training on depressive symptoms, it may be inopportune to confirm the inefficacy of this intervention in Depression treatment in view of the reviews' number suggested that WM stimulation could activate executive system and improve inhibitory processes control (e.g. Bickel et al., 2011; Morrisson & Chein, 2011; Olesem et al., 2014) and also might alleviate negative emotions (e.g. Roughan & Hadwin, 2011;

Sheweizer et al., 2011, 2013; Franken, 2014, Tkeuchi et al., 2014; Sari et al., 2015; Hadwin & Richards, 2016).

Yet, little information is available about brain changes in Depression following cognitive rehabilitation. In Han and colleagues (2017), a group of 40 depressed participants with Traumatic Brain Injury (TBI) were assigned into SMART (Strategic Memory Advanced Reasoning Training) that comprises 12 sessions (1,5 hour per session) for 8 weeks and targets inhibitory control, WM and mental flexibility. It has been identified a reduction in depressive symptoms using Beck Depressive Inventory, increase of cortical thickness and decrease in resting state functional connectivity (rs FC) in four regions within the right prefrontal regions. In addition, Siegle and colleagues (2007) suggested that cognitive control training program (CCT) which focuses on the executive functions specially target neural activity associated to Depression. They have noticed decreased disturbance in DLPF and amygdala activity while effecting emotional and cognitive tasks. Also, it has been increasing Dopamine activity in the course of and after the WM training (Bäckman et al., 2011) and it's known that Dopamine system has a prominent interest in WM training because of its effect in both WM performance (Luciana et al.,1992) and neural plasticity (Stroemer et al., 1998).

3. Working memory training in Neurodevelopmental Disorders

Concerning Neurodevelopmental Disorders, researchers regard WM deficit as a common feature in these psychopathologies (e.g. Majerus, 2017). The dysfunction of WM had been indicated in many studies, we may cite, for instance, Intellectual Deficit (ID) (e.g. Büchel & Paour, 2005; Chapell, 1997; Ellis, 1970, Jarrold et al., 2008; Rowe et al., 2006; Schuchardt et al., 2011). Learning Disabilities (LD) (e.g. Holmes et al., 2010; Majerus, 2017). Attention Deficit/ Hyperactivity Disorder (ADHD) (e.g. Barkley, 2010; Kasper et al., 2012; Kofler et al., 2009; Lambek et al., 2011; Martinussen & Major, 2011; Willcut et al., 2005), Autism Spectrum Disorder (ASD) (e.g. Habib et al., 2019; Hughes et al., 1994; Garcia & Sala, 2002; Gilloty et al., 2002; Kercood et al., 2014; Landa & Goldberg, 2005; Minshew et al., 2005; Ozonoff et al., 1991; Ozonoff & Mc Evoy, 1994; Prior & Hoffman, 1990; Rumsey & Hamburger, 1988; Steele et al., 2007). Developmental Coordination Disorder (e.g. P. Alloway et al., 2009) and Specific Language Disorder (SLD) (e.g. Marton, 2008; Alloway et al., 2009; Kirsten et al., 2013; Saeed, 2011).

Regarding the outcome of these studies, it obviously seems that WM training could be a useful tool to enhance cognitive functioning in Neurodevelopmental Disorders given the significant corelation between the capacity of WM and several cognitive abilities (Engle et al., 1999; Kan et al., 2004; Rosenberg et al., 2020; Sehmiedek et al, 2010).

In effect, the knowledge base relating to WM training has been expanded in some disorders such as ADHD but still quite limited in others. However, the results of the studies conducted in this area provide some evidence of a positive benefit from WM training. For example, Söderquist & al., (2012) investigated the effects of WM training on 52 children with (ID) aged between 6 and 12,5. The experimental group profited from 20-25 WM training sessions, each session lasts 20 minutes. The post intervention outcomes confirmed a positive effect on the verbal WM, on the visuospatial WM and also on the language comprehension. Further, the meta-analysis of Danielsson and al.

(2015) concluded that mixed WM training that targets both verbal and visuospatial components led to remarkable gains in (ID).

In respect to (LD), Pumaccahua & al. (2017) aimed to examine the effectiveness of this cognitive remediation in increasing cognitive abilities in children with (LD). They used Captain's Log designed to develop attention skills, problem solving skills and WM. Post-tests had indicated gains in verbal and visual WM. Also, Aljundi (2020) explored whether WM training can improve the WM in 10 children with (LD) aged between 10 and 11. The post evaluations of the experimental and control groups were compared after 2 months training, they had shown significant amelioration in WM and notable achievement in learning reading in the experimental group. As specified by Eden & colleagues (2004), the imaging studies have shown that the dysfunctional phonological processing in dyslexia is localized in the left hemisphere perisylvian regions and 8 weeks of intensive phonologically training leads to significant improvements in the use of the left hemisphere parietal cortex as well as numerous right hemisphere regions. This kind of remediation is associated with the normalization of left hemisphere brain regions (Shaywitz & al., 2004). It also shown a boosted metabolic activity in left hemisphere temporoparietal language regions during the assignment of the letter rhyming task in dyslexia readers (Temple & al, 2003).

In regard to ADHD, it seems that is the most studied disorder in terms of WM training influence. A large number of conclusions had corroborated the advantages of this intervention in this illness. By way of example, Klingberg et al. (2005) confirmed that children showed less ADHD symptoms (hyperactivity, impulsivity, and motor activity) after WM training and the executive functioning of trained adult has been improved. Furthermore, the training gains persisted for at the minimum 3 months. Green et al. (2012) reported an enhancement in WM tests and significant reductions in "off-task" ADHD behaviour related to academic tasks. Also, the performances of participants in Passarotti et al. (2002) indicated both near and transfer. The ameliorated in Digit Span Test, Spatial Span Test, Trails Making Test B and the Reading Fluency Test. Although, Ackermann et al. (2018) supported the near transfer and reduction of hyperactivity/ impulsivity symptoms but not far transfer.

According to Stevens and colleagues (2016), many researchers have noticed effects on brain networks following working memory training in adults and adolescents with ADHD but not de Oliveira Rosa and colleagues (2019), they did not report any cerebral modulations relating to this intervention that might be associated with the age of participants or the small sample size in their study (Stevens et al.,2016). Even using the same training program (CWMT), the fMRI data are heterogeneous. Constantinidis and Klingberg (2016) reported an increased activity in frontoparietal regions although other researchers did not (e.g. Mawjee et al., 2017).

As to ASD and despite the lack of research that attempted to examine the effectiveness of WM training in this disorder, the systematic review by Bourgeois (2017) collected 5 studies that confirmed a positive influence of WM training in children with ASD (Baltrushat et al., 2011a; Baltrushat et al., 2011b; Baltruschat et al., 2012; de Vries et al., 2015; Miyajima et al., 2016) in spite of the differences between the testing and training instruments used. As well, notable improvement post intervention was seen in subjects with ASD that completed 12 hours of training (Kerns et al., 2017). Likewise, the outcomes of Sedjari and El-Mir (2021), using a computerized training program, had shown a significant improvement in the three components of WM (phonological loop, visuospatial sketchpad, and central executive) directly after 40 training session and 3 months follow-up. Additionally, to direct effect far transfer was noticed in some of these studies; reading fluency (Kerns et al., 2017), verbal fluency and planning (Myajima et al., 2016).

To explore whether WM training could improve the syntactic abilities in SLD (Delage et al., 2021) had instructed 32 children presenting this disorder to complete 12 hours training using iPad application designed to train the three components of WM. The program leaded to an expansion of WMC that transferred to syntactic performance and the effects relatively persisted over time. In the same context, Holmes et al. (2015) confirmed significant evidence of WM training in children with low language abilities, participants had shown great amelioration in visuospatial short-term memory.

Discussion

The aim of the present work was to reveal the positive effect of cognitive remediation, in particular WM training in some mental disorders such as Schizophrenia, Depression and Neurodevelopmental Disorders. Researchers consider cognitive impairment as a common characteristic in these psychopathologies. Since the relationship between WM and other cognitive processes, numerous studies have focused on WM training as a treatment of these illnesses. In this paper, we tried to summarize many conclusions in each disorder to highlight the importance of this cognitive therapy.

As described above, WM training has positive repercussions on three domains of WM as well as on other domains like attention, perception, and episodic memory. Also, it's reported that this intervention can improve daily functioning and academic abilities. In addition, imagine studies have affirmed the association of this therapy and normalization or increasing activities, specifically in frontal lobes.

We recognize that we have focused in this work on positive outcomes of WM training despite their absence in some studies; it's due to the reviews numbers have confirmed the efficacy of this remediation on executive system. From our perspective, the number of research presented in this paper is significant to say that WM training can be recommended to enhance cognition in several mental disorders. Furthermore, and considering the experimental protocol used in most of studies presented above; we put forward the idea that WM training in its computerized form could be effective in terms of time and effort.

In summary, we note that the results reported in this paper are promising and confirm both the feasibility and benefits of WM training in mental disorders, it can be a valuable therapeutic approach and a powerful aid in the treatment of these illnesses. Nevertheless, more research is needed in this area to provide more data and validate this conclusion.

Conclusion

This paper focused primarily in showing the efficacy of working memory training in improving mental health. Furthrmore, the main objectives of this article consisted in demonstrating that working memory training could be beneficial to cognition and then to the compensatory intervention that aimed mental disorders. The data stemmed from previous explorations indicate that cognitive deficiencies are the nucleus of mental disorders symptoms. Since traditional therapies face great difficulties in reducing mental hardship, along with the fact that mental health problems usually go hand in hand with cognitive deterioration; clinical professionals direct their attention to therapies centered on empowering cognitive abilities.

The review of the data resulted from WMT of patients with mental illnesses uncovered that exercising working memory could have positive repercussions on patients suffering from emotional, neurodevelopmental and schizophrenia disorders. These applied studies also revealed the helpful aspects of making use of working memory exercices.

Besides, these discoveries in cognitive training are very promising, and open a window into more efficient tools to alleviate mental distress symptoms and enhance everyday life of patients complaining of mental disabilities. Finally, we can conclude that WMT and other cognitive remediation tools illustrate the future of a new psychotherapy based on cognitive workouts.

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