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Original Paper

The Development of Working Memory in Children with Autism and the Future

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Abstract

Autism spectrum disorder (ASD), characterized by persistent deficits in social communication and restricted/repetitive behaviors, has a global prevalence of approximately 1-2%, with males diagnosed 4.3 times more frequently than females. Working memory profiles in autistic children exhibit heterogeneity, with studies reporting spatial working memory deficits contrasting relatively preserved verbal working memory, though inconsistent findings persist due to methodological variability, age-related factors, and IQ discrepancies. Interventions such as cognitive behavioral therapy and gamified working memory training demonstrate potential efficacy but necessitate longitudinal implementation and multidisciplinary collaboration (e.g., caregivers, educators). Future research must prioritize elucidating neurocognitive mechanisms underlying working memory impairments and refining targeted, stepped-care intervention models to enhance academic and sociofunctional outcomes. Early, individualized approaches remain critical for optimizing developmental trajectories in ASD.

Keywords

Autism Spectrum Disorder (ASD), Working Memory, Executive Function

Introduction

Autism is a is a common, highly genetic, heterogeneous neurodevelopmental disorder that can co-occur with other disorders (Lord et al., 2020). It is diagnosed through a 36-month behavioural diagnosis and is characterised by persistent deficits in social interaction and communication, as well as the presence of repetitive stereotypical patterns of behaviour (APA, 1994). Of these, communication deficits are a core feature necessary for an autism diagnosis. "Autism spectrum disorder (ASD)" is a term widely used in the current reference literature as a summary of the impairments that affect social interaction. Its use is based on individuals who share common autistic traits, but there are individual differences and, in addition, the disorders included do not always have working memory impairments (Irwin, MacSween, & Kerns, 2011). A number of theories have been developed to explain the deficits in ASD,

a common one being the mental deficit theory, which suggests that individuals with ASD do not have the ability to mentalise or to infer the mental states of others (Baron-Cohen et al., 1985), which may affect social interaction deficits. Of these theories, the one on the non-social aspects of autism is the executive dysfunction theory, which states that most of the abnormalities in people with ASD may be related to executive dysfunction and is perhaps the only theory on the cognitive and motor aspects of autism (Rajendran & Mitchell, 2007). Many studies have shown that individuals with ASD often have deficits in multiple aspects of executive functioning compared to typical development, resulting in differences (Pellicano, 2012).

Epidemiology

With the development of DSM, there has been an increase in the reported prevalence of autism. About fifty years ago, autism was reported as a neurobiological disorder (Rutter, 1970), and although current research suggests that autism is caused by a combination of different genetic variants, there are no known genetic findings to date (Lord et al., 2022). However, as awareness of autism has increased, the psychiatric diagnostic system has recognised the 'developmental' nature of autism (APA, 2014), which may have led to an increase in the prevalence of autism. a 20-fold increase compared to the last three decades. In addition, Maenner et al. (2020) also analysed the prevalence of children with autism, reporting that 16.8 per 1000 8 year olds had autism in 2014, approximately 2.5 times higher than in 2000. In addition, the report points out that there are gender differences in the prevalence of autism, with boys having a prevalence of about 4.3 times that of girls. This may be due to a lack of awareness of autism in females or an under-diagnosis of females. Some studies have shown that when gender differences occur, women are diagnosed later than men (Daniels & Mandell, 2014). At the same time, some studies have reported that women with autism have lower levels of stereotypical behavioural patterns but more severe social impairment (Frazier et al., 2014), which may contribute to the under-diagnosis of female females. For the overall population, the global prevalence of autism is approximately 1-2%, meaning that there are approximately 78 million people with autism worldwide (Lord et al., 2022). However, the majority of people with autism in low- and middle-income countries are not diagnosed (WHO, 2013), and the Global Research on Developmental Disabilities Collaborators (2018) report that approximately 95% of children under the age of five with autism occur in low- and middle-income countries. Where this may be due to a lack of resources resulting in a lack of developmental monitoring settings or limited ability for families to access services, poor staff knowledge of autism in this setting may also lead to parents receiving incorrect diagnoses and thus patients with less obvious symptoms and possibly not being diagnosed. Kommu et al. (2017) also report that children with more severe or complex symptoms (e.g. intellectual disability, epilepsy) are more likely to receive clinical attention and eventually be diagnosed. However, there are fewer studies for high-income countries. Furthermore, Baxter et al. (2015) concluded that there are essentially no regional differences in the prevalence of autism.

Working memory

Executive functioning is defined as a cognitive process that is based on goal-directed behaviour (Zelazo, Craik, & Booth, 2004). In general, executive functioning includes skills such as transference or cognitive flexibility, priming and working memory, as well as abilities such as planning, problem solving, and self-control (Chan et al., 2008). Executive functioning has a significant impact on people's daily lives and is related to communication and the ability to respond to others. It has been shown that children, adolescents and adults with autism have age-specific impairments in executive functioning during development (Luna et al., 2007), and although not a signature deficit of autism, there is a general impairment at the group level (compared to typological development). Pellicano (2010) found that not all children with autism exhibit executive functioning deficits, implying that possibly due to individual differences in autism, executive functioning deficits are not a core deficit in autism. Whereas working memory is an important component of executive functioning, much of the existing research is on working memory in individuals with autism. Working memory is a process in which information remains active so that the persistence of behaviour can be maintained (Baddeley, 1992). Working memory updating is the ability to modify or update recalled information in response to a change in goal (St Clair-Thompson & Gathercole, 2006), and Baddeley (2012) refers to working memory as "a complex interactive system" and "an interface for processing information". "an interface for processing information". This means that working memory is important in people's everyday lives, a short example being when people talk, they need to remember what the other person says and remember what they need to say in response. In addition, working memory is also relevant to learning, with Barker's (2016) study demonstrating that working memory provides the necessary support for the learning of numeracy in pupils with typical development. This report similarly demonstrates that skills related to reading/auditory comprehension, following directions and written expression related to learning all appear to be associated with general working memory capacity. In addition, studies have reported that working memory impairment can lead to problems with maintaining attention and abstract thinking, which can lead to academic impairment (Kercood et al., 2014).

The first model of working memory was proposed by Baddeley & Hitch (1974). They divided working memory into three systems: the central executive system, the visual-spatial sketchpad, and the phonological loop. In these systems, the central executive system controls the transfer of information between the other two systems (as command structures). Beyond this original model, other models of working memory include the long-term working memory model (Ericsson & Kintsch, 1995), the embedded process model (Cowan, 2016), and the integrative model (Dehn, 2008).

Study of working memory in children with autism

The impact of working memory impairment on children with autism is multifaceted, and some studies have shown that children with autism may exhibit information processing difficulties, task planning and execution difficulties due to working memory impairment (Wang et al., 2017), all of which may

directly affect their daily life and learning abilities. Kimhi et al. (2014) showed deficits in task planning skills in children with autism, which can lead to increased stress in their schooling. Therefore, it is important to recognise and intervene with working memory impairments in children with autism in order to improve their daily lives and schooling. There are many studies on working memory impairment in children with autism, but it appears that the findings vary. Some studies have shown that children with ASD have impaired working memory, however some studies have shown that children with autism do not differ significantly from children with typical development in terms of working memory. Corbett et al. (2009) did a comparative analysis of an equal number (18) of children with autism (IQ >70) and typically developing children, after excluding medication, fragile X chromosomes and other influences of psychiatric and medical disorders, the results found that children with autism showed impairment in a wide range of executive functioning tasks. In that report, children with autism showed significant differences in inhibition, working memory, and flexibility/shifting. Subsequently, Kado et al. (2012) tested working memory in children using the Wisconsin card sorting test (WCST) and showed that working memory in children with autism was not significantly different compared to children with attention deficit hyperactivity disorder (ADHD), however, working memory impairment was seen in comparison to children of the same age with comparable IQs. The WCST was designed to be a comprehensive measure of executive function including inhibition, transfer and working memory, and in the test, children with autism had fewer categories and more errors on six consecutive cards, implying impairment in working memory. However, Roelofs et al. (2015) came to a different conclusion in that they did not find significant differences in working memory between individuals with ASD and non-autistic individuals who were matched for intelligence. Furthermore, other studies have not identified individuals with ASD as having working memory impairment compared to normally developing individuals (Morsanyi & Holyoak, 2010). The reason for such inconsistent results may be related to models of working memory, which may not have been divided into verbal and spatial working memory according to Baddeley's model. For example, studies of children with autism have shown uneven development of working memory, with strengths in verbal working memory but deficits in spatial working memory (Cui et al., 2010). Also, tests of executive functioning may lead to inconsistent results. Tests of executive functioning often test more than one single executive function, for example, cognitive transfer, problem solving and response maintenance are measured alongside working memory, and the inability to discuss a single target for analysis may lead to inconsistent results. Finally, differences in the age of the sample selected for different studies may also lead to different results.

There are many factors that influence working memory, and early research has shown that children with autism show relatively poor memory for complex information and spatial working memory, while verbal working memory and recognition memory are relatively intact (Williams et al., 2006). This may suggest that working memory impairment in individuals with autism may be related to cognitive load or cognitive processing. One study comparing intelligence and age-matched ASD, ADHD and

typological development groups on a number of executive functioning tasks showed that both the ASD and ADHD groups showed significant working memory impairment compared to the TD group, and that the ASD group performed worse on cognitive tasks (Happé et al., 2006). Age-related factors were also reported in Happé et al.'s (2006) study, where younger individuals with ASD made more errors in a spatial working memory task, whereas older individuals showed no significant difference compared to controls, implying that individuals with ASD had This implies that there are age-related improvements in working memory for individuals with ASD. Other studies have also shown an effect of age on working memory, using the WCST to investigate similar findings: the younger group yielded more unfavourable scores, while the older group did not show significant group differences, leading to speculation that the degree of impairment in working memory changes with age (Kado et al., 2020). However, a meta-analysis by Wang et al. (2017) et al. concluded that WM impairment was not related to age, which supports persistent WM impairment across age in individuals with autism. Redcay & Courchesne (2005) demonstrated that individuals with autism between the ages of 2 and 5 years had the greatest deviation in size brain size from normally developing individuals, meaning that children with autism received the the greatest impairment. However, the majority of studies have sampled beyond this age range. The majority of individuals with autism exhibited intellectual disability, leading to speculation that intelligence may be related to working memory impairment in children with autism.

In order to gain a clearer understanding of working memory in children with autism, some studies have divided working memory into two domains: the spatial or visual working domain, and the verbal working memory domain. One study, in order to assess working memory in children with autism aged 5-8 years, divided children into two groups: those with both verbal impairment and those with typical or normal language skills (Hill et al., 2015). It was found that children with ASD and language impairment performed worse on a verbal working memory task than children with autism without language impairment, however, there were no between-group differences on a visual working memory task. In general, individuals with ASD show signs of impaired verbal and, in some cases, higher visual abilities, as evidenced by the block design task and the child-embedded graphics task done in Jolliffe and Baron-Cohen with children with autism as early as 1997. Koshino et al. (2005) showed that in order to compensate for their language deficits, individuals with autism tend to prefer visual processing stimuli. Kercood et al.'s (2014) review of working memory demonstrated that visuospatial working memory is more impaired than verbal working memory, meaning that individuals with autism are impaired in working memory tasks, especially those requiring spatial working memory.

Different interventions and their effects

A number of intervention methods have been used to improve working memory in children with autism. Examples include cognitive behavioural therapy, neurofeedback and pharmacotherapy. The relationship between executive functioning and language skills in autism raises questions about the impact of interventions. The implication is that if structural and/or verbal language skills are in fact related to

executive functioning, it can be argued that interventions targeting one domain will lead to general improvements in the other. On such a basis, the HCSM argues that executive function can improve with language ability, however Haebig et al. (2015) report the opposite results, showing that improvements in executive function can improve language performance skills. However, in general, some studies will consider executive performance as a post-intervention outcome, which is consistent with the HCSM. Furthermore, the study by Baltruschat et al. (2011) was able to demonstrate that working memory in children with autism can be positively improved with positive reinforcement interventions.

One study conducted a randomised group trial to test the evaluation of a classroom intervention for children with autism and found that the classroom intervention improved the social skills and executive functioning of children with autism, possibly due to increased engagement and social communication (Prizant et al., 2006). However, it is worth noting that because teachers know they are intervening when the intervention is delivered in the classroom, classroom-reported scales assessing post-intervention outcomes for social skills and executive functioning may be inaccurate (Morgan et al., 2018). In addition, Wagle et al. (2021) used a game to intervene with working memory in children with autism and although there was no significant improvement in working memory after one month of training, children who performed better in the game showed more changes in their working memory, speculating that better improvements in working memory may occur if the duration of the game or intervention is lengthened. A similar conclusion was reached by a study using adaptive working memory training, where training with a play element improved working memory in children with autism (de Vries et al., 2015). In addition, the study found that the results from the training could be transferred far into everyday life.

The Future

There is considerable variation in findings and contradictory reports on the performance of executive functioning and its relationship to language ability in children with autism. In the future, there is a need for researchers to characterise samples more clearly and carefully so that studies with specific impairments can draw clear conclusions and lay the foundations for further knowledge of working memory in children with autism. At the same time, as working memory is of great importance in daily life and learning abilities, affecting children's academic performance and social communication, and as interventions in small areas of executive functioning are always one affecting the other, it is important to look at the interactions between different areas in the future so that more effective interventions can be designed to further help improve children with autism's working memory impairment. On the other hand, it is not entirely clear until now which assessments or treatments are most effective for autism or which areas of autism are most effective, and a better understanding of the mechanisms underlying working memory impairment in children with autism could help to provide more effective therapeutic interventions for patients and families. Furthermore, interventions for working memory in children with autism are not done in isolation, meaning that teachers or parents need to be involved, which represents

the importance of a stepped approach to care that optimises the sharing of tasks between the various stages (parents, community health workers, educators, early intervention workers).

Conclusion

Overall, although not a core deficit, children with autism have extensive working memory impairment compared to children with TD. This paper has described the impact of working memory impairment on children with autism, the factors that influence working memory impairment, the extent of impairment in different areas, and interventions to improve working memory in children with autism. These aspects of research seem to indicate that there is a growing understanding of working memory impairment in children with autism. Although the most effective and targeted interventions are not yet available, the benefits of early intervention for children with autism are clear. Further research into mechanisms or improved treatments will be a long-term process, but stepped care can help improve as many aspects of autistic children as possible. It is certain that there will be more research on working memory and measures to help more children with autism improve their symptoms in the future.

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