# Visuospatial Working Memory Capacity in Parents of Children with Neurodevelopmental Disorders

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**Abstract**

*Working Memory Capacity (WMC) is the ability to actively maintain a goal in the presence of interference due to habit or secondary task processing. WMC is often reported in individual differences of typical participants when delineating the working memory (WM) system as a whole. But few have studied WMC in healthy irst-degree relatives of a clinical sample. This study attempts to examine visuospatial WMC in healthy parents of children with neurodevelopmental disorders (NDD). NDD is deined in a unitary conceptual manner. A one-group design for a purposive sample of 54 parents (42 mothers and 12 fathers) were screened for psychiatric morbidity and cognitive impairments in this study. Visuospatial N-back and Spatial span tasks were used for our assessment of WMC. Results suggested a signiicant difference between the two task performances. The nature of the tasks and the sample characteristics, along with its implications on parenting, were discussed in brief.*

***Keywords:*** *Working Memory Capacity, Neurodevelopmental disorders, Parents, Visuospatial tasks*

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## Introduction

Working memory (WM) is defined as a structure and system to temporarily hold and manipulate information, against any other distracting process or interference (Jaeggi, Buschkuehl, Perrig & Meier, 2010). WM tasks are quite powerful and informative tools in the hands of a cognitive psychologist. This is especially true of the tasks that are quick and easy to administer (Jarrold & Towse, 2006). WMC and WM constructs have been used in varied studies with different meanings (Wilhelm, Hildebrandt & Oberauer, 2013).

The tripartite model of working memory suggested in 1974 (Baddeley & Hitch, 1994), reported a master coordinating unit called as the central executive. The most important functioning of this component is the ability to sustain information in WM and protect it from disturbance or hindrance. This ability is called working memory capacity (WMC). This active goal maintenance in spite of hindrance due to habit is the crux of WMC (Kane & Engle, 2002). In other words, it is defined as the effectiveness of a WM system in an individual (Harisson, Shipstead & Engle, 2015).

The WMC concept is connected and better explained with the tasks used for its measurement (Barrett & Tugade, 2004). Individuals differ in WMC and those differences can be assessed using specifically designed tasks to tap WMC called the complex span tasks (Hofmann, Gschwendner, Friese, Wiers & Schmitt, 2008). These tasks are span tests of memory nested in another secondary task requiring processing. That is, on one hand, the participant is required to hold information for recall (digits, words, spatial location, etc.) and in between they are required to perform another task requiring attention such as reading, solving arithmetic problems, mental rotation of images, counting, etc. These serve as hindrances for adequately performing the first memory task given. The accuracy of performance is then computed as the maximum number of digits/words/spatial location/images (depending on the task) recalled without error (Barrett & Tugade, 2004).

Classic complex span tasks have been reading (Daneman & Carpenter, 1980), operation (Turner & Engle, 1989), and counting (Case, Kurland & Goldberg, 1982), and N-back (Conway, Cowan, Bunting, Therriault & Minkoff, 2002). WMC experiments have been conducted in healthy

participants to decipher the psychometric nature of these tasks (Jaeggi, Buschkuehl, Perrig & Meier, 2010). These tasks have been studied especially with fluid intelligence (Kane & Engle, 2002). Fluid intelligence is largely connected to the concept of WMC. It is noted as the ability to problem-solve and adapt to novel issues/situations respectively along with reasoning appropriately (Conway, Cowan, Bunting, Therriault & Minkoff, 2002).

While many studies report WM functioning, WMC studies in clinical populations have been sparse. Nevertheless, studies have applied WMC in real-world conditions and not limited to just being a cognitive laboratory task (Barrett & Tugade, 2004). WMC has been related to giving optimal problem solving especially creatively (Wiley & Jarosz, 2015), reasoning (Süß, Oberauer, Wittmann, Wilhelm & Schulze, 2002), adapting strategies to success or failures in situations (Schunn & Reder, 2001), emotional processing (Garrison & Schmeichel, 2018) amongst many others.

**The present study:**

This study intended to explore WMC in healthy relatives of a clinical population. We would like to examine the difference between two measures of visuospatial capacity of WMC in the healthy parents of children with NDD. NDD has been defined as a unitary concept. That is it is defined in the context of "functioning" and lumped together as a group.

Question on why the parents of children with NDD for the assessment of WMC needs to be raised. Answers to this cannot be given merely with genetic predispositions but also due to its importance in everyday parenting. Executive processes of a parent are of importance as it impacts parental behaviors and their direct abilities to support and rear a child (Wilson & Gross, 2018). Hence, increased WMC might be necessary and expended more in the case of parents with children with disabilities, given the many associations of WMC to higher-order cognitive tasks.

Two tasks used to assess WMC in this study are the N-back and spatial span tasks. The N-back tasks are the most frequently used (Kane & Engle, 2002) and are a favourite in most neuroimaging studies (Lezak, Howieson, Bigler & Tranel, 2012, pp 417). It was first presented by Krishner in 1958. This task has the face validity of WM (Gajewski, Hanisch, Falkenstein, Thones & Wascher, 2018). Here, the participant is expected to indicate which of the presented stimulus matches the stimulus from 'N' steps prior in the series. This 'N' is the load factor that can be adjusted giving many variations to this task. Thus, just like a memory-based board game of "concentration" where the player has to recall the exact location or position of the stimulus, herein, during each turn, the participant has to remember 1-N (one turn back) or 2-N (two turns back) and so on. This task, therefore, has a processing demand in addition to the temporary storage requirement (Conway et al., 2005). Many studies have supported this task's ability in the measurement of WMC (Gajewski, Hanisch, Falkenstein, Thones & Wascher, 2018). Nevertheless, further research on individual differences of this task with other cognitive functions are reported as well (Jarrold & Towse, 2006).

The Spatial span task is noted as a non-verbal counterpart of the often-used WM measure -- digit span task (Berch, Krikorian & Huha, 1998). First introduced after hemispheric specialization studies appeared (Milner, 1971) followed by block tapping task by Corsi, it has seen many variants (Woods, Wyma, Herron & Yund, 2015). The forward span is regarded to tap attentional capacity while the backward span taps the WMC. Limited capacity is one of the mainstays of all span tasks tapping attention, short term memory (STM), and WM (Lezak, Howieson, Bigler & Tranel, 2012). Studies on visuospatial tasks of WMC have been sparse (Lecerf & Roulin, 2009).

**AIMS AND OBJECTIVES:**

The aim is to examine the visuospatial WMC of parents of children with NDD. Therefore a question of whether there are significant differences in the performance, between the visual N-back and Spatial span tasks, in the parents of children with NDD, was raised.

**Operational Definitions**

1. WMC: The number of items that are recalled in the visuospatial N-back and Spatial span task.
2. NDD: It is any impairment characterized in delay by three or more months or disturbance in the acquisition of skills in at least two domains such as motor, sensory, speech, and language, social, cognition, play and academics as measured on valid tools, during the developmental period. It was measured using Activity Checklist Preschool Children -- Developmental Disabilities (ACPC-DD) (Venkatesan, 2004).

**METHOD**

A cross-sectional one-group design was employed. The sample was recruited with written consent and the data included in the manuscript is compliant with all the ethical rules as necessary for biobehavioral research (Venkatesan, 2009a). The period of collection of the data was from September 2019 to February 2020.

**Sample:**

A non-probability purposive technique was used to collect the sample. The sample consisted of parents of children with NDD. A final total sample of 54 parents was selected (Figure 1). The parent's selection was dependent on the assessment of their children. The children were from the age group of 6 to 8 years, above 70 in their level of intellectual functioning and with developmental delay of more than 3 months in at least two domains of development. The parents were in the age group of 25 to 48 years with both mothers (N= 42; Mean Age: 35.17 years; SD: 4.77; 77.8%) and fathers (N=12; Mean Age: 37.50 years; SD: 4.23; 22.2%) included. All the parents were of Indian origin, right-handed with no visual-hearing impairment. The criteria for the inclusion of the sample are given in Table 1. Though the efforts were toward including both the parents, only a few families consented and so the final target group consisted of few fathers in comparison to mothers.

**Figure 1**

***Flow diagram on the recruitment of the sample***

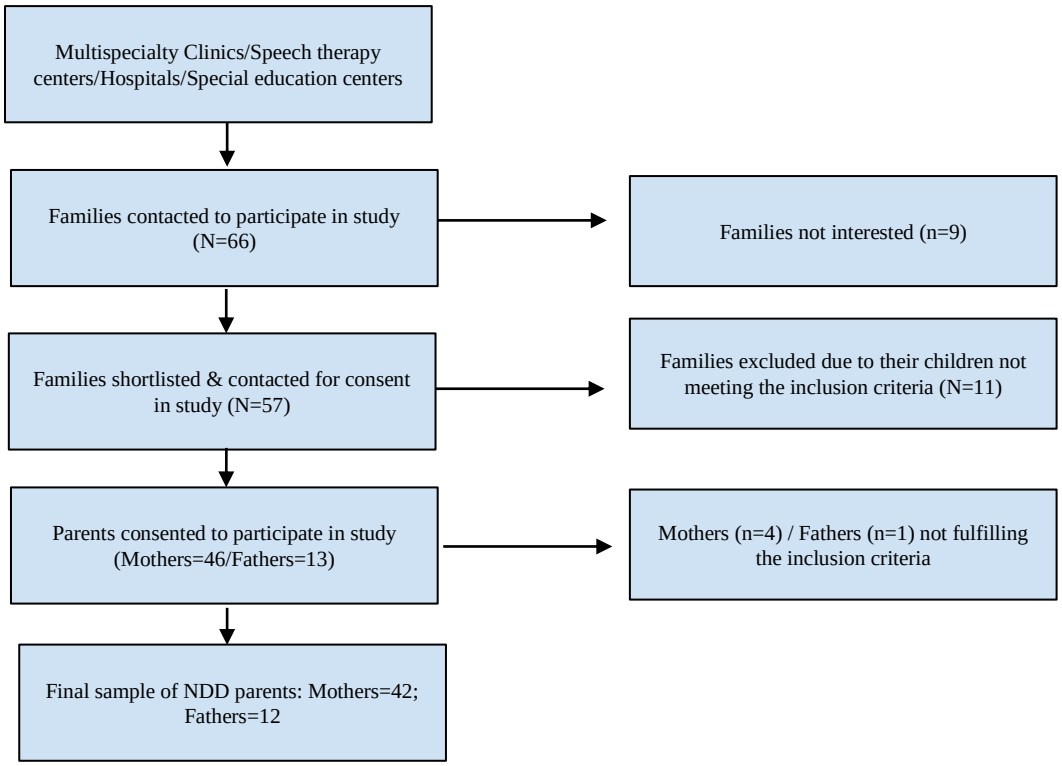

**Table 1 Inclusion criteria for the recruitment of the sample**

| Sr. No | Parents |
|---|---|
| 1 | Probands staying with them |
| 2 | No medical/mental illness |
| 3 | Of Indian origin, speaking Tamil, English, kannada, or hindi |
| 4 | Absence of any major life event/chronic illness/ on psychotropic medication since the past 6 months |
| 5 | Formal education of graduation or above |
| 6 | Belonging to upper socioeconomic status |
| 7 | Biological parents/parent only |
| 8 | Family size of 4or 5, Including themselves |

**Tools & Procedure:**

A computer coded data intake and record sheet were used for every parent to facilitate administration of the tasks and for ease of scoring. Each parent was assessed in one session of 45 to 50 mins, and the investigator was not blind to the developmental status of the child.

The tools administered may be provided in two inter-related headings which have the background tools and the stimuli tasks consisting of n-back and spatial span tasks:

1. Background tools: The sample was assessed for socioeconomic status (SES) using the National Institute of Mental Health (NIMH-SES) scale (Venkatesan, 2009b). A parent/s score of 16 and above are considered for this study. The psychiatric morbidity was assessed using the self-report questionnaire (SRQ), standardized and validated on the Indian population (Kumbhar, Dhumale & Kumbhar, 2012). Negative answers of 10 and above indicated nil psychiatric morbidity. An assessment of general cognitive impairments was conducted using the Hindi Mental Status Examination (HMSE) (Ganguli et al., 1995). Here a score of 17 and above was indicative of nil cognitive impairments.
2. Stimuli tasks: The n-back tasks (Smith & Jonides, 1999) incorporated here is taken from NIMHANS Neuropsychological Battery (Rao, Subbakrishna & Gopukumar, 2004) and consisted of the visuospatial component. This task had 36 cards of 3.5 by 5.5 cms each. Each card had the same dimension black dot randomly placed. The participant in the 1-back level taps if he/she succeeds in finding the dot on the same place in cards presented consecutively. While in a 2-back level, he has to identify the cards with the dot in the same place alternatively, after one randomly intervening card. The number of accurate responses and errors committed is noted for all the levels of n-back tasks.

The Spatial span task (Weschler, 1997) has a baseboard on which 10 cubes of 3 cm are fixed on to it. The investigator taps forward and backward sequences using a cube. On successful completion of each trial, a score is given, with the length of each trial increasing. Each length has 2 trials, out of which at least one trial should be successfully completed to proceed to the next. The test ceases when in any sequence length, both the trials are not successful.

**RESULTS**

All analysis proper was performed using the Statistical Package for Social Sciences (SPSS version 23.0) (IBM Corp, 2015). Shapiro Wilk's test was used to screen for normality of the data. The obtained results suggested the use of a non-parametric (skewed distribution) test to infer appropriately. The findings could be outlined in two distinct but interrelated labels:

(1) Sample demographic characteristics

(2) Distribution of scores on stimuli tasks

(1) Sample demographic characteristics:

A perusal of demographic characteristics of the sample (Table 2) shows the parents to be at an average of 36 years and between the ages of 25 to 48 years.

**Table 2**

**Demographic details of the sample (N=54)**

| Sample characteristics | Parents (N=95) | | |
|---|---|---|---|
| | Mean | SD | Range |
| Age | 35.63 | 4.66 | 25-58 |
| % of parents below 30 years | 14.82 | | |
| % parents from 30 to 40 years | 68.52 | | |
| % parents from 40 to 50 years | 16-.67 | | |
| SES Score | 19.65 | 1.40 | 19-20 |
| HMSE Score | 29.57 | 1.11 | 27-31 |
| SRO Score | 18.72 | 0.98 | 17-20 |

It should be noted that the percentage of parents appeared more in the 30 to 40 years age group. The sample was without any cognitive impairments and psychiatric morbidity, as assessed at the start of the study ($p>0.05$).

(2) Distribution of scores on stimuli tasks:

Table 3 depicts a significant difference in visuospati al performance in the parents.

| Stilmulti tasks | Parents (n=54) | | | Wilcoxon-Sign Rank test | |
|---|---|---|---|---|---|
| | Median | Mean rank | IQR | Z | P |
| Visuo spatial N-back acacuracy scores | 10.00 | 19.08 | 3.00 | 3.296 | 0.001* |
| Spatial spam accuracy scores | 9.00 | 24.42 | 2.00 | | |

A Wilcoxon-Sign Rank test indicated that the spatial span task (Mean Rank = 24.42) was performed better by the parents than the visual n-back task (Mean Rank =19.08), $Z=3.296$, $p<0.01$. The visual N-back accuracy score has been computed as a composite of visual 1 and 2 tasks' accuracy scores. The Spatial span accuracy score has been computed as a composite of the forward and backward sequence accuracy scores. This inclusion of the composite is noted to increase the reliability of the measure (Wilde, Strauss & Tulsky, 2004). This analysis supports our research question positively.

## DISCUSSION

We examined if these tasks --- N-back and Spatial span --- brought a significant variance in the specific population of parents of children with NDD when used as measures of WMC. There appeared to be a significant difference in the performance of the two measures in the parents ($p < 0.01$). A look into the neural substrates of the N-back task using such non-verbal stimuli of location appeared to enhance the activity of dorsal cingulate, lateral premotor, right dorsolateral prefrontal, right medial posterior parietal, right medial premotor and inferior parietal lobe (Owen, McMillan, Laird & Bullmore, 2005). The visual WM task, such as the spatial span, activates the distributed network of prefrontal and inferior and medial temporal cortex (Ranganath, 2006).

A study concordant to our findings assessed two groups of healthy older adults. One group with susceptibility for Alzheimer's Disease (AD) due to genetic risk (family history in first-degree relatives), while the other with no such risk of AD (no family history). Both were assessed on the WMC operation task and digit forward task. The genetic risk group performed inadequately on the WMC task, while no significant group differences were seen for the forward digit span task assessing verbal WM (Rosen, Bergeson, Putnam, Harwell & Sunderland, 2002).

Our findings could likewise be explained with our current understanding of WMC. Firstly as a WMC measure, the N-back task is regarded as complex measures whose processes are not entirely understood. They involve multiple processes independent of the stimulus and material (Jaeggi, Buschkuehl, Perrig & Meier, 2010). They have different processes between familiarity and recollection. Successful performance in these tasks requires an ability to establish connections and effectively manage them between temporal context and the contents towards completion (Oberauer, 2005). Thus more executive processes could be necessary for the successful execution of the N-back task. On the contrary, the spatial span is a simpler task that requires active temporary storage and recalls for

the forward sequence. While the backward sequence requires active recall along with manipulation. Conway et al. (2005) noted that WMC was reflective of the domain of executive attention, while short term memory capacity (STMC) tasks were reflective of the domain of temporary storage and recall. Conway and his colleagues (2002) explained that no task could be considered a "pure" test of measuring solely STMC or WMC, as each would tap a capacity to a greater/smaller extent. When a task allows the participant to process effortfully rather than automatically, then more of WMC is tapped than STMC and vice versa. The Spatial span task could be regarded as predominantly a recall task of WMC while n-back on recognition of location measure of WMC.

Thus, the variance in the parents' was because the Spatial span task had more straightforward task demands in comparison to the N-back task. Further, the forward and backward sequences are the same in the spatial span task, thereby promoting implicit learning (Milner, 1971; Kessels, van der Berg, Ruis & Brands, 2008). Secondly, a major percent of our sample was from the middle age group of 30 to 40 years, at an average of 36 years. WMC is known to decline gradually in comparison to other cognitive functions and STMC tasks as age progresses (Gajewski, Hanisch, Falkenstein, Thones & Wascher, 2018). Hence N-back task performance declined while the spatial span task performance was performed better. Thirdly, our sample has not been assessed on its intellectual functioning. The intellectual ability has been associated with the performance on the n-back task (Conway, Kane & Engle, 2002). Likewise, processing speed (Salthouse, 1992), distraction inhibition (Lecerf & Roulin, 2009) has been correlated to WMC performance.

The genetic risk component of this finding could not be ignored. The parents could be susceptible to a poorer WMC, given evidence of compromised performance in WM tasks in the probands with NDD (Eugland, Decker, Allen and Roberts (2014).

WMC is the ability of an individual's WM, which in turn is involved with our competence of cognitive behaviors such as our reasoning ability, comprehensibility, and ability to problem-solve (Engle, 2002). Application of these competencies to parenting might indicate that in the face of interference and distraction, parents of children with NDD have fewer resources to handle a cognitive function. This could have a direct bearing on the parental coping mechanism and child-rearing, more in a family of a child with NDD. Interventional techniques and therapy targeting WMC could be incorporated to the parents of children with NDD. WMC training may help the parents cope better in the tasks pertaining to the management of children with NDD.

Larger sample sizes and better span tasks may bring generality to the results obtained. After all, the development of a child with NDD and his/her adaptation to family, pose many challenges not only to the parents but to researchers, policymakers, and practitioners as well (Hanser-Cram et al., 2001).

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