WORKING MEMORY IN CHILDREN WITH SPEECH SOUND DISORDER

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MANASAGANGOTHRI, MYSURU - 570 006

April, 2018

CERTIFICATE

This is to certify that this dissertation entitled **"Working Memory in Children with Speech Sound Disorder"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student bearing the Registration Number: 16SLP014. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that this dissertation entitled **"Working Memory in Children with Speech Sound Disorder"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree

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DECLARATION

This is to certify that this dissertation entitled **"Working Memory in Children with Speech Sound Disorder"** is the result of my own study under the guidance of Dr.Priya.M.B., Lecturer in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Registration No. 16SLP014**

April, 2018

I DEDICATE

THIS PIECE OF WORK OF MINE

TO MY MOM, DAD

&

TO MY FAMILY MEMBERS

SPECIALLY TO ADI

&

ALL CHILDREN

WHO PARTICIPATED IN THIS STUDY

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1. INTRODUCTION

Speech sound disorders (SSD) are characterized by delay in the accurate production of age-appropriate speech sounds (Lewis et al., 2015). During the development of speech sound system, children depend on emerging skills in multiple domains such as perceptual, cognitive, linguistic and motoric for accurate speech production. Investigators have reported that children with speech sound disorders do have cognitive linguistic processing difficulties i.e. phonological organization difficulties (Munson, Baylis, Krause, & Yim, 2010). Early school going children are at risk of academic, social and occupational difficulties due to unknown cause of speech sound disorder (McCormack, McLeod, McAllister & Harrison, 2009).

Children with SSD are reported to have difficulties in segmenting new words into phoneme units in order to make correct associations between the sounds and the motor patterns necessary to articulate the new words (Munson, Edwards, & Beckman, 2005). This continues throughout the period of language development leading to poorly specified phonological representations in these children (Tkach, et al., 2011). Catts (1986) hypothesized that phonological representations are developed partially in children with SSD. These partially developed phonological representations lead to difficulty in perceiving or storing individual phonemes and phoneme sequences which in turn lead to difficulty in perceiving subsequent letter-sound mappings (Serniclaes, Van Heghe, Mousty, Carre, & Sprenger-Charolles, 2004). As a result, there are deficiencies in the storage of information pertaining to speech sounds in the long term memory or in the way they are represented within working memory.

The term, “working memory” refers to the capacity to store and manipulate information for periods of time. It refers to the capacity to store information temporarily when engaging in cognitively demanding activities (Baddeley, 1986). It provides a mental workspace that is used in many important activities of everyday life. Working memory is a pure measure of a child's learning potential and is not strongly influenced by the child's prior experiences such as preschool education or their socio economic background. The structure of working memory is based on the widely used model developed by Baddeley & Hitch (1974) and is supported by evidences from studies of children (Alloway, Gathercole & Pickering, 2006; Alloway, et al., 2005). Compared to short-term memory, working memory plays a more influential role in children's academic performance (Baddeley, 1986). Working memory has the capacity to encode, store and retrieve the processed data for any task related to cognition (Baddeley, 1986) and also it is directly related for reasoning and attainment of academic skills (Bayliss, Jarrold, Baddeley, & Leigh, 2005).

Working memory can be conceived as a system of inter-linked memory components that are located in different parts of the brain. Few of these components are specialized to store material of particular kinds although they are part of the larger working memory system. For example, visual-spatial short term memory can hold images, pictures and information about locations. In order to recall the physical characteristics and location of objects in a picture when it is no longer in view, we need to rely on visuo-spatial short-term memory. This part of working memory is located in the right hemisphere and is a completely different system from verbal short-term memory.

The component that controls attention and is involved in higher-level mental processes is the central executive, which is responsible for all mental activities that involve coordinating both storage and effortful mental processing, such as mental arithmetic and many classroom activities. The central executive is located in the front regions of both the left and right hemispheres of the brain. Children who have poor central executive capacity will have more difficulties in working memory activities that have demands on central executive irrespective of the memory involved.

Working memory capacity steadily increases across the childhood years. The youngest age at which working memory can reliably be tested is about four years (Alloway & Temple, 2007). The growth functions are very similar for all three aspects of working memory, with marked increase in working memory capacity between 5 and 11 years of age, followed by small but significant increases up to 15 years, when adult levels are reached.

Children with poor working memory tend to perform poorly on all working memory tests, irrespective of whether they involve verbal or visuo-spatial material as they are unable to hold in mind sufficient information to allow them to complete the task. This suggests that the central executive is involved in processing and manipulating any kind of material and contributes to both verbal and visuo-spatial working memory tasks. Children who have poor central executive function would be expected to have deficits in both types of working memory assessment.

Working memory plays a major role in the development of phonological memory consisting of detailed information about the sound strings necessary for the formation of new representations in the long term memory (LTM). Working memory is also considered to be important during the process of speech learning in young children (Adams & Gathtercole, 1995; Munson et al., 2005; Raine, Hulme, Chadderton & Bailey, 1991; Speidal, 1993).

For the past few decades a lot of research has been done on cognitive linguistic processes especially with respect to memory processes in detail, which plays an important role in language acquisition and its processing. More attention is given to the working memory in children, an important cognitive process in the language learning and processing in both typically developing and atypically developing children (Gatherole & Baddley, 1990; Montgomery, 1995, 2000, 2002). Many academic tasks involve multiple steps with intermediate solutions that are to be remembered for short period of time to complete the task. Thus, research on working memory abilities both in typical children and children with communication disorders are valuable to understand their learning potential.

1.1 Need for the study

Working memory is involved in the selection, initiation and determination of information processing functions such as encoding, storing and retrieving data. Working memory capacity has been found to be related to various cognitive tasks such as verbal reasoning skills, learning abilities, math skills and processing linguistic features (Baddeley, 2003; Engle, 2005; Conway et al., 2005). WM plays a significant role in one's ability to perform crucial activities, such as reading, word learning, acquiring language, mathematical processing and reasoning (Alloway et al., 2005). For speech production, it is necessary to accurately and consistently store sounds and readily and appropriately retrieve them (Oakhill & Kyle, 2000). According to Adams and Gathercole (1995), preschoolers have high and low working memory, based on their performance on non-word repetition and digit span recall tasks. Research evidences support the plausible role of working memory deficit in children with SSD. Given the fact that children with SSD are at an increased risk for academic difficulties and working memory plays a crucial role in academic learning, assessment of working memory in children with SSD assumes importance. Speidel (1993) found poor performance on non-word repetition, which is a common metric for working memory, in a child with SSD compared to his typically developing twin. Children with SSD are also reported to have weak executive functioning (Crosbie, Holm, & Dodd, 2009). In a recent study by Farquharson, Hogan and Bernthal (2017), school age children in the age range of 7.5 to 11.8 years with persistent SSD were reported to have deficits in working memory. Similarly Afshar, Ghorbani, Rashedi, Jalilev, and Kamali (2017) reported weak working memory skills in a sample of 4 to 6 year old Persian children with SSD compared to typical children. However, there are not many studies examining various components of working memory in children with SSD, particularly in the Indian scenario. Hence, the present study is undertaken to explore working memory abilities in young native Kannada speaking children with SSD in comparison with typically developing children.

1.2 Aim

The study aimed to primarily investigate working memory abilities in Kannada speaking typically developing children (TDC) and children diagnosed with Speech Sound Disorder (SSD) in the age range of 4-7 years using three tasks - digit span forward recall, digit span backward recall and digit running span. The secondary aim of the study was to compare the performance across the subgroups of age.

1.3 Objectives of the study

The specific objectives of the study were:

1. To compare the scores of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span
2. To study the effect of age on the scores obtained by TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span
3. To compare the scores of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span across subgroups of age

1.4 Hypotheses

The study assumed the following null hypothesis:

1. There is no significant difference between TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span tasks
2. There is no significant effect of age on the scores obtained by TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span tasks

3. There is no significant difference across subgroups of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span tasks

2. REVIEW OF LITERATURE

Speech sound disorder (SSD) is a term referring to any difficulty with perception, motor production, and/or the phonological representation of speech sounds and speech segments (phonotactic rules that govern syllable shape, structure, and stress, as well as prosody) that impact on speech intelligibility. The major causes of SSD are motor-based disorders (apraxia and dysarthria), structurally based disorders (e.g., cleft palate and other craniofacial anomalies), syndromic disorders (e.g., Down syndrome and metabolic disorders, such as galactosemia), and sensory disorders (e.g., hearing impairment).

When the form of speech sounds or the speech sounds within the language are affected by SSD, they are referred to as articulation disorders and are generally associated with structural (e.g., cleft palate) and motor-based difficulties (e.g., apraxia). On the other hand, when the functioning of speech sounds (phonemes) change within a language owing to SSD, it is referred to as phonological disorders. Phonological disorders occur due to impairments in the phonological representation of speech sounds and speech segments within the context of spoken language. The phonological representations are gradually developed by continuous refinement both in terms of perception and manipulation of phonemes.

The commonly occurring speech errors in SSD are usually rule based patterns like deletion of final consonants, simplification or reduction of consonant clusters, or substitutions like stops in place of fricatives and affricates. Apart from this, idiosyncratic error patterns like substitution of several sounds with a specifically preferred sound may also exist. For example, use of sound /d/ in “door” for different words like shore, sore, chore, and tore (Grunwell, 1987).

Another point to remember is that not all substitutions and omissions can be referred to as speech errors. The production of a particular sound may vary based on the language and its rule reflecting the regional and social background of an individual otherwise referred to as the dialect or the dialectal variations of a language.

2.1 Incidence and Prevalence of Speech Sound Disorder

Law, Boyle, Harris, Harkness, & Nye (2000), carried out a systematic review study on prevalence of SSD and reported the prevalence to be 2% to 25% for children in the age range of 5 – 7 years. The available data suggests a higher prevalence rate in males than females, and a low positive correlation with socioeconomic status.

2.2 Memory and its types

Memory is central to almost all cognitive processes. It plays an essential role in speech and language learning. The three main divisions of memory are defined as sensory memory, short term memory and long term memory. The first one, the sensory memory holds information in its raw form for a very brief duration (200-500 ms). Different sensory stores exist for information received from different senses. The next is the short term memory which forms an active part of the memory system. It helps in rehearsals, aggregation of information and aids in storing information to long term memory. The information stored in short term memory is usually available for a few seconds to a few minutes. The third division is the long term memory where the information can be stored for almost a lifetime.

The distinction between short-term and long-term storage systems was introduced by the pioneering American psychologist William James in the late nineteenth century. James named these 2 forms of memories as (i) primary memory and (ii) secondary memory. He used these terms to indicate the degree of relationship of stored information to consciousness. Primary memory is the base to store the information and made available to conscious inspection, attention and introspection (James, 1890). He contrasted primary memory with long-term storage system, or secondary memory, in which information cannot be retrieved without initiating an active cognitive process. The link between working memory and consciousness described by James remains a core component of current thinking. The current models suggest that only a subset of working memory is consciously experienced (Cowan, 1995).

2.2.1 Working Memory: The form of memory which stores information temporarily in the service of ongoing cognitive tasks is not new but the ideas regarding the nature and function of short term storage have evolved during the last hundred years. The terms regarding the storage systems have undergone many transformations, from primary memory to short-term memory to working memory.

The term 'working memory' was proposed by Miller, Galanter, and Pribram (1960). Working memory is regarded as one of the important mental faculties, playing a crucial role in cognitive activities such as planning, problem solving and reasoning. In our day to day activities it is necessary to have the critical information in mind, store and retrieve them when needed. To retain bits of information in mind we have to perform cognitive operations to manipulate or transform them. This short-term mental storage and manipulation operations are collectively referred to as working memory. For example: When we need to remember a phone number from the time of hearing it and dialing it ("1 646 766-6358"); Remembering driving directions in mind until we reach the destination we were told to watch for ("take the first left, continue for one mile, past the school, bear right, left at the four-way intersection, then it's the third building on the left - you can pull into the driveway").

2.2.2 Implications of the Nature of Working Memory: The nature of human working memory helps us to understand, why people differ in their cognitive skills and abilities to achieve their goals in real world situations. Various research activities imply that people vary in their working memory capacity which is also known as working memory span and the volume of information that can be accessed (Daneman & Carpenter, 1980). These differences predict general intelligence which is measured by standard IQ tests, verbal scholastic aptitude test (SAT) scores and the speed with which a skill such as computer programming is acquired (Kane & Engle, 2002; Kyllonen & Christal, 1990). The relationship between working memory and cognitive ability indicates how working memory affects complex cognitive tasks.

Working memory allows an individual to: "(1) consider alternatives, (2) incorporate new information and mentally update knowledge, (3) derive general principles, (4) identify relationships between ideas, and (5) perform critical reasoning" (Diamond, 2013). Working memory can also be considered an 'updating' system.

2.2.3 The Characteristics of Short-Term Memory (STM): Until 1950's there was a dearth of literature on short term memory storage and behaviorist view was dominant which prevented the focus of research on cognitive studies. George Miller, a cognitive theorist, gave detailed evidence that the capacity for short-term information storage is limited. In his paper, titled "The Magical Number Seven, Plus or Minus Two," he suggests that any person can keep only seven items active in their short-term storage and this limitation influences performance on a wide range of mental tasks. The short term memory tests are done by repeating a series of digits, regardless of how long the series is and the correct recall of digits appears to plateau for about seven times. For few individuals this plateau may be lower while it might be higher for others (Guildford & Dallenbach, 1925).

Miller (1956) indicates that even though there is a limitation on number of items that can be simultaneously held in short term memory, the definition of an "item", is flexible and modifiable. He suggests that single items can be grouped into higher level units of organization called chunks. Three single digits are chunked together into one three-digit unit: 3 1 4 become 314. Now the question arises, how much information can be chunked together? Miller suggests that chunking is governed by meaningfulness.

For example, numbers 3 1 4 are our area code; there is a very natural process to store them together as a chunk. These grouping processes is found everywhere in language. We effortlessly group letters into word-chunks and words into phrase-chunks. This is the reason, an individual has the ability to maintain verbal information in short term memory and it is considered to be better than any other types of information.

When participants are prevented from using strategies such as chunking or rehearsal the storage capacity is reported to be lower than seven (Cowan, 2001). The work done by Miller (1956) has drawn attention of the researchers on short term memory and its functional aspects. Evidence indicates that the concept of short term memory storage system originated from the studies on amnesic patients where long term memory was impaired and performance on immediate recall tasks was preserved (Scoville & Milner, 1957). This led to the idea that short term memory storage is structurally and functionally different from long term memory and it should be studied separately.

3.3 Models of Working Memory

As mentioned earlier, working memory is central and essential to several cognitive processes. This captivated the attention of psychologists in early twentieth century who later formulated working memory models and provided an explanation of how the information is stored and retrieved. Hereunder, two of the popular working models are discussed briefly.

2.3.1 The Atkinson-Shiffrin Model. One of the first models of working memory was proposed by Atkinson-Shiffrin in 1968. This is a multi-stage model with following three divisions: (i) sensory memory, (ii) short term memory, and (iii) long term memory.

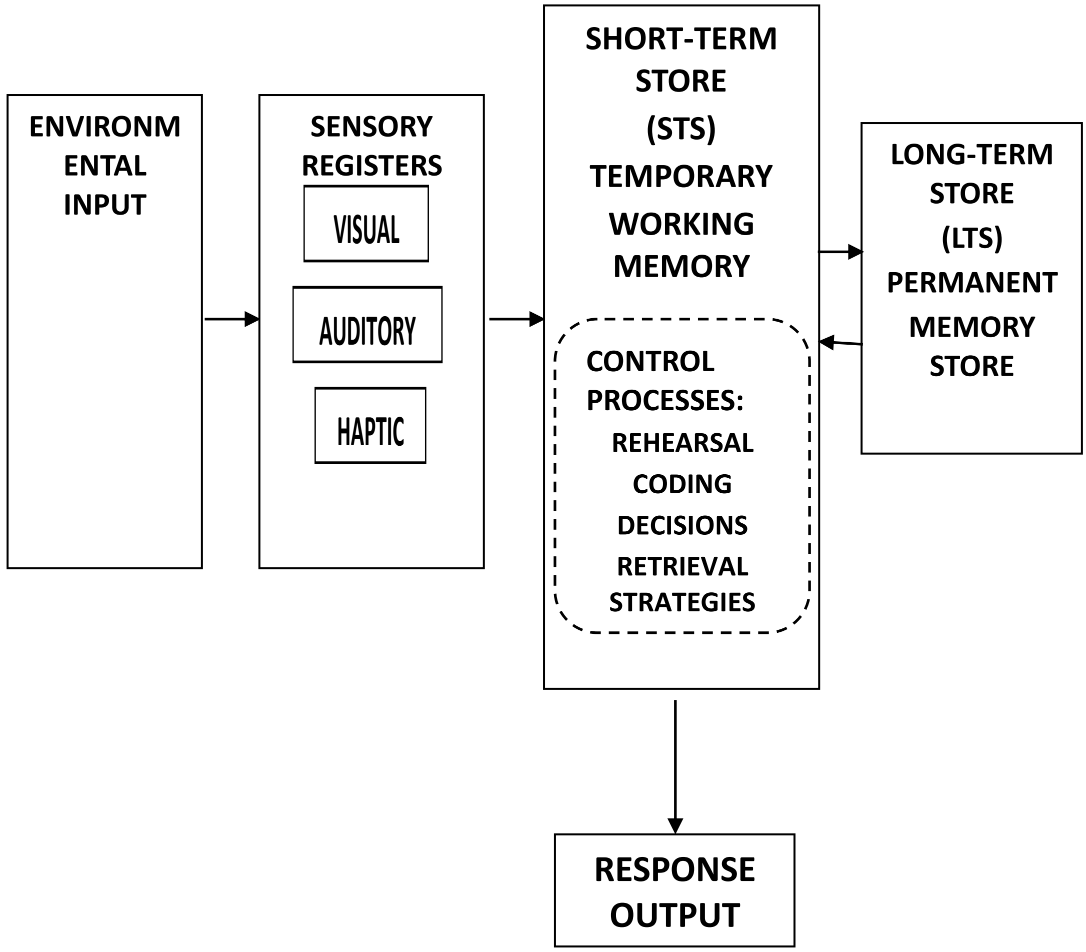

Figure 2.1. (R. C. Atkinson and R. M. Shiffrin, "The control of short-term memory" Scientific American, Aug. 1971, Vol. 225, No. 2 Reprinted with permission).

The short term and long term memory have distinct modes of storing information as depicted in the model proposed by Richard Atkinson and Richard Shiffrin (Atkinson & Shiffrin, 1968). In this model, short-term memory has the gateway to access the long term memory. The main function of short term memory is to control and enhance via rehearsal and coding strategies such as chunking and then the information is pushed into long term memory. The Atkinson-Shiffrin model was highly influential because it gives a detailed view of information processing in memory and it is referred to as the modal model of memory.

The modal model suggests that the flow of information from sensory input to long term memory should pass through short term memory. Visual, auditory, haptic (touch) and other sensory receptors, registers the information from the environment and passes on to short term memory and here it is rehearsed or manipulated before the entry to long term memory. This forms as the strategy to retrieve information from long term memory.

However, with time the belief in 'modal model of memory' faded and most psychologists favored a different conceptualization of short-term storage, one that is not exclusively focused on its relationship to long-term storage and has a more dynamic role than storage alone. This shift in view is reflected in the increased use of the term "working memory" which better captures the belief of temporary storage system providing a useful workplace to engage in complex cognitive activities.

This shift in perspective is attributed to inability of the Atkinson-Shiffrin model to explain the adequate storage and processing of information in long term memory in individuals with brain damage who exhibited short term memory impairment. According to the modal model, information passes through sensory system to short term memory and then the long term memory. Thus, impairment in short term memory would in turn affect long term memory as well. However, evidence from neuropsychological research showed few individuals with parietal lobe injury with short term memory impairment were able to store and process new information in their long term memory like neurologically healthy individuals (Shallice & Warrington, 1970). Further, few evidences from behavioural studies in neurologically healthy individuals, indicate that there are multiple systems for short term storage system (Baddeley & Hitch, 1974).

2.3.2 The Baddeley-Hitch Model of Working Memory. Baddeley-Hitch model focuses on two short term stores and one control system as the main core components of working memory, which is opposite to the simple information store suggested in Atkinson-Shiffrin model. Firstly, the primary function of STM in this model is not of a relay centre directing incoming information to the long term memory. Instead it focuses to enable the complex cognitive activities needed for integration, coordination and manipulation of information. Secondly, there is a relationship between a control system, - a central executive responsible for the deposition and removal of information from STM & storage buffer themselves. This well knitted level of interaction is what makes the short term stores an effective workplace for various mental processes. Third, this model describes two STM buffers, one for verbal information in the form of ‘phonological loop’ and the second one for visuospatial information as ‘visuospatial sketchpad’. These two buffers are independent providing greater flexibility in storing information Even if one buffer is busy the other can be utilized to its maximum potential. These two buffers are controlled by the central executive that suggests that information can be easily shuttled and coordinated between them. In 2000, Baddeley offered an update of his model and added a fourth component 'episodic buffer' to it. This episodic buffer was proposed as a limited capacity space where information from different sources integrates or bound together for manipulation. It was also suggested that for speech production tasks, this space is utilized to integrate phonological and linguistic representations with motor representations.

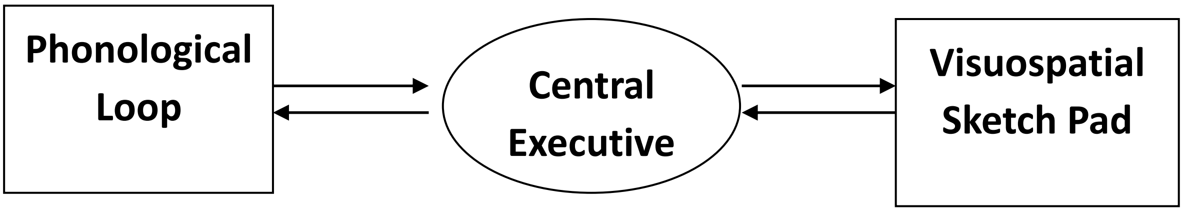

Figure 2.2. The Baddeley-Hitch Model of Working Memory (1986) (Baddeley, A. D., and Hitch, G. J. (1974) Working memory in G. Bower (ed.), The psychology of learning and motivation (Vol. VIII, pp. 47–89). New York: Academic Press. Reprinted with permission from Elsevier).

2.4 Tasks used to assess Working Memory

Researchers have used several tasks to assess the nature and function of working memory. Working memory has been assessed using both simple span task (Forward digit, backward digit, ascending digit and descending digit and visual spatial spans) and complex span tasks (reading span, operational tasks, rhyme judgements: visual letter monitoring and n-back task). Digit recall, word recall and nonword repetition are some of the commonly used tasks to assess working memory and have been used extensively in the past (Adams & Gathercole, 1995; Bayliss et al., 2005; Eaton, 2014). Among these, nonword repetition was reported to be a sensitive measure invoking several short term memory processes like storage, processing and retrieval (Gathercole & Baddeley, 1990). However, some investigators opposed the use of nonword repetition as a measure of working memory and considered it to be a part of language measure (Snowling, Chiat, & Hulme, 1991). Few others argued that non-word repetition involves multiple processes, and hence its clinical utility as a measure of working memory is questionable.

In a recent study, along with the traditional digit recall a pointing task was also included (Waring, Eadie, Liow, & Dodd, 2017). Here the participants had to point at the items in a forward and reverse order. In another study, working memory was assessed in terms of its three components (Phonological loop, central executive & visuospatial sketchpad). Phonological loop was assessed using digit recall, word-list matching, word-list recall, and non-word list recall. Block recall and maze memory was used to assess visuospatial sketchpad. Further, to investigate the function of central executive listening recall, counting recall and recall of digits backwards were used (Schulze, Vargha-Khadem, & Mishkin, 2018). As observed digit recall has been a preferred choice of researchers as a measure of working memory over the years.

2.5 Working Memory in Children

Working memory is considered to be an essential pre-requisite for phonological development (Adams & Gathercole, 1995) and literacy skills (Alloway et al., 2005; Vandenbrouckea et al., 2018). Investigating working memory in typically developing children (TDC) is essential to understand normal aspects of development and identifying working memory deficits in various clinical populations.

Adams and Gathercole (1995) investigated phonological working memory and speech production in preschool children using non-word repetition and auditory digit span test. They reported that children with good phonological working memory had better language abilities and produced longer complex sentences with a rich array of vocabulary when compared to children with poor phonological memory. Vandenbrouckea et al. (2018) administered working memory tasks on 107 children at the end of kindergarten and first grade. Results revealed significant development of phonological loop and visuospatial sketchpad and large gains in the central executive. These components and their functioning were found to be important to predict the performance in literacy tasks like reading, spelling and mathematics. They emphasized the importance of assessing working memory and works towards prevention, early identification and intervention of working memory deficits at an early stage to prevent future academic problems.

Another study by Torrens and Yague (2016) assessed working memory in children with Specific Language Impairment (SLI) using word and non-word repetition, and digit memory tasks. They reported that children with SLI performed poorer when compared to typically developing children across all age groups and suggested that these tests could be used clinically to differentiate between SLI and TDC.

Speidel (1993) reported poor performance on non-word repetition, which is a common metric for working memory, in a child with SSD when compared to his typically developing twin. Children with SSD are also reported to have weak executive functioning (Crosbie et al., 2009). Farquharson (2012) assessed phonological short term memory and phonological working memory in school-aged children with SSD and reported significant deficit in the phonological loop. In another study, 20 children diagnosed with phonologically-based SSD in the age range of 4-5 years were found to perform poor on traditional forward digit span task and the non-word repetition task (Eaton, 2014). However, no significant difference was found between SSD and TDC in phonological memory tasks.

Waring et al. (2017) investigated phonological working memory in fourteen monolingual preschool children with phonological delay and age matched TDC. They used the following tasks: forward recall of words (pointing), reverse recall of words (pointing), and reverse recall of digits (spoken). Findings revealed that TDC performed better than children with phonological delay on all tasks. A qualitative analysis of the findings revealed that both the groups made similar errors on forward digit recall task, however performed differently on reverse recall of digits (spoken) suggesting a link between immediate memory and delayed phonological development. The same group of researchers replicated this study with same tasks in another group of sixteen monolingual preschool children with phonological disorder (PD) and their age and gender matched typically developing peers. Findings of this study revealed no significant differences in the forward recall task. However, TDC outperformed children with PD on both the reverse recall tasks. These findings suggest phonological memory deficits in children with PD and which further indicate executive function impairment in specific subtypes of speech sound disorders (Waring, Eadie, Liow & Dodd, 2018).

In another recent study, school age children in the age range of 7.5 to 11.8 years with persistent SSD were reported to have deficits in working memory (Farquharson et al., 2017). They focused on assessing each of the three components of working memory according to Baddeley model. Non-word repetition was used to assess phonological loop, visuospatial sketchpad was assessed using spatial relations subtest from the Woodcock-Johnson III Test of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001), and a stop signal inhibition task was used to assess central executive (Gray, Hogan, Alt, Cowan, & Greene, 2011-2016). It was found that children with SSD performed poor when compared to TDC only on phonological loop task suggesting underlying phonological memory deficits. Similarly, poor working memory skills were reported in 4 to 6 year old Persian speaking children with SSD in comparison to their typically developing peers (Afshar et al., 2017).

It is observed that though strong evidence exists for role of working memory in phonological development, there is a dearth of literature investigating various components of working memory in children with SSD, particularly in Indian context. Hence, the present study is undertaken to explore working memory abilities in young native Kannada speaking children with SSD in comparison with typically developing children.

3. METHODS

The study aimed to primarily investigate working memory abilities in Kannada speaking typically developing children (TDC) and children diagnosed with Speech Sound Disorder (SSD) in the age range of 4-7 years using three tasks - digit span forward recall, digit span backward recall and digit running span. The secondary aim of the study was to compare the performance across the subgroups of age.

3.1 Objectives of the study

The specific objectives of the study were:

1. To compare the scores of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span
2. To study the effect of age on the scores obtained by TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span
3. To compare the scores of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span across subgroups of age

3.1.1 Research Design: Standard group comparison with two groups - control group (TDC) and clinical group (children with SSD) was used to accomplish the objectives of the study.

3.2 Participants

Two groups of participant namely clinical group and control group in the age range of 4 to 7 years were included in the study. The clinical group consisted of 22 children (12 boys & 10 girls) diagnosed with SSD (mean age – 5;6 years) chosen from a clinical setup. The control group consisted of age matched 30 TDC (16 boys & 14 girls) (mean age – 5;9 years). All the participants recruited in the two groups resided in and around Mysuru city and were studying in English medium schools. The details of the participants in the two groups are given in the Table 3.1. An informed consent was obtained from parents/caregivers/teachers of all the participants before including them in the study.

Table 3.1. *Details of age and gender distribution of participants of the study*

Age range (in years)	TDC	SSD
4;1 – 5;0	6 (4 B : 2 G)	8 (5 B : 3 G)
5;1 – 6;0	11 (5 B : 6 G)	8 (3 B : 5 G)
6;1 – 7;0	13 (7 B : 6 G)	6 (4 B : 2 G)
Total	**30** **(16 B : 14 G)**	**22** **(12 B : 10 G)**

Note: B – Boys, G - Girls

3.2.1 Participant Selection Criteria

- All participants were native speakers of Kannada language residing in the city of Mysuru
- All participants included in the study belonged to middle socio-economic status as assessed by the revised NIMH Socio Economic Status Scale (Venkatesan, 2011)
- All participants were assessed informally to ensure structurally normal and functionally adequate oral mechanism
- Participants in the control group were screened informally to rule out any structural, behavioural, emotional and sensory impairment

- Participants were screened to rule out any speech, language or hearing deficits using the WHO Ten Question Disability Screening Checklist (cited in Singhi, Kumar, Prabhjot, & Kumar, 2007)
- Participants in the clinical group included only those children who were formally diagnosed as SSD by qualified speech language pathologists
- Children with misarticulation due to any structural abnormality, Otological problems, hearing loss or neurological deficits were excluded. Further, children with other co-morbid conditions such as learning disability, autism etc. were also excluded from the clinical group.

3.3 Stimuli

The stimuli were presented using the software Smriti Shravan V 1.0 (Kumar & Sandeep, 2013) installed in a laptop. The stimuli consisted of number strings in English (length of two digits to ten digits) including numbers from 0 – 9 arranged in a random order in each string. The stimuli were presented in ascending and descending fashion through the software, based on correct and wrong responses of the participants respectively.

3.3.1 ***Description of the Software used:*** The software was developed by Kumar and Sandeep (2013) as a departmental project titled "Development and test trial of computer based auditory-cognitive training module for individuals with cochlear hearing loss" at All India Institute of Speech and Hearing, Mysuru. The software was originally designed for individuals with hearing loss; however, it can also be used to check the working memory skills in individuals with different communication disorders like SSD, dementia, Traumatic Brain Injury, schizophrenia and progressive neurological disorders wherein working memory deficits are known to persist.

This software consists of two modules Smriti – I, Smriti – II & Shravan. Smriti – I contains Auditory Stimulus, Visual Stimulus & Spatial Stimulus. Smriti – II contains, N-Back Auditory Stimulus, N-Back Visual Stimulus, and Math Span as Stimulus, Operating Span Stimulus, and Reading Span Stimulus & Symmetric Span Stimulus. Shravan contains auditory stimulus to check out hearing loss. Auditory Stimulus from the module Smriti Shravan – I was used as stimuli for the present study.

3.3.2 Instrumentation: Presentation of the stimuli and acquisition of the responses was controlled using the software Smrithi-Shravan V 1.0 (Kumar & Sandeep, 2013) installed in the laptop. The stimuli were presented through Zebronics multimedia headphone - ZEB – 2200HMV auditorily at comfortable listening levels to the participants using a personal Lenovo laptop, B 570 Model.

3.4 Test Environment

The entire test was carried out in a quiet and distraction free environment, with adequate lighting and comfortable seating. All tests were administered individually for each participant in both clinical and control group.

3.5 Procedure

Initially, two practice trials were given for each task to familiarize the participants with the task and instructions. The practice items were similar but different from the test items. The practice trials were followed by test trials. The order of testing i.e., the order of tasks was randomized across participants. Participants were praised regardless of the accuracy of response, with no indication as to whether the response was correct or incorrect.

The starting level in each task was two-digit span i.e. two digits such as 2 5 was spelled and the number of reversals was four i.e. the test will be running continuously until the participant makes four wrong responses and then the test ends for the fifth wrong response. The reversal discard was two i.e. the first two wrong responses were discarded and the remaining four mistakes were considered by the software as set prior to start the test.

As long as the participant gives the correct response, the test moves on to the next level i.e. from two digits to three digits, then to four digits and so on. When the participant gives a wrong response, the level of the digit span is lowered by one level i.e. from four digits to three digits and so on. The responses were recorded in the software to determine the nature of the following stimulus item.

The test trials included three tasks as described in the following section.

3.5.1 Digit Span Forward Recall

Administration of the test: As mentioned earlier, number strings were presented as stimuli wherein numbers from 0 to 9 were arranged randomly and presented in audio mode to both the ears simultaneously through a headphone. The participants were expected to repeat the numbers heard in the same order.

Scoring

- Scoring and analysis was carried out as described in the original test
- Both item score and accuracy score were computed

Item Score:

- If all the test items were present in the participant's response irrespective of the position, a score of "1" was given (For example: If 2438 was the stimulus and the response was 2483, then a score of "1" was given)
- If all the test items were not repeated correctly, a score of "0" was given

Accuracy Score:

- If all the test items were present in the correct order of presentation, a score of "1" was given. If not, the score given was "0"

3.5.2 Digit Span Backward Recall

Administration of the test: Similar to task one, number strings were presented as stimuli. Each string had randomly arranged numbers presented auditorily to both ears simultaneously through a headphone and the child was expected to repeat the numbers heard in the reverse order i.e. when 2438 was the stimulus, the expected response was 8342.

Scoring

- Scoring and analysis was carried out as described in the original test.
- Both item score and accuracy score were computed

Item Score

- If all the test items were present in the participant's response irrespective of the position a score of "1" was given (For example: If 2438 was the stimulus and the response was 8342, then a score of "1" was given)
- If all the test items were not repeated correctly, a score of "0" was given

Accuracy Score

- If all the test items presented were repeated in the correct reverse order; a score of “1” was given (For example: If 8342 was the stimulus and the response was 2438, then the score of “1” was given).
- If all the test items were not repeated correctly, a score of “0” was given.

3.5.3 Digit Running Span

Administration of the test: Number strings with randomly arranged numbers from 0 to 9 were presented continuously in audio mode to both ears simultaneously through headphones and as per the instructions, participants was expected to repeat the last two, three, four or five digits from the set of numbers heard auditorily in a forward fashion.

Scoring

- Scoring and analysis was carried out as described in the original test
- Both item score and accuracy score were computed

Item Score

- The presence of all items, irrespective of the position was considered as a correct response and was scored as “1” (For example: If the child was asked to repeat the last four digits in the stimuli 7492438, and the response consists of the digits 2, 4, 8 and 3 in any order, a score of “1” was given). When the participant was not able to follow the task or did not repeat the last ‘n’ digits correctly as instructed, then a score of “0” was given.

Accuracy Score

- If the last 'n' digits were repeated in correct order, a score of '1' was given (For example: If the participant was asked to repeat the last four digits in the stimuli 7492438, and the response was 2438, then a score of "1" was given).
- If the numbers were not repeated in the same order, then a score of "0" was given.

3.6 Interpretation

An analysis report was generated by the software for each participant. The total number of scores were added together to obtain the item score and accuracy score separately for each task.

3.7 Statistical Analysis

Based on the data obtained, non-parametric tests were done due to small sample size. Kruskal Wallis Test was used to compare across age range in TDC and children with SSD. Mann Whitney U Test was used to compare the performance of clinical and control group within each age range. Wilcoxon's Sign Rank Test was administered to compare the performance of participants across the three tasks within each age group.

4. RESULTS

The primary aim of the study was to compare the working memory capabilities in children with speech sound disorder (SSD) and typically developing children (TDC) in the age range of 4 – 7 years. The specific objectives of the study were to compare the performance of children in the two groups for the following three tasks: (i) Digit span forward recall (ii) Digit span backward recall and (iii) Digit running span. The secondary aim of the study was to compare the performance across the three age groups.

The results of the present study are reported under the following headings:

4.1. Results of digit span forward recall in TDC and children with SSD

4.2. Results of digit span backward recall in TDC and children with SSD

4.3. Results of comparison between digit span forward recall and digit span backward recall tasks

4.4. Results of comparison between item scores and accuracy scores

Statistical analysis was done using the software Statistical Package for Social Sciences (SPSS) version 20.0. The overall mean, median and standard deviation for the scores on two tasks i.e. the forward span test and backward span test obtained by TDC and children with SSD are depicted in Table 4.1. Similarly, Table 4.2 shows the mean, median and standard deviation of the scores obtained by the two groups of participants across age groups. None of the participants included in the study in both clinical and control groups were able to carry out the digit running span task, and hence the results for this task are not presented.

Table 4.1. *Mean, Standard Deviation (SD) and Median of the scores obtained by TDC group and children with SSD group*

Group		**ISFS**	**ASFS**	**ISBS**	**ASBS**
TDC (N = 30)	**Mean**	7.10	5.93	7.00	4.50
	Median	7.00	6.00	7.00	4.00
	S.D.	1.21	1.20	1.25	0.97
SSD (N = 22)	**Mean**	5.95	4.90	3.77	2.40
	Median	6.00	5.00	4.00	2.00
	S.D.	1.29	130	2.26	179

Note: TDC – Typically Developing Children; SSD – Speech Sound Disorder; ISFS – Item score forward span; ASFS – Accuracy score forward span; ISBS – Item score backward span; ASBS – Accuracy score backward span

From Table 4.1, it may be observed that the scores obtained by TDC were higher than children with SSD for both digit span forward recall and digit span backward recall tasks. This was found to be true for both item scores and accuracy scores. Further, in each of the groups it was observed that the scores obtained were higher for the digit span forward recall task compared to digit span backward recall task. The item scores were found to be higher than the accuracy scores for both tasks in each group of participants.

Table 4.2. *Mean, Standard Deviation (SD) and Median of the scores obtained by TDC and children with SSD across age groups of Forward span and Backward span task*

TASK	SCORE		TDC			SSD		
			4 – 5 Yrs	5 – 6 Yrs	6 – 7 Yrs	4 – 5 Yrs	5 – 6 Yrs	6 – 7 Yrs
FORWARD SPAN	ITEM SCORE	Mean	5.83	7.00	7.76	5.50	5.87	6.66
		SD	1.16	1.09	0.83	1.41	1.24	1.03
		Median	5.50	7.00	8.00	5.00	6.00	7.00
	ACCURACY SCORE	Mean	4.83	5.72	6.61	4.37	4.75	5.83
		SD	1.16	0.90	1.04	0.91	1.48	1.16
		Median	4.50	6.00	7.00	4.00	5.00	6.00
BACKWARD SPAN	ITEM SCORE	Mean	6.00	7.00	7.46	2.62	3.25	6.00
		SD	1.78	1.18	0.77	1.76	2.12	1.54
		Median	5.50	7.00	7.00	2.50	3.00	6.00
	ACCURACY SCORE	Mean	3.83	4.18	5.07	1.50	1.87	4.33
		SD	0.98	0.75	0.86	1.30	1.35	1.50
		Median	4.00	4.00	5.00	1.50	1.50	5.00

From Table 4.2, it is observed that both item scores and accuracy scores increased with increase in age range of TDC for digit span forward recall and digit span backward recall tasks. The same findings were also observed for children with SSD in each of the tasks. In addition, the scores obtained by TDC in each of the age groups were higher than the corresponding age group of children with SSD.

The data was subjected to Shapiro Wilk's test of normality and the results revealed non-normal distribution of data. Further, owing to the small sample size non-parametric tests were used for analysis.

4.1 Results of digit span forward recall in TDC and children with SSD

The results presented in this section addresses objectives 1(a), 2(a) and 3(a). Mann Whitney U test was administered to compare the scores obtained by TDC and children with SSD in the digit span forward recall task. The results revealed significant difference between the scores obtained by the two groups of participants for item scores ($|z| = 2.92$, $p < 0.05$) as well as accuracy scores ($|z| = 2.62$, $p < 0.05$).

Kruskal Wallis H test was carried out to check for the effect of age on the scores obtained in the digit span forward recall task by TDC and children with SSD separately. The findings revealed significant effect of age for item scores ($\chi^2 = 9.79$, $p < 0.05$) and accuracy scores ($\chi^2 = 8.99$, $p < 0.05$) in TDC. However, no significant effect of age was in children with SSD for both item scores ($\chi^2 = 3.00$, $p > 0.05$) and accuracy scores ($\chi^2 = 4.71$, $p > 0.05$).

Further to identify the age groups in TDC which were significantly different from each other, Mann Whitney U test was done. The results are summarized in Table 4.3 below.

Table 4.3. *Results of Mann Whitney U test in digit span forward recall task across age groups in TDC*

Pairs of Age Group (in years)		**|z| value|**	
		Item Score	**Accuracy Score**
4;1 – 5;0	**5;1 – 6;0**	2.051*	1.71
4;1 – 5;0	**6;1 – 7;0**	2.79*	2.59*
5;1 – 6;0	**6;1 – 7;0**	1.79	1.96

*Note: *p < 0.05*

Results revealed a significant difference in the item score between children in the age range of 4;1 -5;0 years and 5;1 – 6;0 years, and between 4;1 – 5;0 years and 6;1 – 7;0 years. No significant difference was found between children in the age range of 5;1 – 6;0 years and 6;1 -7;0 years. Results for accuracy scores revealed significant difference only between children in the age range of 4;1 – 5;0 years and 6;1 – 7;0 years. No significant difference was found between other age groups.

The data was also analyzed to compare the scores between TDC and children with SSD in each of the age groups. Mann Whitney U test was carried out and the results revealed significant difference ($|z| = 2.18$, $p < 0.05$) between the two groups of participants for item score in the age range of 6;1 – 7;0 years but not for the other age groups. Further, no significant differences were found for accuracy scores in any of the age groups. Results of Mann Whitney U test are presented in Table 4.4.

Table 4.4. *Comparison of scores of TDC and children with SSD in digit span forward recall*

Score	**|z| value**		
	4 – 5 years	**5 – 6 years**	**6 – 7 years**
Item Score	0.67	1.90	2.18*
Accuracy Score	0.69	1.62	1.27

4.2 Results of digit span backward recall in TDC and children with SSD

The results presented in this section addresses objectives 1(b), 2(b) and 3(b). Mann Whitney U test was administered to compare the scores obtained by TDC and children with SSD in the digit span backward recall task. The results revealed significant difference between the scores obtained by the two groups of participants for item scores ($|z| = 4.69$, $p < 0.05$) as well as accuracy scores ($|z| = 4.02$, $p < 0.05$).

Similar to digit span forward recall, Kruskal Wallis H test was administered to analyze the effect of age on the scores obtained in the digit span backward recall task by TDC and children with SSD separately. The findings revealed no significant effect of age for item scores ($\chi^2 = 5.20$, $p > 0.05$). However, the age effect was found to be significant for accuracy scores (χ^2 = 9.82, p < 0.05). In case of children with SSD, a significant age effect was observed for both item scores (χ^2 = 7.80, p < 0.05) and accuracy scores (χ^2 = 8.74, p < 0.05).

This was followed by Mann Whitney U test to identify the age groups in TDC and SSD which were significantly different from each other. The results are summarized in Table 4.5.

Table 4.5. *Results of Mann Whitney U test for backward recall span task across age groups in TDC and children with SSD*

Score	**|z| value**					
	TDC (Age in years)			**SSD (Age in years)**		
	4-5 & 5-6	**4-5 & 6-7**	**5-6 & 6-7**	**4-5 & 5-6**	**4-5 & 6-7**	**5-6 & 6-7**
ISBS	-	-	-	0.42	2.62*	2.22*
ASBS	0.43	2.48*	2.61*	0.54	2.69*	2.42*

*Note: *p < 0.05; TDC – Typically Developing Children; SSD – Speech Sound Disorder; ISBS – Item score backward span; ASBS – Accuracy score backward span*

Among TDC, significant difference was obtained for accuracy scores between children in the age ranges of 4;1 - 5;0 years and 6;1 – 7;0 years, and between 5;1 – 6;0 years and 6;1 – 7;0 years. No significant difference was obtained between children in the age range of 4;1 – 5;0 years and 5;1 – 6;0 years. Results in children with SSD revealed a significant difference for both item scores and accuracy scores between children in the age range of 4;1 – 5;0 years and 6;1 – 7;0 years, and between 5;1 – 6;0 years and 6;1 -7;0 years, but not between children in the age range of 4;1 – 5;0 years and 5;1 – 6;0 years.

Analysis of data for comparison of scores between TDC and children with SSD in each of the age groups was carried out using Mann Whitney U test. The results, as summarized in Table 4.6, revealed significant difference between the two groups of participants for item scores in each of the three age groups. On the other hand, significant differences were observed in the age groups of 4;1 -5;0 years and 5;1 – 6;0 years for accuracy scores, but not in the age group of 6;1 – 7;0 years.

Table 4.6. *Comparison of performance of TDC and children with SSD in digit span backward recall*

Score	**|z| value**		
	4 – 5 years	**5 – 6 years**	**6 – 7 years**
Item Score	2.61*	3.18*	1.99*
Accuracy Score	2.61*	3.33*	0.80

4.3 Results of comparison between digit span forward recall and digit span backward recall tasks

The data was analyzed to compare the scores between digit span forward recall and digit span backward recall within the groups of TDC and children with SSD using Wilcoxon Signed Rank test. In the TDC group, results revealed significant difference between the two tasks for accuracy scores but not for item scores. On the other hand, significant differences were obtained for both item scores and accuracy scores between the two tasks in children with SSD. The results of Wilcoxon Signed Rank test are presented in Table 4.7.

Table 4.7. *Comparison of scores in digit span forward recall and backward recall across age groups in TDC and children with SSD*

Scores	|z|					
	TDC (Age group in years)			SSD (Age group in years)		
	4-5	**5-6**	**6-7**	**4-5**	**5-6**	**6-7**
Item Score		0.260			3.732*	
Accuracy Score		4.277*			4.044*	
Item Score	0.447	0.72	0.905	2.585*	2.205*	1.414
Accuracy Score	1.857	2.701*	2.862*	2.565*	2.539*	2.041*

*Note: * $p < 0.05$*

Comparison of scores between digit span forward recall and digit span backward recall was also carried out within each age group of TDC and children with SSD. Results of Wilcoxon Signed Rank test showed no significant difference between the item scores of the two tasks in any of the age groups of TDC. However, significant differences were observed for children with SSD in the age ranges of 4;1 – 5;0 years and 5;1 – 6;0 years, but not for 6;1 – 7;0 years. In terms of accuracy scores, significant differences were found between the two tasks in each of the age groups of TDC and SSD, except for the age range of 4;1 -5;0 years of TDC.

4.4 Results of comparison between item scores and accuracy scores

The data was analyzed to compare between item and accuracy scores in each of the two tasks i.e., digit span forward recall and digit span backward recall separately in the two groups of participants. Wilcoxon Signed Rank test was administered and the results revealed significant differences between the item and accuracy scores for digit span forward recall and digit span backward recall tasks in both TDC and children with SSD. The results of Wilcoxon Signed Rank test are presented in Table 4.8.

Comparison of item scores and accuracy scores of each task was also carried out within each age group of TDC and children with SSD using Wilcoxon Signed Rank test. Results as given in Table 4.8, showed significant differences between the item scores and accuracy scores for both digit span forward recall and digit span backward recall tasks across all age groups in TDC as well as in children with SSD.

Table 4.8. *Comparison of item scores and accuracy scores across age groups in TDC and children with SSD*

Tasks	|z|					
	TDC (Age group in years)			**SSD (Age group in years)**		
	4-5	**5-6**	**6-7**	**4-5**	**5-6**	**6-7**
DSFR		4.427*			3.502*	
DSBR		4.792*			3.926*	
DSFR	2.121*	2.739*	2.913*	2.041*	2.264*	1.890*
DSBR	2.032*	3.025*	3.222*	2.530*	2.456*	2.236*

Note: TDC – Typically Developing Children; SSD – Speech Sound Disorder; DSFR- Digit span forward recall; DSBR – Digit span backward recall

In summary, significant differences were observed between TDC and children with SSD for both digit span forward recall and digit span backward recall tasks. TDC performed significantly better than children with SSD on both tasks in terms of item scores as well as accuracy scores. Similar results were obtained when subgroups of age were considered. In both groups of participants, the scores obtained were better for digit span forward recall task compared to the digit span backward recall task. Further, item scores were better than accuracy scores for both tasks in control group as well as clinical group.

5. DISCUSSION

The study aimed to investigate the working memory abilities in TDC and children with SSD in the age range of 4 to 7 years both as a whole and across subgroups of age.

The findings of the present study are discussed under the following headings:

5.1 Digit span forward recall in TDC and children with SSD

5.2 Digit span backward recall in TDC and children with SSD

5.3 Comparison between digit span forward recall and digit span backward recall tasks

5.4 Comparison between item scores and accuracy scores

5.1 Digit span forward recall in TDC and children with SSD

As presented in the results, a significant age effect was observed in TDC but not in children with SSD. This indicates a developmental trend in the digit span forward recall ability of TDC. This finding is in consonance with earlier research (Baddeley, 1990) which attributed the increase in performance with age to the nature of the task. The task involves a dual paradigm including both verbal execution process, and storage and retrieval. There is increase in flexibility with increase in the age of children in each of these abilities which is further known to be mediated by the phonological loop. It was observed that with increase in the number of items in each string, participants in lower age groups i.e. 4;1 – 5;0 years and 5;1 – 6;0 years had difficulty in recalling the digits in the same order when compared to participants in higher age group i.e. 6;1 – 7;0 years. This could be because of the limitations in the memory capacity of younger children in comparison to older children. The difference in the performance between the three age groups in digit span forward recall task may also be attributed to development in the components of working memory. Specifically, development in the verbal executive mechanism, activation of phonological loop and the sub vocal rehearsals could play an important role in increased abilities in participants in the higher age group. In the present study, it was observed that the participants were able to better recall digits using sub vocal rehearsals, thereby supporting the views put forth by Baddeley (1990) and Alloway et al. (2005).

Comparison of performance between the two groups of participants revealed poor performance of children with SSD than TDC in the digit span forward recall task. This finding is in agreement with similar findings reported in children with phonological disorder (Eaton, 2014; Farquharson, 2012; Waring, et al., 2017). Poor performance was attributed to poor short term memory and poor working memory. In particular, difficulty in holding phonological information in short term memory was suggested to be the most probable factor by these authors. Further, attention deficits in the performance on working memory tasks cannot be ruled out as suggested in the literature (Conway, Cowan, Bunting, Therrjault, & Minkoff, 2002). Poor selective attention leads to poor performance on recall and recognition of spoken words. However, as attention skills were not evaluated in the present study, no conclusions can be drawn in this regard.

5.2 Digit span backward recall in TDC and children with SSD

A significant effect of age was found only for accuracy scores in TDC whereas the age effect was significant for both item scores and accuracy scores in children with SSD. This finding reflects the developmental trend seen in both TDC and children with SSD with respect to DSBR. As discussed in the digit span forward recall section, with increase in age, there is a corresponding increase in the working memory abilities which is reflected as better performance in higher age groups than the lower age groups. These findings are supported by Vandenbrouckea et al. (2018) who reported that there were moderate to large gains in the components of working memory i.e., phonological loop, visuospatial scratchpad and central executive with increase in age.

Further, comparison of performance between TDC and children with SSD revealed poor performance by the latter group. This finding is in consonance with the existing literature (Eaton, 2014; Farquharson, 2012; Waring, et al., 2017, 2018). As researchers suggest, the digit span backward recall task requires both phonological short term memory (to retain the items) and phonological working memory (to manipulate the items i.e., arrange in reverse order). It was proposed that children with SSD perform poorly due to underlying short term memory deficit and not due to the inability to manipulate the item (Waring et al., 2017). However, in a subsequent study by Waring et al (2018), they emphasized the role of phonological working memory in developing speech accuracy. In agreement with Eaton and Ratner (2016), Waring et al. (2018) proposed that children with phonological disorders exhibit deficits in mental manipulation of verbal material which in turn could be leading to their inability to differentiate between their own production and the correct production of a speech sound. It was also suggested that this phonological working memory deficit may co-occur with other deficits in executive function, i.e., cognitive flexibility (Dodd & McIntosh, 2008). Similar to digit span forward recall task, the influence of attention deficits on performance in working memory tasks is difficult to rule out (Conway et al., 2002).

Hence, it was observed that there was significant difference between TDC and SSD and also between subgroups of TDC and children with SSD in both digit span forward recall and digit span backward recall. Thus, hypothesis 1 and 3 of the study are rejected. Further significant age effect on the scores obtained in the two tasks was present for TDC but not for SSD. Thus hypothesis 2 of the study is partially accepted.

5.3 Comparison between digit span forward recall and digit span backward recall tasks

The comparison of two tasks revealed significant difference in accuracy scores in TDC and significant difference in both item and accuracy scores in children with SSD. Further, participants in both groups performed better on digit span forward recall than digit span backward recall task owing to the increased difficulty of the latter task. The forward recall involves only the storage and retrieval, while in the backward recall task an additional step of manipulation (reversing the order) is involved making it more complex (Waring et al., 2017). Waring et al. (2018) suggested that children with SSD might have difficulty in both storing and manipulating information in the phonological store, thus leading to difficulty in digit recall tasks, particularly in backward recall.

5.4 Comparison between item scores and accuracy scores

The study also compared item scores with accuracy scores within each of the two tasks. The findings revealed a significant difference between the two scores for digit span forward recall and digit span backward recall tasks in both TDC and children with SSD. Further, item scores were found to be better than accuracy scores in both groups of participants. This could be attributed to the nature and the complexity of the two scoring patterns. For item score to be correct, participants only were expected to correctly repeat all items presented in the number string irrespective of the order of presentation. On the other hand, to score correctly on accuracy participants needed to maintain the order of presentation in addition to ensuring the presence of all items. This makes scoring with respect to accuracy more complex which could have been difficult for participants in both groups, thereby leading to higher item scores than accuracy scores.

Though extant literature suggests that underlying working memory deficits contribute to poor speech production skills in children with SSD, few researchers propose a possibility of an inverse condition (Holm, Farrier, & Dodd, 2008; Farquharson et al., 2017; Waring et al., 2018). In other words, it is plausible that speech errors or difficulties in children with SSD may in turn lead to impaired phonological memory. The difficulty in speech production might be negatively influencing their articulatory rehearsal or subvocal rehearsal stage of working memory processing leading to poor performance in these tasks. Future investigations focusing on determining the direction of relation between phonological working memory deficits and speech errors may provide a better insight. Nevertheless, whatever may be the direction of relation, a strong link does exist between phonological working memory and speech production skills. This further justifies and strengthens the need to assess working memory skills in children with SSD in depth.

6. SUMMARY AND CONCLUSIONS

Working memory is a prerequisite for several cognitive tasks like reading, word learning, language acquisition, mathematical processing and reasoning. Further for speech production, accurate and consistent storage and appropriate retrieval of sounds is necessary. Recent research evidence supports a plausible role of working memory deficits in children with SSD. Considering the fact that children with SSD are at risk of academic difficulties and working memory is essential for academic learning, assessing working memory abilities in children with SSD becomes important.

Thus the current study was aimed to investigate the working memory abilities in Kannada speaking, typically developing children (TDC) and children with SSD in the age range of 4 – 7 years. The secondary aim of the study was to compare the performance across the subgroups of age.

The specific objectives of the study were:

- To compare the scores of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span
- To study the effect of age on the scores obtained by TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span
- To compare the scores of TDC and children with SSD in (a) digit span forward recall (b) digit span backward recall and (c) digit running span across subgroups of age

Participants were divided into two groups of namely clinical group and control group in the age range of 4 to 7 years. The clinical group consisted of 22 children with SSD (12 boys & 10 girls) chosen from a clinical setup and the control group consisted of age matched 30 TDC (16 boys & 14 girls). All the participants recruited in the two groups were native speakers of Kannada and were studying in English medium schools.

The participants were tested individually on three tasks for assessing working memory namely digit span forward recall, digit span backward recall, and digit running span. Two types of scoring were considered for each task i.e., item score and accuracy score. The stimuli consisted of number strings ranging from two digits to ten digits and included numbers from 0 to 9 in English arranged in a random order in each string. Presentation of stimuli and recording of responses were done using the software Smriti Shravan V 1.0 (Kumar & Sandeep, 2013) installed in a laptop. The stimuli were presented in ascending and descending fashion based on correct and wrong responses of the participants respectively. The data obtained was statistically analyzed using SPSS (version 20.0). The results of the present study revealed the following:

- There was a significant difference between TDC and children with SSD in digit span forward recall task both for item scores and accuracy scores. Further, TDC scored higher than children with SSD. However, when comparison was made between corresponding age ranges of TDC and SSD, differences were observed only for 6;1 – 7;0 years of age.
- There was also a significant age effect observed for digit span forward recall in TDC thereby indicating a developmental trend in forward recall abilities. Further, differences were observed mainly between the lowest and the highest

age groups considered for both item and accuracy scores. However, similar findings were not present in children with SSD.

- There was a significant difference between TDC and children with SSD in digit span backward recall task both for item scores and accuracy scores. TDC scored higher than children with SSD.
- Significant effect of age was observed in digit span backward recall task in TDC for only accuracy scores, while in children with SSD it was observed for both item scores and accuracy scores
- Significant difference was observed digit span forward recall and digit span backward recall in terms of accuracy score in TDC but not for item scores. On the other hand, in children with SSD significant differences were found for both item scores and accuracy scores of two tasks.
- A significant difference was observed between item scores and accuracy scores for both tasks in each group of participants. In addition, same findings were observed when sub groups of participants were compared.

Implications of the study

- The current study provides an insight into working memory in children with SSD in Kannada speaking population and their typically developing counterparts. It provides an understanding about how these skills varies with age.
- The present study adds support to the existing literature that children with SSD demonstrate some deficiencies in working memory. Given the fact that working memory contributes to literacy skills and later language development, assessment of the same at an early stage becomes essential. The findings of

this study can be utilized to make suitable changes in the assessment and intervention protocols for children with SSD in order to effectively ameliorate learning issues associated with working memory deficits in children with SSD.

Limitations of the study

- Generalization of the findings should be done with caution owing to small sample size
- Participants in clinical group i.e., children with SSD were not differentially diagnosed as having either articulation disorder or phonological disorder
- All the components of working memory were not evaluated by the tasks included in the present study

Future Directions

- Future research can include a wider age range and a larger sample size in order to generalize results of the current study
- Working memory can be added on to the assessment protocol in children with SSD
- Strategies for improving working memory can be included in intervention protocol for children with SSD.

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