VERBAL WORKING MEMORY AND READING COMPREHENSION OF SYNTACTIC AMBIGUITIES IN TYPICALLY DEVELOPING CHILDREN

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Manasagangothri,

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April, 2018

Certificate

This is to certify that this dissertation entitled **"Verbal Working Memory and Reading Comprehension of Syntactic Ambiguities in Typically Developing Children**" is a bonafide work in part fulfilment for the Degree of Master of Science (Speech- Language Pathology) of the student (Registration No. 16SLP015). 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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Declaration

This dissertation entitled "**Verbal Working Memory and Reading Comprehension of Syntactic Ambiguities in Typically Developing Children**" is the result of my own study under the guidance of Dr. Jayashree C. Shanbal, Reader in Language Pathology; Head, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru (570006) and has not been submitted earlier in any other University for the award of any Diploma or Degree.

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CHAPTER 1: Introduction

Cognitive theorists believe that language is acquired due to cognition and general intellectual processes, that language and cognition can't be two separate entities. Piaget (1936) put forth the cognitive theory of language acquisition in which he opinionated that the development of linguistic expression is due to cognitive processes that underlie it (Language is only one expression of a more general set of cognitive activities and proper development of the cognitive system is a necessary precursor of linguistic expression (Bohannon & Bonvillian, 2005). The knowledge of language is no different from the rest of cognition, and is based on conceptual mechanisms (Perlovsky, 2009). Taking the example of metaphors, not all language is compositional, i.e. not all phrases are constructed from words using the same syntax rules and maintaining the same meanings (Croft & Cruse, 2004; Evans, 2006). Language and cognition is embodied. Cognition is said to encompass the following components- attention, memory, reasoning and logic, problem solving, judgment, evaluation and decision making. In layman terms, cognition consists of general intelligence and abstract thoughts.

Decades of work has gone into researching what is memory, how does it work, what affects memory, how to preserve it, etc. In spite of medico-scientific advances in the present day, the true nature of it still evades scientists. Memory, an essential component of cognition, can be defined as "a lasting representation that is reflected in thought, experience, or behaviour" (Baars & Gage, 2010). Based on the duration of storage and qualitative aspects, the human memory can be broadly classified as follows- sensory memory (lasting for less than 1 second) specific to one sensory modality like audition or vision, short term memory- STM (lasting for around 1 minute) and long term memory-LTM (lasting for a life time). The LTM can then be further divided into declarative and procedural memory, episodic and semantic memory (http://www.human-memory.net)

Atkinson and Shiffrin (1968) proposed a 2 compartment model of memory in which STM acted as a temporary storage compared to the permanent LTM. They assigned the role of the now working memory (WM) to STM for complex activities like problem solving, language comprehension and long term learning (Baddeley & Hitch, 1974). Soon, more research in the field created a need for another workspace that could explain active manipulation of information as well as temporary storage. Thus, Baddeley and Hitch (1974) and Baddeley (1986) proposed a model that added a facet to STM- WM; as STM could not explain these higher mental functions. They claimed that the WM is not a unitary store but instead, consists of a unit called the 'central executive' that acts as the mediator between the 'phonological loop' (PL) and the 'visuospatial sketchpad'(VSS).The PL is responsible for obtaining speech based info from the auditory modality whereas the VSS is responsible for receiving and analysing visual info. Thus, WM came to be described as the process used for temporary storage and manipulation of information.

Comprehension of sentences that have only one explicit meaning becomes fairly straightforward. However, there are certain sentences that have more than one meaning due to its phonology, semantics or syntax structure. These are known as phonological ambiguity, lexical/ semantic ambiguity and syntax ambiguity respectively. Other types of ambiguity are anaphoric ambiguity, non-literal speech and ellipsis. Syntactically ambiguous sentences, also known as amphiboly or amphibology are those that can be interpreted in more than one way due to its syntax (Wikipedia). The intended meaning of the sentence can be understood from contextual cues. For e.g. 'Put the egg in the bowl over the flour'. When an individual comes across such a sentence, parsing or syntactic analysis is done wherein the relationship between the words of the sentence is explored adhering to the rules of grammar. These sentences have multiple parse trees, like, the phrase ‘egg in the bowl’ can be attached to ‘over the flour’ or ‘put the egg’ can be attached to ‘in the bowl over the flour’. The sentence can have two possible meanings when parsing is done differently (the sentence either instructs to ‘put the egg that is there in the bowl’ ‘over the flour’ or ‘put the egg’ on a ‘bowl that is over the flour’). Models were proposed to explain how a listener may comprehend such sentences. The Garden-Path Model (Frazier, 1987) opined that 2 principles guide comprehension when an ambiguity is encountered- 1. Minimal attachment principle dictates that the listener choose the most parsimonious meaning, i.e. syntactic analysis presenting a simple parse tree with minimal nodes. 2. The late closure principle dictates that the parser make an attachment with the phrase being processed currently in order to simplify things (proximity of N-V determines attachment). Another model called the Constraint Based Model (MacDonald et al., 1994; Trueswell & Tanenhaus, 1994) proposed that resolution of ambiguities is a constraint satisfying procedure in which the alternative satisfying the maximum constraints is chosen as the meaning.

Research has suggested that VWM has a pivotal role in comprehension and processing of complex language like syntactic ambiguities, deciphering metaphors, making inferences, etc. Linguistic parsing models like the ones mentioned above attribute the inability to formulate multiple interpretations of temporarily ambiguous sentences/ garden-path sentences to limitations in working memory capacity (e.g. Frazier & Fodor, 1978). Several studies like MacDonald (1989) claim that the inability to determine and process syntactic gaps in ambiguous sentences is because of restricted WM capacity.

CHAPTER 2: Review of Literature

According to Baddeley and Hitch (1974), working memory (WM) refers to the resource used to maintain and manipulate information over brief periods of time. A need for quantification of WM emerged after the existence of such a system was established. Research was done to devise tasks to study WM, the first of its kind dating back to the early 19th century by Wilhelm Wundt. Wundt formulated Digit Span Forward and Backward tasks to initially assess consciousness. Later, scientists linked this ability to recall with working memory. The recall value according to a number of studies is now fixed at 7 +/- 2 (e.g. Glassman et al, 1994). These tasks however, measured only the 'storage' aspect of WM whereas the 'manipulation' aspect got missed out. Also, storage of numbers alone could not predict outcome on language based verbal tasks like reading comprehension. Thus, other tasks like reading span (Daneman & Carpenter, 1980) also came to be devised to test verbal WM (VWM). In the studies reviewed, the task chosen for measuring VWM was the original Reading Span Test (RST) by Daneman and Carpenter (1980) or a similar adapted version. The original RST required the participant to read aloud sets of 2-6 sentences and recall the last word of each sentence at the end of a set in the same order of presentation. Adapted versions had the participant listen to sets of 2-6 sentences of varying lengths and judge whether the sentence was right or wrong. Then, after presentation of a set, the participant had to recall the last word of each of the sentences in any order. Turner and Engle (1989) made slight changes to the RST wherein a simple digit or word span was assessed in the background while the individual performs a processing task. Finally, to rule out individual differences in reading ability, the word span was replaced with alphabet span wherein the participants had to recall single letters presented alternately with sentences after judging the sentence for its semantic and syntactic accuracy (Kane et al., 2004). This task had the same premise as that of operation span or counting span that WM is taxed for storage in the light of a distractor task to engage executive attention processes. Oswald et al. (2014) generated a computer-based RST on the same lines for their study.

Research has established that there is a linear increase in VWM scores as age increases. However, there are only a few articles that have examined the developmental trend in VWM in the age group that was chosen in the present study. In one such study, Isaacs and Vargha-Khadem (1989) used digit forward and backward spans to test for VWM scores in children from 7-15 years of age. The results of their study revealed that there was a developmental progression of scores as age increased. Similarly, Gathercole et al. (2004) discuss the trend of WM in children from 4 to 15 years of age. The authors aimed to assess all the three subsystems of the WM model given by Baddeley and Hitch (1974) namely the CE, PL and VSS. They used the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) which had tests like word and non-word list recall, Visual Patterns Test, block recall, etc. They tested 700 children and found out that the basic structure of WM starts functioning by the age of 6 years and. These structures undergo expansion and refinement as age progresses and continue to grow through school years up to adolescence.

A similar progressive trend is also observed in the development of sentence ambiguities. A study done by Shultz and Pilon (1973) investigated the developmental pattern of comprehension of phonological, lexical and syntactic ambiguities (deep and surface structure) in children from 6 to 15 years of age. Results revealed that the ability to comprehend surface and deep structure syntactic ambiguities occurred only after age of 12 years. Even older children resolved phonological and lexical ambiguity significantly better than syntactic ambiguity. It has been proven by research that phonological and lexical processes emerge before syntactic processes and are thus executed earlier than the latter. Evidence supporting the above claim is provided by authors like Chomsky (1969) and Macnamara et al. (1972). Studies in adults also illustrate a similar trend. A study done by MacKay and Bever (1967) on undergraduate students suggested that adults also resolved lexically ambiguous sentences more easily than syntactically ambiguous sentences.

Now, a question can be posed as to how memory, especially VWM, influences language production and comprehension. Reading is one modality used frequently by the literate population to grasp linguistic skills. The act of reading is complex and requires the amalgamation of higher cognitive skills. The processes encompassed by reading involve identification of individual letters and words, decoding their meanings and storing it in memory to subject it to inference and interpretation. These processes can be categorised as bottom-up and top-down processes based on the flow of information and are said to function simultaneously for efficient comprehension. Baddeley et al. (1985) carried out a study in which the findings reported working memory span to be a significant predictor of reading fluency and reading comprehension. Findings have also suggested that for children with written language disability, procedures that clarify the relationship between working memory and language performance could have important clinical and research implications (Gaulin & Campbell, 1994). Engelhardt (2016) reported that sentence comprehension and its relation to VWM is the most researched among domains of executive function. In his study, results showed that high level of intelligence and processing speed correlated with resolution of syntactic ambiguities. These type of sentences require the engagement of higher cognitive processes and demand high language abilities. Lethlean and Murdoch (1997) described High Level Language (HLL) as language abilities requiring extensive linguistic and other cognitive processes. Cognitive abilities that are crucial for HLL production are attention, working memory and executive functions such as problem-solving and ability to plan (Lewis et al., 1998). Antonsson et al., (2016) conducted a study involving healthy adults from 20 to 79 years. They aimed to find the nature of performance of participants between VWM tasks and tasks assessing HLL. They used digit forward and backward span as a measure of VWM and compared it with performance on tasks like repetition of long sentences, comprehension of lexical and syntactic ambiguity, metaphor inferences, etc. They found robust correlation of VWM with HLL apart from factors like education that had an overall influence on test results. Authors explain that when a sentence having simple semantics and syntax is encountered, there is negligible role of VWM in its comprehension. However, when the syntactic structure of a sentence is complex, the VWM system behaves as a backup to store and interpret information during linguistic processing (Gathercole & Baddeley, 1993).

On similar lines, other authors like Caplan and Waters (1999) bestow the role of a control mechanism to VWM during complex sentence analysis. VWM was studied to be essential to the execution of complex language tasks (Nadeau, Rothi & Crosson, 2000). Studies have also positively correlated VWM with cognitive control in interpretation of garden-path sentences (e.g. Vuong & Martin 2013). Fedorenko, Gibson and Rhode (2006) also reported similar findings that VWM resource pools are important for online linguistic processing. Extensive research in this field has ascertained that VWM helps a listener to make sense of a sentence by storing individual pieces of it to rapidly process end to end information before it decays (Lewis et al., 2006). Increased capacity of VWM determines higher scores on a standardized reading test as it helps to encode and retrieve info from LTM that is stated explicitly in the text while simultaneously making inferences from the derived info (Masson & Miller, 1983). Daneman and Carpenter (1980), in their study, reported a high positive correlation between scores on the RST and reading comprehension. The Speaking Span Test (Daneman & Green, 1986) assessed the capacity of VWM for sentence production. It required participants to make sentences out of increasingly longer sets of unrelated words they saw on the computer screen. In the same study, the authors also used a similar version of the RST to judge novel word comprehension ability in adult readers. Results suggest that individuals with smaller VWM capacities spend most of their resources to reading process and don't have any left to integrate relevant contextual cues in order to derive meaning of a novel word. During sentence comprehension, the listener or reader first has to recognize each word of a sentence, determine the syntactic and semantic relationship between these words and then interpret the intended meaning. Similarly, while reading a passage, VWM aids the reader in encoding new information whilst incorporating relevant, previously known data stored in the LTM. This ensures that coherence is maintained throughout (Kintsch & Van Dijk, 1978; Carpenter & Just, 1977; Haviland & Clark, 1974). Ericsson and Kintsch (1995) predict a long-term working memory (LT-WM) that plays a pivotal role in cognitively loaded activities like text comprehension. When it comes to child readers, data available is more variable. Inference making, comprehension monitoring and understanding text structure are skills that make up performance on a reading comprehension task (Cain et al., 2004). Each of the skills are underpinned by several sub-skills in children. Similar to adult data, children with lower VWM spans use up most of their resources on the process of reading to end up with little usable capacity for arriving at a conclusion by integrating past information (Curtis, 1980; Hannon & Daneman, 2001; Perfetti,1985).

Some other factors apart from VWM have been discussed by authors to be influencing language processing tasks. Authors suggest that word reading is the best predictor of reading abilities in formative years (Juel et al., 1986) with contradicting data available in some studies. Just and Carpenter (1992) identified that size of vocabulary and motivation can have significant contributions to way a child makes sense of language input. On similar lines, Sternberg and Powell (1983) have commented that reading comprehension correlates well with vocabulary size. Cain et al. (2004) report that age, vocabulary, practice, verbal IQ and word knowledge have an impact on reading comprehension tasks other than VWM capacity. The same authors also assert that when verbal ability and word reading skill have been accounted for, variable capacity of VWM explains the differential performance in reading comprehension by 8 to 11 year old children. Oakhill, Cain and Bryant (2003) and Seigneuric, Ehrlich, Oakhill and Yuill (2000) reported that both number and word span in children contribute to their reading comprehension abilities. Consistent with the above findings, Daneman and Green (1986) conducted a study in which they correlated VWM measures using the original RST (Daneman & Carpenter, 1980) with a 'Contextual Word Comprehension Task' that tested for novel word comprehension. The authors reported that persons with a low VWM capacity were less capable that persons with a high VWM capacity to interpret words with information from the surrounding context.

Globalization has led to many children learning more language(s) apart from their native language (L1). It is only rational to assume that a test of VWM in their L2 (second learnt language) will have analogous correlation with reading comprehension in L2. The proficiency in L2 plays an important role in determining the trade-off between the processes used for the physical act of reading and the higher-level act of making semantic and syntactic inferences. Clear differences have been identified in skilled v/s unskilled readers. The unskilled readers devote maximum resources to decoding graphic cues in a given text and have very less residual resources to devote to making inferences. Skilled readers on the other hand, use very little resources to activate the bottom-up processes in the act of reading and utilise a greater chunk to carry out higher level processing, making them good readers. In such a study, Harrington and Sawyer (1992) assessed the relationship between VWM and reading comprehension on adults who had Japanese as L1 and English as their L2 (English as second language or ESL). These adults had moderate to advanced skills in English as assessed by their scores on the Test of English as a Foreign Language (TOEFL). The authors used the original RST (Daneman & Carpenter, 1980) as a measure of VWM and Grammar and Reading sections from TOEFL along with a cloze passage to measure reading comprehension. The results of the study disclosed that subjects with a larger VWM capacity scored higher on reading comprehension tasks compared to subjects with low scores on VWM task. This was consistent with previous results predicting performance in reading comprehension using VWM measures.

Research has been done to identify the task best suited for taxing the VWM system in individuals to predict performance on tasks involving reading or listening comprehension. Daneman and Carpenter (1980) stated that simple tasks like digit forward and backward spans showed a poor correlation with functioning on linguistically loaded tasks as they didn't challenge the VWM system enough on its processing and maintenance domains. Only a task that would be heavily demanding on these domains will elicit a stark trade-off between them and thus differentiate between individuals with low and high VWM capacity. Thus, the authors devised the RST as a measure of VWM and found out that it had high positive correlations with scores on a reading comprehension test used in their study. This study was however conducted in 'bright' undergraduate students and information for a younger age group is not available. Likewise, a meta-analytic study done by Daneman and Merikle (1996) supported their hypothesis that measures such as reading span or listening span that tax both storage and processing aspects of WM are better predictors of language comprehension than tasks that measure only storage capacity of WM. King and Just (1991) conducted a study with undergraduate college students in which the original RST was used as a measure of VWM and compared with performance of the participants on a measure of comprehension of syntactically complex sentences (object relative sentences) like 'the reporter that the senator attacked admitted the error'. The author categorised readers as High Span, Low Span and Medium Span. He defined the reading span as the "size of the largest set for which the subject had perfect recall for final words in three out of five sets of that size". High span readers obtained a score of 4 or more on the RST, medium span readers obtained a score of 3 to 3.5 and low span readers obtained a score of 2 or lesser. Results indicated that low span readers had poorer comprehension of syntactically ambiguous sentences compared to their age matched peers with high reading spans. Waters (1996) carried out a study to determine the reliability of the original RST (Daneman & Carpenter, 1980) and compared it with standardised measures of reading comprehension. She stated in her report that although the original RST (Daneman & Carpenter, 1980) was designed for assessing the storage-recall and processing aspects of VWM, it actually measures only the former. In such a task, the trade-off between the two facets becomes cumbersome to comment upon. She suggested that reading span tasks are rendered inadequate for predicting performance on a reading comprehension task unless both components of VWM are not appraised. Nonetheless, analysis of data also showed that the processing aspect of the RST correlated best with operation on the reading comprehension task with a small contribution observed from the recall component as well. She also made a comment stating that the modality used for administering the RST (reading or listening) will influence the score obtained by the individual on VWM and hence, prediction for a language comprehension task will accordingly vary.

One of the most highlighted works exploring the relationship between VWM and comprehension of syntactic ambiguities is by MacDonald, Just and Carpenter (1992). They propose the 'Capacity Constrained Parsing Model' in which resolution of an ambiguity is explained by way of having multiple representations. These representations are said to be based on the alternative syntactic analyses of the sentence. The model postulates that multiple representations are formulated for both high and low span readers but the maintenance of these representations is decided by individualistic WM capacities. Now, among these representations, there is one that is grammatically simpler, pragmatically more appealing, contextually favourable and more frequently encountered. Such a representation is held at a higher activation level by the individual as compared to the one which is lesser preferred in all the mentioned aspects (e.g. Carpenter and Daneman, 1981). A low span reader, doesn't have the necessary capacity to withhold multiple representations in his/her VWM and thus is more likely to make errors while comprehending an ambiguous sentence. Although such individuals may produce multiple analytic by-products from the sentence, their VWM capacity doesn't permit them to store the by-products for an extended period as the sentence is read further. Both high and low span readers are said to perform similarly if the ambiguity resolution has to be done with the more preferred interpretation. Nevertheless, when the ambiguity has to be resolved with the lesser preferred meaning, only a high span reader will be able to do so accurately. Thus, the authors report that only high span readers are 'affected by ambiguity' unlike their low span counterparts.

This model also discusses on the downside for the high span reader for holding multiple parse trees. The authors opine that since multiple representations are stored in their VWM, the trade-off between processing and storage gets affected. There are lesser resources to spare to execute comprehension of higher language. It is hypothesised that a high span reader delays such an execution until disambiguating information is reached in the sentence, consequently increasing time for processing of the ambiguity even if it is done accurately. In case of low span readers, since there is only a single parse tree in memory, they can utilise the freed up VWM resources for analysis after the point of disambiguation. This model supports the hypothesis that an individual's VWM potential decides the acuity with which an ambiguity can be analysed and that whether he/she will be able to store multiple representations that are a product of this analysis. This demonstrates that person to person variations in VWM determine single/ multiple outcomes of ambiguity processing and thus difference in their comprehension. The authors have included a note that semantic, syntactic and pragmatic factors stand to contribute to ambiguity resolution along with the number of times an individual has been exposed to such types of sentences. To conclude, the model also claims time and accuracy to be a function of the individual's VWM capacity and their ability to resolve sentence ambiguity.

It has now been elucidated that individualistic VWM capacity is a determinant of the ability to resolve complex language tasks like syntax ambiguities and that a higher score for VWM will consequently express itself as higher scores on a linguistically loaded activity. However, there is an alternative approach that has been proposed by a study done by Turner and Engle (1989). They report that the resource of

WM should not ideally be task dependent for predicting higher cognitive abilities as a good reader will have a greater WM pool than a poor counterpart. Thus, a memory span task can be embedded in a processing task that doesn't tap on a specific measure and still predict success on a higher level task. Older children who attend school are bombarded with a gamut of reading comprehension tasks that require constant engagement of their higher cognitive skills like VWM to assimilate and process the input accurately. At around the same time, they also develop the habit of reading for leisure. Books and magazines are a rich source of syntactic ambiguities in the form of jokes, metaphors and proverbs. Older children thus need to increase their VWM pools to accommodate the complex linguistic processing they encounter in learning. These parameters need to be explored in school going children to study if they can be predictors of any form of language based learning disabilities or indicate inefficient language processing. Hence there is a need to study the relationship between VWM and resolution of syntactic abilities in this age group.

Aim of the study

The primary aim of the study was to explore the relationship between verbal working memory and resolution of syntactic ambiguities on reading comprehension in English speaking typically developing older school-going children.

The objectives of the study were as follows:

- To study the performance of typically developing older children on VWM in English.
- To study the performance of typically developing older children on reading comprehension of syntactically ambiguous sentences in English.
- To study the relationship between VWM and reading comprehension of syntactically ambiguous sentences in English.

The hypotheses of the study were as follows:

- There is no significant difference in the performance of typically developing older children in verbal working memory in English
- There is no significant difference in the reading comprehension of syntactic ambiguities in typically developing older children in English.
- There is no significant difference between the reading comprehension of syntactic ambiguities and verbal working memory ability in typically developing older children in English.

CHAPTER 3: Method

The primary aim of this study was to explore the relationship between verbal working memory (VWM) and resolution of syntactically ambiguous sentences on reading comprehension in English speaking older school going children. The present study followed a between groups correlational research design to compare the capacity of VWM and resolution of syntactically ambiguous sentences on reading comprehension in typically developing English speaking school going children.

3.1 Participants

A total of seventy-seven (77) typically developing children were chosen from grades 8th ($13.0 \leq A \leq 14.0$ years), 9th ($14.0 \leq A \leq 15.0$ years) and 10th ($15.0 \leq A \leq 16.0$ years) where 'A' is the age of the child. Thirty participants in each group with equal number of males and females were targeted initially for data collection. However, due to subject attrition, data only from the mentioned number of participants could be analysed. These were randomly chosen from English medium schools (state, central and international syllabus) in Bangalore and Mysore, Kannada being their native language. Table 3.1 shows the participants' age and gender selected for the present study.

Table 3.1

Age and gender of participants included in the study.

Age range (in years)	**No. of Children**	
	Males	**Females**
≥ 13.0 to ≤ 14.0	13	13
≥ 14.0 to ≤ 15.0	12	12
≤ 15.0 to ≤ 16.0	12	15
Total	**37**	**40**

Participant selection criteria

All the participants in the study had Kannada as their native language and English as second language. An informed consent was obtained from the class teacher and Principal of the school or the parent with prior information about the purpose of the study. None of the participants had any history of speech, language or hearing impairment according to the ICF-CY Checklist (WHO Work Group, 2003). Participants had normal or corrected to normal vision. All participants were attending regular English medium schools and were proficient in English language (obtained a score of ≥ 4 on the ISLPR checklist of Ingram, 2006 or answered 'most of the time' for > 50% of the questions in the Language Use Questionnaire (Shanbal & Prema, 2007)

3.2 Test Material

The Reading Span Test (RST) was adapted for the mentioned population from the complex RST (Oswald et al., 2014). Fifty English sentences of approximately 12-14 words each were chosen from story books/ novels and text books read commonly by students of 8^{th} to 10^{th} grade. Numbers from 0 to 9 were included to be added in the RST (Appendix I).

For the Syntactic Ambiguity Resolution Test (SART), 17 ambiguous sentences were taken from books and internet sources and modified to suit the mentioned Indian population. 13 control sentences were also formulated similarly (Appendix II).

All sentences in RST and SART were subject to judgement based on 2 parameters- 'appropriateness' and 'difficulty'. The stimulus was given to 3 experienced Speech-Language Pathologists (SLPs) for validation on the same parameters. 'Difficulty' was rated on a 4 point Likert scale 1- very difficult to 4- easy whereas 'appropriateness' was rated on a 7 point Likert scale 1- absolutely inappropriate to 7-absolutely appropriate. Stimuli that were rated from 1-3 for 'appropriateness' and 1-2 on ‘difficulty’ were modified and given for validation again till they were scored as 4-7 in ‘appropriateness’ and 3-4 in ‘difficulty’ categories respectively.

3.3 Instrumentation

A 15.5 inch Sony Vaio laptop was used to conduct the RST part of the study. The PsychoPy software, version 1.85.6 (Pierce, 2007) was used for programming the RST stimuli. It is a freely downloadable application that was programmed to give reaction time and accuracy. The other experiment (SART) was a reading comprehension test and was conducted in printed form on A4 size sheets of paper.

3.4 Procedure

Informed consent was taken from the parents/ teachers of the students before testing and the protocol adhered to the AIISH ‘Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects’’. The testing was carried out in a well lit room, with minimal environmental noise during day time.

The RST had two types of sentences- semantically correct and semantically incorrect. The participants were seated comfortably and the distance between the laptop screen and them was approximately 30 cms for ease of pressing keys. As mentioned earlier, stimuli presentation was controlled by the PsychoPy software, version 1.85.6 (Pierce, 2007). All sentences included were syntactically correct. The test involved presentation of alternate sentences and single digit numbers (0 to 9) that lasted on the screen for 5 seconds each. Initially, it was decided to have presentation of English alphabets in random order after each sentence instead of numbers. However, during pilot testing, it was noted that the participants found it cumbersome to memorise alphabets, given that 26 options could be possible. Thus, numbers from 0-9 were utilised to make the task easier. These were presented in Arial, size 0.1 (PsychoPy units), left aligned in black text on a white background. The position of a sentence and digit was marked by a plus (+) sign appearing at the centre of the screen for 0.5 seconds. The participant was instructed to read the sentence, ascertain its veracity and press the ‘Y’ key on the keypad if the sentence was semantically accurate and press ‘N’ if otherwise. For their response to be recorded, they were instructed to press either of the keys before or until the sentence remained on the screen. Responses after the sentence disappeared weren’t recorded by the software. The participants were directed to place two fingers simultaneously on the mentioned keys for achieving the task in the limited time. The number that followed each sentence was instructed to be memorised for recall in the same order when prompted. Sentences and numbers were arranged in sets of 3 to 7, each set having 2 trials and programmed to be presented in random order to every student. For e.g. set of 3 consisted of 3 sentences alternated with 3 numbers. Each set had randomly arranged semantically correct and incorrect sentences. After completion of a set, the screen prompted the participant to ‘recall numbers and type’. The time given to recall and enter the digits was infinite. The student was instructed to press the ‘enter’ key on the keyboard for the next sequence to begin soon after.

In the SART, as mentioned, there were 17 ambiguous sentences and 13 unambiguous sentences that acted as the control. These were arranged in random order and printed on A4 size sheets in ‘Arial’ font type and ‘14’ font size. Each sentence was followed by a polar question relating to the meaning of the sentence. For the ambiguous sentences, the question pertained to the less common among the 2 possible meanings. The participants were instructed to read the sentence and answer the question only as either ‘yes’ or ‘no’. They were also instructed to avoid interpreting the sentences logically or literally. There was no time limit given to them for completion. Before starting the test, the participants were given an explanation of an example of an ambiguous sentence, how it can be interpreted in more than one way and also of an unambiguous sentence and its interpretation. An example of an ambiguous sentence and its question in SART is as follows- ‘the thief threatened the student with a knife. Did the student have the knife?’. This sentence can mean either that ‘the thief had the knife with which he threatened the student’ or ‘the thief threatened the student who had a knife’. The answer to this question will be ‘yes’. An example of a control (unambiguous) sentence in SART is- ‘I saw a man on the mountain who had a telescope. Did I have the telescope?’. The answer to the question will be ‘no’ as the sentence has only one meaning that ‘only the man had the telescope’. The participant was allowed to change his/her response by scratching off the previously written one.

3.5 Scoring and analysis

The responses for the RST recorded in Excel format for each participant by PsychoPy software (Pierce, 2007) were analysed. For the RST, scoring was done differently for the sentences and numbers. For the former, if the participant verified the sentence correctly by pressing the correct key, he/she was scored ‘1’ point. For an incorrect response, ‘0’ points were given. For the numbers, every correct recall (all the numbers in the presented order) was given a score of ‘1’. For an incorrect recall (missing numbers or different order), 0 score was given. Thus, the RST was scored out of 60 points (50 for sentences- 1 each and 10 for numbers- 1 for each trial, 10 such trials). For the SART, the participant was given a score of 1 for each correct response and a score of 0 for every incorrect response.

The data was tabulated and subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS) version 21.0

CHAPTER 4: Results

The primary aim of this study was to explore the relationship between Verbal Working Memory (VWM) and resolution of syntactically ambiguous sentences on reading comprehension in English speaking older school going children. Seventy-seven typically developing children (37 males and 40 females) across 8^{th}, 9^{th} and 10^{th} grades participated in the study. VWM was assessed using a software based task of the Reading Span Test (RST) and performance on reading comprehension of syntactically ambiguous sentences was measured using a written test- Syntactic Ambiguity Resolution Test (SART).

Descriptive statistics was used to compute mean, median and standard deviation (SD) values for the participants across grades and gender. Shapiro-Wilk's test was used to check for normality. However, the test revealed that the data followed non-normal pattern of distribution. The participant showed ceiling effect and removal of outliers was not possible. Thus, it was decided to use non-parametric tests to infer the relationship between VWM and the resolution of syntactic ambiguities. Mann-Whitney U Test was administered to find whether there was a difference in performance between males and females on the above-mentioned parameters in each grade. Results revealed that the performance of participants was similar between males and females. Hence, a gender-wise difference was not observed for the VWM task on 8^{th} grade (/z/= 0.284, $p>0.05$), 9^{th} (/z/= 1.16, $p>0.05$) and 10^{th} grade (/z/= 0.59, $p>0.05$). No gender-wise differences were observed on resolution of syntactic ambiguities task for 8^{th} grade AMBR (/z/= 0.602, $p>0.05$) and UNAMBR (/z/= 0.134, $p>0.05$), for 9^{th} grade AMBR (/z/= 0.089, $p>0.05$) and UNAMBR (/z/= 0.122, $p>0.05$) and for 10^{th} grade AMBR (/z/= 0.397, $p>0.05$) and UNAMBR (/z/= 0.491, $p>0.05$). Thus, gender as a variable was combined and Kruskal-Wallis test was done to compare the performance of participants across the three grades without gender being considered as a contributing factor. Mann-Whitney U Test was further used to find pair-wise differences of performances of students between two grades (8^{th}v/s 9^{th}, 9^{th}v/s 10^{th} and 8^{th}v/s 10^{th}). Pearson's Correlation was used to find out whether there was a significant correlation between VWM task and resolution of syntactic ambiguities in participants across grades.

The results of the study are delineated under the following sections:

4.1 Performance of the participants from 8^{th}, 9^{th} and 10^{th} grades on Verbal Working Memory (VWM) task

4.2 Performance of the participants from 8^{th}, 9^{th} and 10^{th} grades on resolution of syntactically ambiguous sentences

4.3 Relationship of VWM and resolution of syntactically ambiguous sentences

4.1 Performance of the participants from 8^{th}, 9^{th} and 10^{th} grades on VWM

Descriptive statistics was used to calculate mean, median and SD values for responses of the participants on each of the trials for sentences and numbers on RST as a measure of VWM. E.g. response for 1^{st} trial for set of 3- sentences and numbers, response for 2^{nd} trial for set of 3- sentence and numbers and so on. These values were calculated across grades and gender. Table 4.1 shows mean, median and SD measures for performance of children in the 8^{th}, 9^{th} and 10^{th} grades on VWM task.

Table 4.1

Mean, median and SD values of 8^{th}, 9^{th} and 10^{th} grades on VWM task

Components	Grade	N	Mean	Median	SD
STOTAL	8	26	36.19	36.00	2.36
STOTAL	9	24	34.50	34.50	8.63
STOTAL	10	27	38.11	40.00	4.66
NTOTAL	8	26	3.96	4.00	1.50
NTOTAL	9	24	4.79	4.50	2.10
NTOTAL	10	27	6.74	7.00	1.89
SNTOTAL	8	26	40.19	40.00	3.22
SNTOTAL	9	24	39.29	41.00	9.27
SNTOTAL	10	27	44.85	46.00	5.16

Note: *STOTAL- total score obtained on sentence trials on VWM task, NTOTAL- total score obtained on number trials on VWM task, SNTOTAL- total scores of sentence and number trials combined*

As indicated in the table 4.1, on STOTAL, the participants in the 10^{th} grade (Median= 40.00, SD= 4.66) showed a better performance, followed by 8^{th} grade (Median= 36.00, SD= 2.36) and then by 9^{th} grade (Median= 34.50, SD= 8.63). On NTOTAL, the participants in the 10^{th} grade (Median= 7.00, SD= 1.89) showed a better performance than the 9^{th} grade (Median= 4.50, SD= 2.10) and the 8^{th} grade (Median= 4.00, SD= 1.50). Similarly, on SNTOTAL, participants in the 10^{th} grade (Median= 46.00, SD= 5.16) showed better performance, followed by 9^{th} grade (Median= 41.00, SD= 9.27) and then by 8^{th} grade (Median= 40.00, SD= 3.22). Figure 4.1 represents the performance of participants on SNTOTAL across grades.

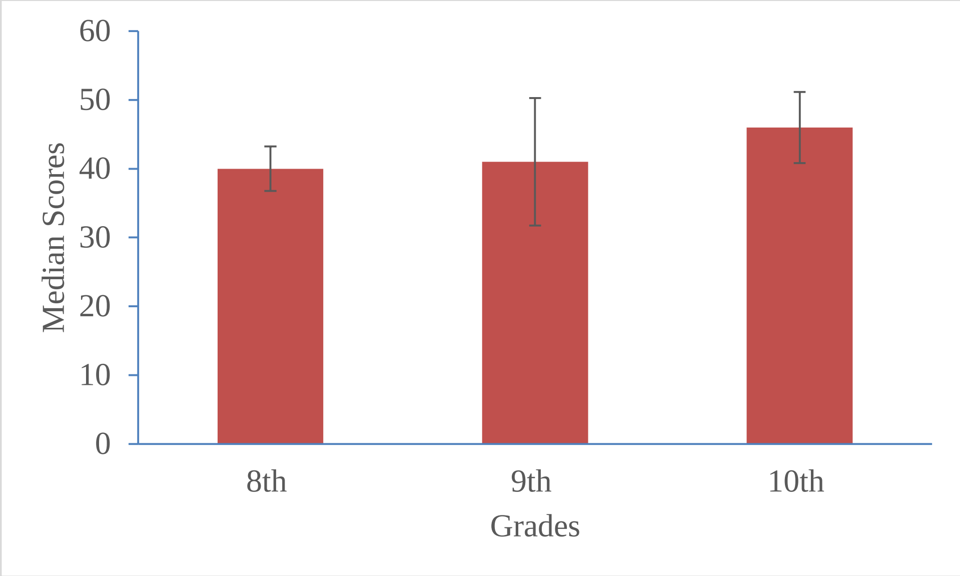

Figure 4.1: Performance of participants for SNTOTAL on VWM task across grades

Analysis of results of Mann-Whitney U Test revealed that there was a significant difference between performances of students between 8th and 10th grade (/z/= 3.372, $p<0.05$) and 9th and 10th grade (/z/= 1.977, $p<0.05$). There was no significant difference between performances of participants between grade 8th and 9th (/z/= 0.36, $p>0.05$) on the VWM task.

Analysis of results of Kruskal-Wallis test gave the following values for STOTAL (χ^2=4.373, $p>0.05$), for NTOTAL (χ^2=22.812, $p<0.05$) and for SNTOTAL (χ^2= 9.901, $p<0.05$) suggesting that there was an overall significant difference between grades on VWM task. A developmental trend was observed among participants from 8th to 10th grade.

4.2 Performance of the participants from 8th, 9th and 10th grades on resolution of syntactically ambiguous sentences

Descriptive statistics was used to calculate mean, median and SD values for responses of the participants on resolution of syntactic ambiguities task across grades.

Table 4.2 shows the mean, median and SD values of the participants from 8^{th}, 9^{th} and 10^{th} grades

Table 4.2

Mean, median and SD values of 8^{th}, 9^{th} and 10^{th} grades on resolution of syntactic ambiguities task

Components	Grade	N	Mean	Median	SD
AMBR	8	26	13.35	13.00	1.57
AMBR	9	24	14.00	14.00	1.50
AMBR	10	27	13.96	14.00	1.58
UNAMBR	8	26	11.88	12.00	1.14
UNAMBR	9	24	11.96	12.00	0.86
UNAMBR	10	27	12.41	13.00	0.75

Note: *AMBR- number of correct responses obtained for resolving syntactically ambiguous sentences, UNAMBR- number of correct responses obtained for resolving syntactically unambiguous (control) sentences*

Analysis of results from table 4.2 revealed that for AMBR, the participants from 9^{th} (Median= 14.00, SD= 1.5) and 10^{th} (Median= 14.00, SD= 1.58) showed similar performance. Participants from 8^{th} grade (Median= 13.00, SD= 1.57) showed poorer performance in AMBR. For UNAMBR, participants in the 8^{th} (Median= 12.00, SD= 1.14) and 9^{th} (Median= 12.00, SD= 0.86) grades showed similar performance. Participants in 10^{th} (Median= 13.00, SD= 0.75) grade showed better performance than 8^{th} and 9^{th} grades. Figure 4.2 represents the performance of participants on AMBR across grades.

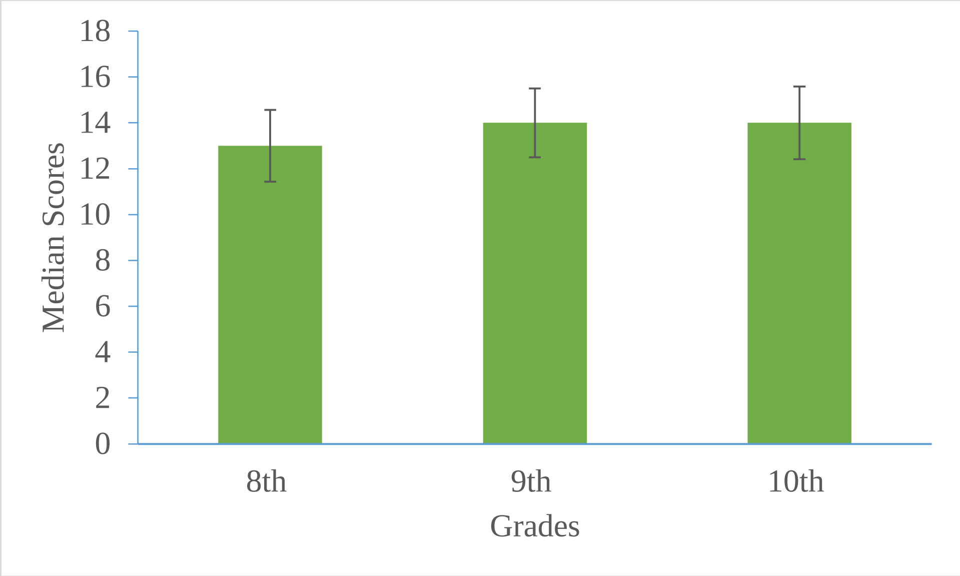

Figure 4.2: Performance of participants on AMBR in resolution of syntactic ambiguities task across grades

Analysis of results of Kruskal-Wallis Test showed that there was no significant difference between the grades on resolution of syntactic ambiguity task; AMBR (χ^2= 2.481, p>0.05) and UNAMBR (χ^2= 4.351, p>0.05)

4.3 Relationship of VWM and resolution of syntactically ambiguous sentences

Tables 4.3.1, 4.3.2 and 4.3.3 show the correlation co-efficient values between different components in the VWM task and resolution of syntactic ambiguities task as measured by the Pearson's Test of Correlation in 8th, 9th and 10th grade respectively. SNTOTAL was calculated by adding the scores obtained by the participant on STOTAL and NTOTAL. Thus, SNTOTAL was the total score obtained by a participant on the VWM task.

Table 4.3.1

Correlation co-efficient values between components of VWM task and syntactic ambiguities resolution task in 8^{th}grade

	VWM	AMBR	UNAMBR
VWM	1.0	0.467^{*}	0.354
AMBR	0.467^{*}	1.0	0.535^{**}
UNAMBR	0.354	0.535^{**}	1.0

Note: VWM- total scores obtained in VWM task, AMBR- number of correct responses obtained for resolving syntactically ambiguous sentences, UNAMBR- number of correct responses obtained for resolving syntactically unambiguous (control) sentences
** p<0.05*
*** p<0.01*

Table 4.3.2

Correlation co-efficient values between components of VWM task and syntactic ambiguities resolution task in 9^{th} grade

	VWM	AMBR	UNAMBR
VWM	1.0	0.265	0.018
AMBR	0.265	1.0	0.606^{**}
UNAMBR	0.018	0.606^{**}	1.0

Note: VWM-total scores obtained in VWM task, AMBR- number of correct responses obtained for resolving syntactically ambiguous sentences, UNAMBR- number of correct responses obtained for resolving syntactically unambiguous (control) sentences
** p<0.05*
*** p<0.01*

Table 4.3.3

Correlation co-efficient values between components of VWM task and syntactic ambiguities resolution task in 10^{th} grade

	VWM	AMBR	UNAMBR
VWM	1.0	0.480*	0.305
AMBR	0.480*	1.0	0.404*
UNAMBR	0.305	0.404*	1.0

Note: VWM- total scores obtained in VWM task, AMBR- number of correct responses obtained for resolving syntactically ambiguous sentences, UNAMBR- number of correct responses obtained for resolving syntactically unambiguous (control) sentences

* *p<0.05*

** *p<0.01*

Analysis of results on Pearson's Correlation revealed that there was a significant correlation between performance of participants on VWM task and resolution of syntactically ambiguous sentences task in the 8^{th} grade (r=0.467, $p<0.05$) and in the 10^{th} grade (r= 0.48, $p<0.05$). There was no significant correlation between performance of participants on VWM task and resolution of syntactically ambiguous sentences task in the 9^{th} grade (r= 0.265, $p>0.05$).

Analysis of results on Pearson's Correlation also revealed that there was a significant correlation between performance of participants on VWM task and resolution of syntactically ambiguous sentences task across grades (r= 0.335, $p<0.01$). Table 4.3.4 shows the correlation co-efficient values between VWM task and components of syntactic ambiguities resolution task across grades

Table 4.3.4

Correlation co-efficient values between components of VWM task and syntactic ambiguities resolution task across grades

	VWM	AMBR	UNAMBR
VWM	1.0	0.335**	0.227*
AMBR	0.335**	1.0	0.511**
UNAMBR	0.227*	0.511**	1.0

Note: VWM- total scores obtained in VWM task, AMBR- number of correct responses obtained for resolving syntactically ambiguous sentences, UNAMBR- number of correct responses obtained for resolving syntactically unambiguous (control) sentences

* $p<0.05$

** $p<0.01$

To summarise, the findings of the study under discussion revealed that there was a linear increase in VWM scores as age increased from 8th to 10th grade. Participants showed similar performance in resolution of syntactic ambiguities task across grades. There was a significant positive correlation between scores on VWM and scores on resolution of syntactically ambiguous sentences task in participants of 8th and 10th grade. There was an overall significant positive correlation between performance in VWM task and resolution of syntactic ambiguities task across the three grades. No gender-wise difference was observed in both the tasks across grades.

CHAPTER 5: Discussion

The aim of the present study was to compare the performance of English speaking older school-going children between a Verbal Working Memory (VWM) task and the resolution of syntactically ambiguous sentences in English. The findings of the study have been elaborated under the following sections:

5.1 Performance of the participants on Verbal Working Memory (VWM) task

5.2 Performance of the participants on resolution of syntactically ambiguous sentences

5.3 Relationship of VWM and resolution of syntactically ambiguous sentences

5.1 Performance of the participants on Verbal Working Memory (VWM) Task

The findings of the current study revealed that there was an overall progression of scores on the VWM task from 8th to 10th grades and there was no difference in performance between male and female participants across grades. The results also revealed that there was a significant difference among performances of students between 8th and 10th grades wherein students of 10th grade performed better than the students in 8th grade and between 9th and 10th grades wherein the latter performed better than the former. These results are indicative of a developmental trend where scores on a VWM task increase as a function of age. Such a developmental progression was observed in a study done by Isaacs and Vargha-Khadem (1989) in which the authors investigated spatial and verbal memory spans in children from 7 to 15 years of age and found that scores for WM increase with increasing age. A study done by Gathercole et al., (2004) also supports this trend wherein they found a developmental pattern of working memory (WM) in children from 4 to 15 years of age. The authors targeted verbal complex WM span and assessed each component of the tripartite model of the

WM given by Baddeley and Hitch in 1974. It was initially thought that the central executive (CE) capacity alone was responsible for performance on such a task. However, recent evidences contradict earlier research. It is now stated that the CE is responsible only for the processing aspect whereas the phonological loop (PL) capacity decides the storage aspect in a verbal complex WM span task (Lobley, Gathercole & Baddeley, 2003). They suggested that the neuroanatomical areas associated with the CE, more specifically, the pre-frontal cortex, undergoes development that starts at birth and continues up to adolescent ages (Nelson et al., 2000). Thus, as a child grows older, his processing abilities become better and compensation for reduced storage abilities provided by the PL and visuo-spatial sketchpad (VSS) becomes possible. An efficient WM system, wherein the CE controls its slave systems (PL and VSS) with stronger inter-dependencies is hence seen in older children. Gathercole et al., (2004) found a linear increase in performance of children on WM tasks from the age of 4 through 15 years. This trend remained consistent across all 3 components (CE, PL and VSS) of the WM model by Baddeley and Hitch (1974). The authors also report that the consistency with which these components function across the 4 to 15 years span and its early resemblance to the adult tripartite WM model are testaments to the fact that short-term memory subsystems analogous to the three components CE, PL and VSS are functional by at least the age of 6 years.

The findings of the study also revealed that there was no significant difference found in the performance of students between 8^{th} and 9^{th} grade. Statistical analysis of normality revealed that participants from the 9^{th} grade demonstrated either a floor effect, i.e. their performance was similar to participants in the 8^{th} grade or a ceiling effect, i.e. their performance was similar to participants in the 10^{th} grade. Greater floor effect was observed in the 9^{th} grade.

5.2 Performance of the participants on resolution of syntactically ambiguous sentences (SART)

Analysis of results of the present study suggested that there was no significant difference between male and female participants in each of the three grades, hence a gender effect was not observed. The findings also revealed that participants across the three grades showed similar performance on resolution of syntactic ambiguities task. There is a lack of research that has investigated the development of syntax ambiguity in the age group tested in the present study. In their study, Shultz and Pilon (1973), investigated the development of Linguistic Ambiguity in English language (phonological, lexical and syntactic) across the ages of 6 to 15 years and found that the ability to comprehend surface and deep structure syntactic ambiguities didn't occur till the age of 12 years. They report that in students of 10th grade, resolution of phonological and lexical ambiguities were significantly better than syntactic ambiguities. Results of adult studies too concur with these findings that adults are able to comprehend lexical ambiguities better than syntactic ambiguities (MacKay & Bever, 1967). Lexical and phonological processing appear earlier in life and thus are executed earlier than syntactic processing. Literature suggests that children process and decipher individual items of a sentence before processing and understanding syntactic nuances (Macnamara, Green & O'Cleirigh, 1972). Chomsky (1969) also provides evidence for later development of syntactic processes. Accurate comprehension of syntax ambiguities entail linguistic competence, a variable that was not equalised in the current study. The participants in the present study were a mixed cohort recruited from schools following state, central and international syllabi. Since all the participants may not have had similar use of and exposure to English language, the results need to be validated with caution. Keeping the evidence given by Shultz and Pilon (1973) in mind, it can be extrapolated that the age group considered for the present study were in the developing phase for resolution of syntactic ambiguities and hence demonstrated similar results across grades. Individual differences in linguistic competence could have also led to these results showing no developmental trend across grades.

Another possible explanation for the results of the present study could be that the participants were unable to efficiently utilise the cues for comprehending two meanings of an ambiguous sentence due to the method of testing. As the test for resolution of syntactic ambiguities involved the participants to read the ambiguous and control sentences for themselves and then answer the corresponding polar question, it is only reasonable to assume that incorrect intonation (pause and stress) could have brought out only one meaning from the sentence which caused the participants to have similar scores across grades.

Just and Carpenter (1992) view 'vocabulary size' and motivation as variables that can have an effect on performance on language processing tasks. Literature suggests that there is a strong positive correlation between vocabulary size and reading comprehension (Sternberg & Powell, 1983). Research has showed that the same processes underlying vocabulary acquisition are responsible for reading comprehension. In concurrence with the above statement, Daneman and Green (1986) found that persons with a higher reading span are endowed with a higher ability to provide a definition for a novel word encountered in a reading or listening task. The same authors postulate that a low score may be obtained, especially by low span readers because they just did not try as hard as the high span readers. These two variables were also not accounted for in the present study. It could be argued that if the participants had been grouped according to their linguistic competence and vocabulary size unlike a simpler categorization using grades, a linear progression of scores across grades would have been obtained. The nature of the present findings could thus be attributed to these two reasons as well.

5.3 Relationship of VWM and resolution of syntactically ambiguous sentences

The analysis of results of the current study revealed that there was a significant positive correlation between performance on VWM task and resolution of syntactic ambiguities resolution task in participants of 8th and 10th grade. An overall positive significant correlation was also observed between VWM and resolution of syntactic ambiguities across grades. There are only a handful of studies which have explored the correlation between VWM and resolution of syntactic ambiguities. In such a report, MacDonald et al. (1992) aimed to formulate a model explaining the processes responsible for resolving sentences with temporary syntactic ambiguity in the background of individualistic VWM constraints. They named this model as the 'Capacity Constrained Parsing Model'. They found out that individuals with larger VWM capacities are capable of maintaining multiple representations of the same sentence as opposed to individuals with a shorter VWM span who are able to maintain only its most likely representation or meaning. The authors opine that irrespective of an individual being a low or high span reader, multiple representations are formed when an ambiguity is encountered. However, individualistic VWM capacity determines whether these representations will be sustained over time. An individual with a better VWM capacity will therefore exhibit greater effect of ambiguity. In the present study, it has been already been established that participants showed a linear increase in their VWM capacities from 8th to 10th grade. This linear increase would consequently mean that their processing and storage components exhibited a certain growth as age progressed. This increased capacity could have led to a better maintenance of multiple representations of the syntactically ambiguous sentences and thus facilitated better resolution. Accordingly, it can be postulated that VWM span is a factor influencing the ability to comprehend syntactically ambiguous sentences.

On similar lines, it has been stated that when the syntax or semantics of a sentence is simple, it is processed without a significant involvement of VWM. But when a sentence with a complex syntactic structure is met with, VWM functions as a backup system to comprehend it (Gathercole & Baddeley, 1993). Antonsson et al. (2016) examined the relationship between VWM and higher level language (HLL) skills like comprehension of syntactically and lexically ambiguous sentences, making inferences, comprehension of metaphors, etc. on healthy adults from 20 to 79 years of age. They used digit forward and backward as measures of VWM. The results of their study showed that VWM correlated moderately with the total score on subtests measuring HLL skills. The authors conclude that even though education influences performance on the subtests, VWM stood out as a robust estimate of HLL. In the present study, a paradigm to test VWM abilities was used to compare performance on resolution of syntactic ambiguities. Syntactically ambiguous sentences present with a complex syntactic and semantic arrangement and require multiple representations to be stored in order to understand them accurately. A larger VWM would have had to be exercised in order to achieve accurate outcomes. Participants who scored higher on the VWM task would have found it easier to comprehend syntactically ambiguous sentences. Thus, the findings of the study under discussion can be ascribed to the above reasons.

There is a plethora of studies which show that higher capacity of VWM is strongly linked to better linguistic comprehension on reading and listening tasks and an overall increased linguistic competence. Investigations have been carried out to understand the type of VWM task that best predicts performance on a reading comprehension task. The authors of the original RST (Daneman & Carpenter, 1980) in their research paper demonstrate a positive correlations shown by their test with measures of reading comprehension that previous tests like digit and word span couldn’t achieve. They purported the results of their study to the fact that the RST could heavily tax on the processing aspect of VWM and strike a distinct trade-off between processing and storage. When the processing component hindered the storage component, an individual with a small VWM capacity performed poorly on reading comprehension measures. The results of a study done by Turner and Engle (1989) define a complex measure of VWM as a word or digit span measured alongside a secondary task. They report that when this task is moderately challenging, the estimation of performance on a language comprehension task is higher than when the VWM task is over simplified or very difficult. The RST used in the study under discussion also involved both storage and processing components. A sentence comprehension task was assessed with a verbal recall task in the background. The test was described as moderately gruelling according to the participants. These may be the reasons why it correlated positively with scores on ambiguity resolution tested by means of reading comprehension.

Further, the storage-recall and processing aspects of VWM have been separately scrutinised in investigations to correlate it with reading and listening comprehension tasks. An inquiry conducted by Waters and Caplan (1996) made use of the original RST by Daneman and Carpenter (1980) to test for VWM and standard vocabulary and reading tests to measure reading comprehension. Results revealed that the processing component of the RST favourably correlated with reading comprehension measures with the recall component having a minuscule, independent contribution. They conclude that reading span tasks compare well with tasks assessing reading comprehension only when both storage and processing aspects are tapped. In the present study also, the task assessing VWM capacity included subtasks that would tax storage and processing facets of VWM in the participants. As this task was favourable and in harmony with the above-presented evidences, it could be presumed that this was one of the reasons why a positive correlation was exhibited with the reading comprehension task.

Analysis of results of the present study also showed that there was no significant difference in the performance of males and females across grades and hence a gender effect wasn't observed. No correlation was observed for participants of the 9^{th} grade between the VWM task and resolution of syntactic ambiguities task.

CHAPTER 6: Summary and Conclusions

The present study was carried out to explore the relationship between VWM and resolution of syntactic ambiguities. The aim of the study was to investigate these parameters in typically developing English speaking older children from 8th, 9th and 10th grades. This area is still poorly researched on with greater studies focusing on correlation between VWM and reading comprehension and other complex linguistic skills. A limited attempt has been made to examine a similar relationship in the mentioned age group with English as second language and in the Indian population, thus the current study was taken up. Older school-going children are flooded with tasks in reading comprehension that require them to allocate a large chunk of their VWM resources in order to effectively process incoming stimulus. It is also at this time that they develop interests like reading novels and comics which are a rich source for sentences involving word-play. It becomes important for children to broaden their VWM capacity to accommodate such higher cognitive-linguistic processing. Literature is suggestive of the fact that shortcomings in the VWM capacities of children can lead to issues in language learning and consequently affect their academic performance. Thus, these components need to be examined in this particular age range of students.

The study hence aimed to explore the relationship between VWM and resolution of syntactic ambiguities in typically developing English speaking older children from 8th, 9th and 10th grades. The objectives of the study were to study the performance of typically developing English speaking older children on a VWM task, to study the performance of typically developing English speaking older children in resolution of syntactic ambiguities on a reading comprehension task and to compare the performance of typically developing English speaking older children between VWM task and resolution of syntactic ambiguities on reading comprehension task.

There were seventy-seven participants (thirty-seven males and forty females) selected randomly from 8th, 9th and 10th grade from English medium schools. A software based version of the Reading Span Test adapted from Oswald et al. (2014) was used to test the students for their VWM measures. The participants were also given a written test to assess reading comprehension for resolution of syntactic ambiguities. The data thus obtained was subject to quantitative analysis. Non-parametric tests were used to analyse the data. Mann-Whitney U Test and Kruskal-Wallis Test were applied to compare the data.

The findings of the study revealed that there was a developmental progression of VWM observed in participants from 8th to 10th grade wherein students of 10th grade performed better than students of the 8th grade. Studies involving students in the mentioned age group also report a similar linear increase in VWM as a function of age. The authors Gathercole et al. (2004) attribute it to the growth and enhancement of associated neurobiological areas sub-serving the components of WM, namely the CE, VSS and PL, as given by Baddeley and Hitch (1974)

Analysis of results revealed that participants performed similarly across grades on resolution of syntactic ambiguities task. The reason for arriving at such findings could be extracted from the developmental pattern in the resolution of three types of ambiguity (phonological, lexical and syntactic) investigated by Shultz and Pilon (1973). They found that children start decoding syntax ambiguities only after the age of 12 years. Phonological and lexical ambiguities were easier to decode than syntactic, even in adult population (MacKay & Bever, 1967). It could be thus inferred that the age group under scrutiny were in the developing state for resolution of syntactic ambiguities and hence didn't demonstrate any difference across age groups. Another plausible reason for obtaining such results may be that the modality of the ambiguity resolution task didn't allow the participants to determine multiple representations of the sentences because of improper pause and stress while reading the text silently. Factors like individual differences in linguistic competence, practice, exposure, vocabulary size and motivation have also been found to contribute to performance on complex language tasks (Cain et al., 2004; Just & Carpenter, 1992; Sternberg & Powell, 1983). These variables have not been credited in the present study. Thus, a consolidation of the above-mentioned factors can be furnished as justifications for the results of the current study.

There was a significant positive correlation observed between scores on VWM task and the ability to resolve syntactically ambiguous sentences in students of 8^{th} grade and 10^{th} grade. There was also an overall significant positive correlation observed between VWM scores and performance on the resolution of syntactic ambiguities across grades. No differences were observed in the performance of males and females in any of the grades. The nature of the results is in accordance with the study done by MacDonald et al. (1992) in which they claim that individualistic VWM capacities determine the ability to comprehend syntactic ambiguities. The authors assert that individuals with higher VWM pools are an advantage as compared to their age matched counterparts with lower capacities when they have to resolve sentences with syntax ambiguities. An individual with a larger VWM resource will be able to sustain the analytic by-products of a syntactically ambiguous sentence for a longer period of time unlike an individual with a diminished VWM capacity who will be able to retain only the most favourable representation of the sentence. The authors thus state that an individual endowed with a superior VWM capacity will exhibit better effect of ambiguity.

Studies have been done to find the best task that tolls VWM enough to predict scores on a language processing task. Authors like Daneman and Carpenter (1980), Turner and Engle (1989), Waters and Caplan (1996) posit that the two components of VWM, namely storage- recall and processing need to be measured if performance on reading or listening comprehension need to be predicted. The storage- recall aspect measured in a generic RST correlates highly with reading comprehension scores along with a small contribution of the recall aspect. The RST in the present study also taxed both aspects of the VWM and thus it could have had a positive correlation with reading comprehension of syntactic ambiguities.

Further analysis of results revealed that correlation between VWM task and reading comprehension of syntactic ambiguities was absent for participants from the 9th grade. Statistically, it was observed that the students in this age group exhibited ceiling and floor effect. It could be implied that participants of the 9th grade were in a transition period and thus didn't show any correlation like participants from 8th or 10th grade. Analysis also showed that males and females had similar performance on both tasks individually across grades, hence a gender effect was not observed.

Implications of the study

The current study provides an insight into the performance of older school going children on a VWM task and their ability to resolve syntactically ambiguous sentences in English. The study also tells us about the correlation of performances of these children on the above-mentioned tasks. Since VWM has been positively correlated to a variety of language processing tasks including reading comprehension in young children and adults, it is essential to know the trend in the intermediate age group.

A linear progression was seen in VWM scores in participants from 8th to 10th grade which is indicative of maturation of processes, both biologically and physiologically as age increases. Thus, we can expect to find better scores in VWM tasks for older school going children.

Participants across the three grades showed similar performance on the reading comprehension of syntactic ambiguities task. These findings are concurrent with studies which assert that students don’t start identifying syntactic ambiguities until the age of 12 years. This ability becomes refined as age progresses (Shultz & Pilon, 1973). It can be reasoned that the participants in the age group considered for the study were perhaps in the developing phase and thus didn’t demonstrate significant differences across grades. The method used in the present study also could have itself possibly inhibited the realisation of ambiguity in the students. A developmental trend will be observed if a broader age group were tested for the study and more opportunities for detecting ambiguity be provided to the participants.

A significant positive correlation was found between measures of VWM and the performance of participants on resolution of syntactic ambiguities. This correlation was found in students of 8th and 10th grade. This implies that the version of RST used for the present study taxed both the processing and recall aspects of VWM and thus could predict performance on syntactic ambiguities. We can extract that students unable to detect and resolve syntactic ambiguities will lack appropriate VWM resources to process other such complex language tasks. The reverse of this statement can also hold water that students with higher reserves of VWM can be expected to comprehend syntactically ambiguous sentences when language competence and word knowledge are controlled. Future research can be taken up in which participants are categorised as high, medium and low span readers and correlated with measures on resolution of syntactic ambiguities in reading and listening comprehension.

The results of this study can be helpful while planning the management of older school going students showing a lacuna in their VWM skills. Exposure to detecting and understanding the distinctions of syntactic ambiguities could boost a child's VWM capacity and thus enhance his/her linguistic processing capabilities. Such a protocol would however require validation and scientific evidence before it can be utilised in speech and language therapy.

Limitations of the study

Various factors like language competence, vocabulary size and exposure to syntactic ambiguities were not controlled for stringently in the present study. Since the students were selected from different academic syllabi, this could have contributed to the results. Also, for a developmental trend to be established, a wider age range of students could be could be considered for future research. These comments specify the need to interpret the results of the study carefully

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Appendix I

Sentences used in Syntactic Ambiguity Resolution Task (SART)

1. The professor said on Monday he would give an exam. Will the professor give the exam on Monday? [ambiguous]
2. The duck is ready to eat its food. Is someone going to eat the duck? [control]
3. The thief threatened the student with the knife. Did the student have the knife? [ambiguous]
4. He didn't like disturbing the children. Were the children disturbing? [control]
5. They are visiting relatives. Are the relatives visiting? [ambiguous]
6. Mohan peeled its skin and ate the apple. Did he eat the apple's skin? [control]
7. Pooja saw the man on the mountain with a telescope. Did the man on the mountain have a telescope? [ambiguous]
8. The sailor's fat wife likes to cook. Is the wife fat? [control]
9. He saw a man eating fish. Does the fish eat humans? [ambiguous]
10. The dog has one eye. Do you have to close one eye to see the dog? [control]
11. I saw a man on the mountain who had a telescope. Did I have the telescope? [control]
12. The industrial workers are revolting. Are they disgusting? [ambiguous]
13. She gave food to her dog. Did she eat food? [control]
14. He got her kids books. Did he buy books for her? [Ambiguous]
15. The woman protester was hurt by stone pelters in the rally. Was she under the influence of drugs? [control]
16. One morning I shot an elephant in my pyjamas. Was the elephant in my pyjamas? [ambiguous]
17. They are cooking apples for tonight's dinner. Does this sentence mention the variety of apples? [control]

18. He fed her cat food. Did she eat cat food? [ambiguous]
19. The police used a gun to kill the man. Did the man have the gun? [control]
20. Look at the dog with one eye. Do you have to close your eye to look at the dog? [ambiguous]
21. Save soap and save waste bits of paper. Does the slogan ask you to waste paper? [control]
22. Jyotsna peeled the skin of the apple and ate it. Did she eat the skin? [ambiguous]
23. Sweety has shapely nails as she files them regularly. Is the sentence about items in a hardware store? [control]
24. Save soap and waste paper. Does the slogan ask you to throw away paper just like that? [ambiguous]
25. The teacher announced on Thursday that she'll be taking a class test in the next week. Will the teacher take the test on Thursday? [control]
26. Newspaper headline: "squad helps dog bite victim" Did the squad make the dog bite the victim? [ambiguous]
27. The police with the gun cornered the terrorist. Did the terrorist have the gun? [control]
28. Headline in a newspaper: "quarter of a million Chinese live on water" Do these Chinese individuals only consume water for existence? [ambiguous]
29. The man was stoned in the rally. Was the man under the influence of drugs? [ambiguous]
30. We saw a yellow duck that belonged to Sandeep. Did they see him stoop/bend? [control]

The answers for Ambiguous sentences were 'yes' and the answers for control (unambiguous) sentences were 'no'

Appendix II

Sentences used in the Reading Span Test (RST)

1. The whiskey that the store sold intoxicated the rioter who broke the office. (right)
2. Varun invited the guests home to serve them food and asked them to sit on the clouds. (wrong)
3. The principal introduced the newly elected prefect to the students in the school. (right)
4. The submarine called the teacher and asked her help to complete her assignment. (wrong)
5. Sam's fairly neat kitchen was infested with big, black cockroaches that showed up only at night. (right)
6. Gowri told the teacher that her pet razor ate the homework that she had done last night. (wrong)
7. Anita was tremendously happy that her best friend, Radhika was coming to India at last (right)
8. A vegan lifestyle discourages followers from consumption of milk and milk tires apart from meat. (wrong)
9. The children caught up with the man, and he stopped, peering at them through his thick rimmed glasses (right)
10. Karan felt sorry for the old book and started speaking to him in perfect English (wrong)
11. Sudha enjoyed her lunch thoroughly and told her mother all about her last semester at school (right)
12. The cook had kept her word and there were caterpillar of warm vadas and a bowl of soup (wrong)
13. A skinny little boy of about eleven, wearing shabby clothes, followed the policemen into the station (right)

14. Prashant got tired of waiting under the harsh towel and thought longingly of lemonade and ice-creams (wrong)
15. The farmer had been complaining bitterly that his flock of sheep was being worried by nasty dogs (right)
16. Visions of a hot cup of strong coffee and a piece of laptop cake floated in Shankar's mind (wrong)
17. Mom appeared at the porch, wiping her flour coated hands on her soiled apron; she'd been cooking (right)
18. The big bagpack strode out to the garden through the kitchen, grabbing the keys to the shed (wrong)
19. The old fellow had on a shapeless dressing gown over pyjamas and a nightcap on his bald head (right)
20. There was a loud knock at the door, the handle turned and an old closet walked in with their dog (wrong)
21. The kitchen shelf was dusty with an old radio and a few pots and pans that seemed unused for years (right)
22. The old lady spoke English extremely well, but had a slight rain that was rather pleasing to the ears (wrong)
23. The children staggered in from the market with baskets full of goodies and arranged them on plates (right)
24. The boy was determined to look up the word in the dinosaur when he got home from school (wrong)
25. He turned his bike to the side of the bungalow and went into the little thicket of bushes behind it. (right)

26. Except for the light that kept burning all dustbin, there was a stove and green curtains left in the room (wrong)
27. Vinay started walking home from the grocer's in a hurry when he realised that he had come on a bicycle. (right)
28. The detective noticed that the tire marks on the wet ground were big and wide, too wide for an ordinary window (wrong)
29. The van was painted a bright yellow and had a few scratch marks around two feet above ground (right)
30. The mouse who could read hands wore a long black skirt, a black jumper, a shapeless red coat and a hat (wrong)
31. A young man dressed in smart overalls lay reading a book on a massive blue boat in the waters (right)
32. He picked up his grandfather from the railway station and took him to a nearby restaurant for a copper meal (wrong)
33. He took a pickup van in the middle of the night and collected all possible furniture from the living room (right)
34. Fathima walked up to the paste of the rather tiny service apartment, put her bags down and fetched the key (wrong)
35. Anjali stared in surprise as the magician started pulling out the selected cards from the curtain hem (right)
36. Meera was someone who loved dressing up and going to newspaper over the weekends; that was her way of de-stressing (wrong)
37. The local pharmacy's narrow shelves were full of small bottles of pills, syrups and colourful tablet strips (right)

38. The vast spread of lawn was bordered with neatly trimmed bushes and bright crowns that lined the porch (wrong)
39. The ambulance squealed to a stop in front of the house and two emergency technicians jumped out of it (right)
40. The fridge contained cartons of milk, some fruit, leftover cooked play-station and jars of jams and pickles. (wrong)
41. Newspapers were scattered across the wooden table, a box of pizza and an empty packet of chips lay on top of it (right)
42. Mother insisted that mobiles be kept away and that eraser be eaten with the entire family at the dining table (wrong)
43. The man stood beside his silent son and looked gloomily at the principal who seemed really annoyed about something (right)
44. The circus tent was massive and was crowded with animals, jugglers, clowns and dancers in bright thrones (wrong)
45. Deepa was asked to buy groceries from the store near her house and water the plants on a holiday (right)
46. Sheryl's mother didn't like her attending mattress or parties when she was in high school, it was a strict household (wrong)
47. The bride was overcome with emotions and cried on her father's shoulder by the end of ceremony (right)
48. The company made it mandatory to have more than one smile of recommendation to apply for a senior post (wrong)
49. Mahira was thrilled to receive a box of chocolates, a huge stuffed toy and a pretty bracelet from her fiancé (right)

50. The careless bedsheet delivered the parcel to the wrong address and refused to take blame for the mistake (wrong)

Numbers included: 0-9