The International Journal of Indian Psychology
ISSN 2348-5396 (Online) | ISSN: 2349-3429 (Print)
Volume 11, Issue 3, July- September, 2023
DIP: 18.01.132.20231103, DOI: 10.25215/1103.132
https://www.ijip.in

Review Paper

Current Updates on Visuospatial Working Memory in Cerebral Palsy: A Mini Narrative Review

Nitya Ann Eapen[1]*

ABSTRACT

Cerebral Palsy (CP) can be defined as a group of disorders that lead to difficulties in motor functions, learning, communication and language. One of the major deficits in CP, in the cognitive realm, is the impairments to the visuospatial memory. Previous papers have failed to focus specifically on the visuospatial aspects of memory with respect to CP. Thus, the objective of this article is to review the latest findings pertaining to the deficits of visuospatial memory in CP and some closely related deficits such as topographical working memory as well as deficits in mathematical abilities in children diagnosed with CP. For the purpose of this review, 17 articles were chosen through the keywords 'cerebral palsy', 'spatial memory', 'visuospatial working memory' and 'topographical working memory'. The findings of this review highlight the severity of visuospatial impairment in children diagnosed with CP while also giving emphasis to rehabilitative practices.

Keywords: *Cerebral Palsy, Visuospatial Memory, Topographical Memory*

The effect of action on perception and more broadly cognition has been understated in the traditional narrative of cognition. The grounded cognition theory posits that neuronal cells rarely perform a single function, thus performing both sensory or motor and cognitive functions. For instance, according to this paradigm, thinking about a cat should stimulate the sensory characteristics of the cat thus stimulating various areas of the sensory cortex. This approach has posed a challenge to the traditional, more conventional connectionist and localizationist approaches of neuroscience which have highlighted the isolated role of cognition (Cardona, 2017).

Cerebral Palsy (CP) is defined as a group of disorders that lead to difficulties in motor functions, learning, communication and language (CDC, 2020). The motor deficits that inhibit accurate movement in CP are thought to be caused by non-progressive damage to the motor cortex (Tajadini et al., 2019). Baddeley's model of working memory highlights the role of the visuospatial sketchpad, a component that is essential for the retention of spatial objects and information (Buchsbaum & D'Esposito, 2008). Considering the tenets of the grounded cognition paradigm, I hypothesise that children diagnosed with CP would have difficulties in navigating through space in addition to widely apparent deficits in visuospatial memory and abilities due to a clearly apparent lack of motor ability. This essay will review

[1]MSc Neuropsychology, CHRIST (Deemed to be) University, India
*Corresponding Author

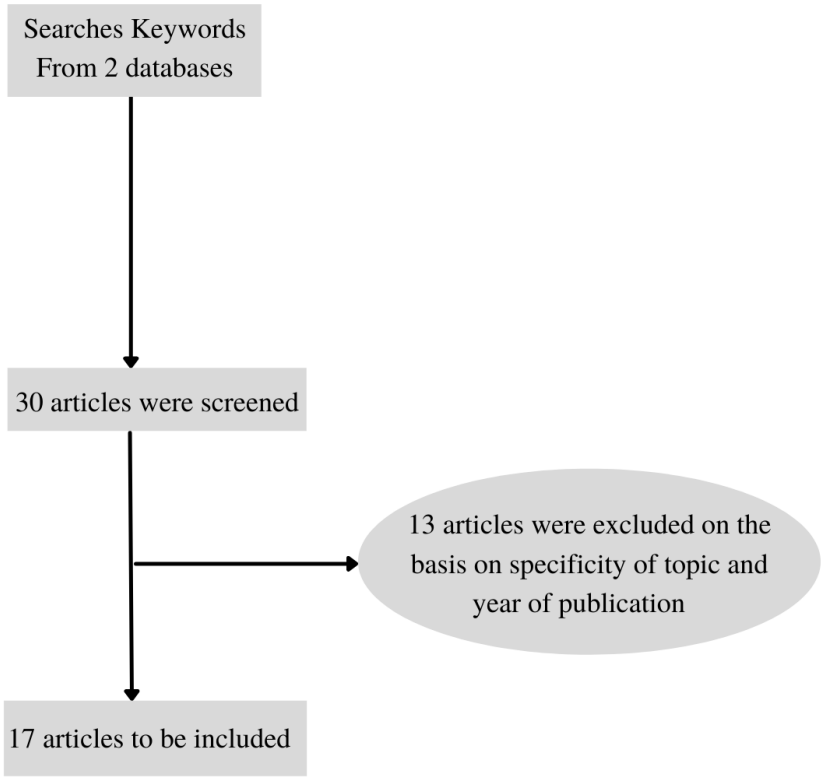
Received: January 19, 2023; Revision Received: July 28, 2023; Accepted: August 02, 2023

the latest research updates in the area of visuospatial working memory in patients diagnosed with cerebral palsy (CP) from 17 journal articles that were published within the last five years.

METHOD

Search interfaces such as PubMed and ScienceDirect were used to search for the respective articles. The keywords, 'cerebral palsy', 'spatial memory', 'visuospatial working memory', 'topographical working memory' were used to find the respective articles, following which about 30 articles were screened. Out of these articles, 17 articles that were published between the years 2017- 2022 were chosen for this review. Figure 1 represents the selection process of the articles.

Figure 1 Flow chart of the selection process



Inclusion criteria for the selection of articles included a time span within the last five years, from 2017-2022. Additionally, the criteria also included articles specifically addressing the visuospatial memory deficits, topographical memory deficits and rehabilitative practices that improve these two components of memory.

RESULTS

Visuospatial Working Memory in CP

The motor disabilities in CP are often accompanied by impairments in cognition as well which vary across the different subtypes of CP namely ataxic, spastic and dyskinetic (Patel et al., 2020). The causal model of CP highlights the multidimensional nature of the disorder, emphasising the impairments associated with it at a biological, cognitive, behavioural and participatory level. Impairment at the cognitive level is associated with the areas of verbal and fluid reasoning, memory, language, attention and visuo-constructive skills. The current

data concerning the domain of memory is mostly concentrated on the paradigm of short-term memory and working memory, showing specific impairments in visual-spatial and verbal working memory in all forms of CP with spastic CP showing higher visual-spatial impairments when compared to dyskinetic CP. However, in spastic CP, no association was found with visual-spatial memory and gross motor impairment (Fluss & Lidzba, 2020). A systematic review conducted by Stadskleiv (2020) highlighted that children with unilateral spastic CP showed levels of IQ greater than 70 with one-third of them having specific deficits in visual-spatial memory. Furthermore, children diagnosed with spastic diplegia had an IQ score above 70 while being associated with impaired visual-spatial abilities (Stadskleiv, 2020).

Biological Basis of Visuospatial Working Memory Impairment in CP

The impairments in visuospatial working memory in CP are directly connected to the size of the lesion in the right hemisphere. However, in the case of unilateral CP, the visual-spatial impairments can be seen as a result of lesions in the left hemisphere (Fluss & Lidzba, 2020). Impairments in the frontostriatal and frontoparietal network were also associated with impaired cognitive ability (Ballester-Plané et al., 2017)

Topographical Working Memory in CP

A closely related concept to visuospatial working memory is topographical working memory, another aspect that is closely associated with the coordination and planning of movement. Movement requires a vast understanding of the spatial location of the environment and of the objects in it, hence one's understanding of the concept of space is inevitably associated with the movements they make through that space. Thus, spatial cognition involves the aspects of spatial coding, spatial awareness, spatial memory and spatial planning and within the paradigm of spatial cognition is the domain of topographical working memory that aids the process of encoding and maintenance of cues that are critical for navigational purposes (Bartonek et al., 2020). Topographical memory is a complex system that makes use of data from visuospatial memory, proprioceptive and vestibular senses as well as information from the continuously changing point of view as the person walks through the environment (Palmiero & Piccardi, 2017). Findings from a recent study showed significant impairment in topographical memory for children diagnosed with CP when compared to healthy controls, which was suggested to be an outcome of damage to the brain structures associated with spatial learning. The study also explored visuospatial memory in relation to spatial and topographical memory and found that children with CP had significant impairments in visuospatial memory, which was tested on the basis of the Corsi Block-tapping test and the Walking Corsi Test (Bartonek et al., 2020). A recent study that made use of virtual reality (VR) technology to assess the navigational skills in children with CP noted impaired performance for the same when compared to healthy controls (Biffi et al., 2020).

Difficulties in Mathematical Reasoning in CP

Visuospatial working memory can be seen as an early predictor of mathematical abilities in young children. A study conducted by Fanari et al. (2019) assessed the interaction between mathematical abilities and visuospatial working memory in young children and highlighted the early influence of visuospatial working memory on mathematical skill and ability. Children achieve numerical sense even before they start formal education by developing a mental number line and once they attain verbal communication, they form what is known as a 'placeholder structure', thus attaining a fixed idea of the concept of numerics (Allen et al., 2019). Working memory and a sense of numbers remain two important cognitive

components that will aid mathematical prowess and children with difficulties in mathematical abilities reported a decreased prowess in number sense and employment of working memory (Nelwan et al., 2021). Children diagnosed with CP with deficits in their visuospatial working memory were found to have considerable deficits in mathematical reasoning. Additionally, the impaired visual memory of children with CP was also connected to their poor mathematical abilities (Tajadini et al., 2019). Findings from the study conducted by Critten et al. (2018) further analysed the effect of visuospatial abilities and mathematic skill and found that children with CP performed significantly worse than healthy controls in the areas of visuospatial and mathematical skill. Additionally, they also found that they were significantly impaired in their visual perception, visual reasoning, mental rotation abilities, which inevitably led to impairments in visual short-term memory as well. Thus, these findings pave the way to help mitigate the mathematical impairments by improving visuospatial abilities.

Interventions to Improve Visuospatial Abilities in CP

Rehabilitative programs that aim at training the working memory of children with CP have seen significant improvement in their visuospatial abilities, executive functioning as well as phonological processing (Di Lieto et al., 2021). Immense attention has been given to physical therapy for children diagnosed with CP with some studies showing the intervention as effective in improving gross motor function (Ryan et al., 2017). Extensive research is required in this field to understand whether the improvement in gross motor function would lead to improvement in visuospatial memory.

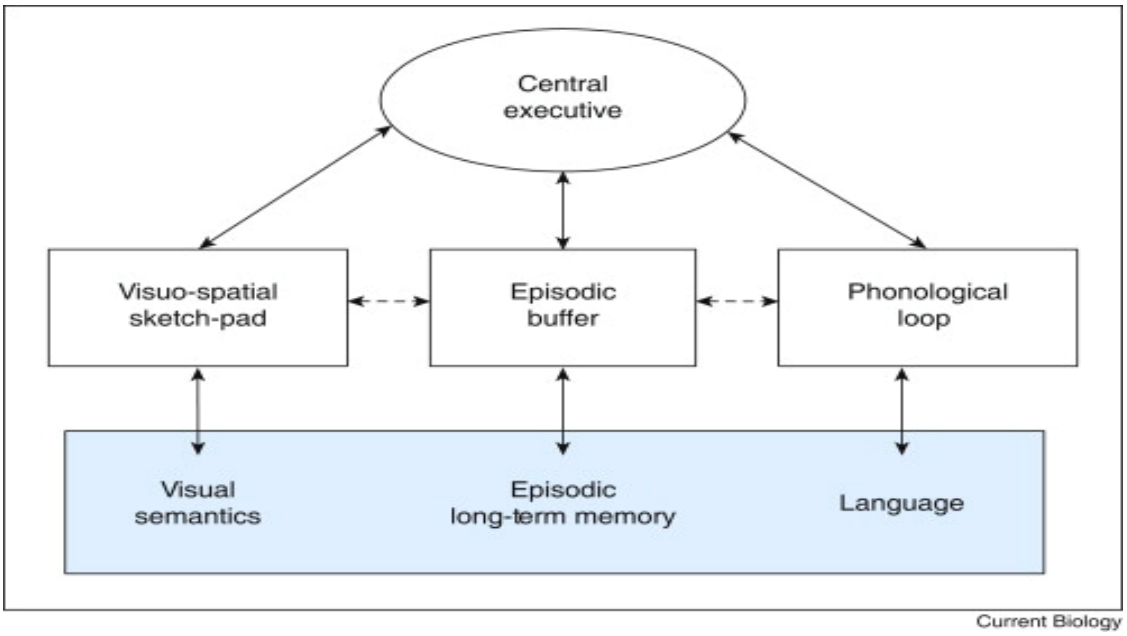
DISCUSSION

Coming back to concepts presented by the embodied cognition paradigm, one can see the intricate connection of the physical senses with the world of cognition. The main objective of this review was to consolidate the findings of multiple relevant papers revolving around the visuospatial deficits associated with CP and other deficits that arise due to impairments in the visuospatial memory system.

The working memory model proposed by Baddeley's challenged the traditional dichotomous view of memory that was then divided into short-term memory and long-term memory. According to Baddeley, 'working memory' is comprised of various components that aid the manipulation and retention of information in order to attain higher cognitive functioning. The components, as proposed by Baddeley, were the phonological loop which can be understood as verbal working memory, the visuospatial sketchpad which can be seen as visuospatial memory, the central executive, which is closely related to the attentional system and the episodic buffer, which can be seen as a temporary storage system as aids in the integration of information from the other components and modalities (Chai et al., 2018). Figure 2 shows an illustration of Baddeley's model.

Relating the findings of this review to this model, one can see that the clear and evident deficits in mathematical ability in children with CP show the important role of the visuospatial memory system in solving basic arithmetic equations such as subtraction and addition (Nelwan et al., 2021). The impaired navigational skills in children suffering from CP can be attributed to their inability to form appropriate navigational strategies (Biffi et al., 2020). Connecting this to Baddeley's working memory model this could be a reflection of an impaired central executive, which can be impaired due to the insufficient data that keeps coming from the impaired visuospatial sketchpad.

Figure 2



Baddeley's Working Memory Model

Note. Shows the working memory model as given by Baddeley. Reproduced from "Working Memory" by Alan Baddeley, 2010, Current Biology. Copyright © 2010 Elsevier Ltd

CONCLUSION

The objective of the paper was to summarise the recent updates on visuospatial memory in children diagnosed with CP. The findings of this review make it clear that children with CP have significant impairments in their visuospatial memory due to which they showcase poor navigational and mathematical skills. Visuospatial memory, thus, forms an important component of complex arithmetic abilities as well as an integral part of what is construed as minute movements. However, data with respect to rehabilitation for the improvement of visuospatial memory in CP was scarce. Future research should focus on rehabilitative efforts to improve the visuospatial abilities in children with CP and should do so via the embodied cognition paradigm.

REFERENCES

Allen, K., Higgins, S., & Adams, J. (2019). The Relationship between Visuospatial Working Memory and Mathematical Performance in School-Aged Children: a Systematic Review. *Educational Psychology Review*, *31*(3), 509–531. https://doi.org/10.1007/s10648-019-09470-8

Ballester-Plané, J., Schmidt, R., Laporta-Hoyos, O., Junqué, C., Vázquez, É., Delgado, I., Zubiaurre-Elorza, L., Macaya, A., Póo, P., Toro, E., de Reus, M. A., van den Heuvel, M. P., & Pueyo, R. (2017). Whole-brain structural connectivity in dyskinetic cerebral palsy and its association with motor and cognitive function. *Human Brain Mapping*, *38*(9), 4594–4612. https://doi.org/10.1002/hbm.23686

Bartonek, Å., Piccardi, L., & Guariglia, C. (2020). Topographical Working Memory in Children with Cerebral Palsy. *Journal of Motor Behavior*, *53*(2), 200–208. https://doi.org/10.1080/00222895.2020.1748861

Biffi, E., Gagliardi, C., Maghini, C., Genova, C., Panzeri, D., Redaelli, D. F., & Turconi, A. C. (2020). Learning My Way: A Pilot Study of Navigation Skills in Cerebral Palsy in

Immersive Virtual Reality. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.591296

Buchsbaum, B. R., & D'Esposito, M. (2008). A framework. *Learning and Memory: A Comprehensive Reference*, 32–61. https://doi.org/10.1016/b978-0-12-375070-9.00002-4

Cardona, J. F. (2017). Embodied Cognition: A Challenging Road for Clinical Neuropsychology. *Frontiers in Aging Neuroscience*, *9*. https://doi.org/10.3389/fnagi.2017.00388

Chai, W. J., Abd Hamid, A. I., & Abdullah, J. M. (2018). Working Memory from the Psychological and Neurosciences Perspectives: A Review. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.00401

Di Lieto, M. C., Pecini, C., Brovedani, P., Sgandurra, G., Dell'Omo, M., Chilosi, A. M., Guzzetta, A., Perazza, S., Sicola, E., & Cioni, G. (2021). Adaptive Working Memory Training Can Improve Executive Functioning and Visuo-Spatial Skills in Children with Pre-term Spastic Diplegia. *Frontiers in Neurology*, *11*. https://doi.org/10.3389/fneur.2020.601148

Fanari, R., Meloni, C., & Massidda, D. (2019). Visual and Spatial Working Memory Abilities Predict Early Math Skills: A Longitudinal Study. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02460

Fluss, J., & Lidzba, K. (2020). Cognitive and academic profiles in children with cerebral palsy: A narrative review. *Annals of Physical and Rehabilitation Medicine*, *63*(5), 447–456. https://doi.org/10.1016/j.rehab.2020.01.005

Nelwan, M., Friso-van den Bos, I., Vissers, C., & Kroesbergen, E. (2021). The relation between working memory, number sense, and mathematics throughout primary education in children with and without mathematical difficulties. *Child Neuropsychology*, *28*(2), 143–170. https://doi.org/10.1080/09297049.2021.1959905

Palmiero, M., & Piccardi, L. (2017). The Role of Emotional Landmarks on Topographical Memory. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00763

Patel, D. R., Neelakantan, M., Pandher, K., & Merrick, J. (2020). Cerebral palsy in children: a clinical overview. *Translational Pediatrics*, *9*(S1), S125–S135. https://doi.org/10.21037/tp.2020.01.01

Ryan, J. M., Cassidy, E. E., Noorduyn, S. G., & O'Connell, N. E. (2017). Exercise interventions for cerebral palsy. *Cochrane Database of Systematic Reviews*, *2017*(6). https://doi.org/10.1002/14651858.cd011660.pub2

Stadskleiv, K. (2020). Cognitive functioning in children with cerebral palsy. *Developmental Medicine & Child Neurology*, *62*(3), 283–289. https://doi.org/10.1111/dmcn.14463

Tajadini, S., Hamid, Farpour, R., Farpour, S., & Farpour, H. (2019). The Relationship between Working Memory and Acquisition of Mathematical Strategies in Children with Cerebral Palsy: A Review of Literature. *JRSR*, *6*, 103–108. https://doi.org/10.30476/jrsr.2019.81223

Acknowledgement

The author(s) appreciates all those who participated in the study and helped to facilitate the research process.

Conflict of Interest

The author(s) declared no conflict of interest.

How to cite this article: Eapen, N.A. (2023). Current Updates on Visuospatial Working Memory in Cerebral Palsy: A Mini Narrative Review. *International Journal of Indian Psychology, 11(3),* 1378-1383. DIP:18.01.132.20231103, DOI:10.25215/1103.132