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Title Page

The role of memory in processing relative clauses in children with Specific Language Impairment.

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Abstract

Purpose: This study investigated the relationship between two components of memory (phonological short-term memory (pSTM) and working memory (WM)) and the control of relative clause constructions in children with specific language impairment (SLI).

Method: Children with SLI and two control groups, an age-matched and a younger group of children with typical development, repeated sentences including relative clauses, representing five syntactic roles and two levels of matrix clause complexity. The Working Memory Test Battery for children was administered.

Results: All three groups showed significant associations between pSTM and both types of matrix clause construction. For children with SLI significant associations emerged between 1) WM and more complex matrix clause constructions 2) WM and relative clauses including a range of syntactic roles 3) pSTM and the least difficult syntactic role. In contrast, the age-matched control group could repeat almost all syntactic roles without invoking the use of either memory component.

Conclusions: The role of pSTM and WM in the production of relative clauses, by children with SLI, is influenced by the degree of difficulty of the structure to be recalled. In therapy, the effect of WM limitations can be minimized by approaching each structure within the context of a simple matrix clause.

Introduction

The understanding and production of complex syntactic structures such as relative clauses is restricted in children with specific language impairment (SLI) (Frizelle & Fletcher 2014a, 2014b; Riches, Loucas, Baird, Charman & Siminoff, 2010). There is also extensive literature showing that many of these children show memory deficits in both phonological short-term memory (pSTM) (Archibald & Gathercole, 2006, 2007; Ellis Weismer et al., 2000; Gathercole & Baddeley, 1990b, Montgomery 1995, 2004) and working memory (WM) (Archibald & Gathercole, 2006, 2007; Ellis Weismer et al., 1999; Marton & Schwartz, 2003; Montgomery, 2000a, 2000b; Montgomery & Evans, 2009) (for reviews see Montgomery, Magimairaj, & Finney, 2010; Ullman & Pierpont, 2005)[1]. Over the last decade evidence for the linkage between the language and memory problems of children with SLI has grown (Marton, Schwartz, Farkas & Katsnelson, 2006). Researchers have investigated pSTM and WM in relation to what are referred to as simple and complex sentence structures (Montgomery & Evans, 2009; Riches, Loucas, Baird, Charman & Simonoff, 2010). However, there are some inconsistencies in the literature in the use of the term *complex sentence* [2] making it difficult to interpret these studies from a

[1] Although there has been a recent interest in declarative and procedural memory systems (e.g. Lum, Conti Ramsden, Page & Ullman, 2012) the current work focuses on the contribution of phonological short term memory and working memory to children's recall of complex syntactic structures (specifically relative clauses).

[2] Here we take the traditional view that a complex sentence is a construction with one or more subordinate clauses -- see for example, Trask, 1992, p.52.

clinical perspective. There are many different types of complex sentence, which may invoke the use of pSTM and WM in different ways. Even a specific term like *relative clause* constitutes a *family* of constructions, different members of which cause varying degrees of difficulty for children with SLI. Variations in difficulty may relate to the memory limitations experienced by these children. The existence of a range of constructions under the heading relative clause, which impact on children with SLI in different ways, makes these constructions an ideal testing ground of the relationship between memory and complex syntax in this cohort. This then is the focus of the current study.

An overview of relative clauses

A relative clause is a subordinate clause, which post-modifies a nominal in a main clause (henceforth 'matrix' clause) thereby giving extra information about the nominal (its characteristics, its actions etc.). The earliest relative clauses that appear in the speech of young children with typical development, are usually attached to an isolated noun phrase (as in 1) or a somewhat formulaic copular clause (as in 2) (Diessel & Tomasello, 2001). They contain a single proposition or idea and can be paraphrased by a simple sentence (shown in parentheses). The most commonly used relative clauses that appear later in children's speech are attached to the direct object of a transitive verb (as in 3) (Diessel & Tomasello, 2001). These are fully bi-clausal; they contain two propositions and therefore require two sentences to paraphrase. Examples are taken from Diessel and Tomasello (2001) p.135.

(1) *The **[girl]*** $_{subject}$ *that came with us.* (The girl came with us.)

(2) *Here's a **[tiger]*** $_{subject}$ *that gonna scare him.* (The tiger is gonna scare him.)

(3) *You left this* ***[toy]*** $_{Oblique}$ *I'm playing with*. (You left this toy. I'm playing with this toy.)

Relative clauses are usually defined by two features: the position of the modified noun phrase in the matrix clause and its position in the embedded clause. Until recently much of the relative clause literature restricted the constructions investigated to either the *subject* or *object* position in both clauses. However research by Diessel and Tomasello (2001, 2005) highlighted the importance of (1) expanding these positions to include the full range of syntactic roles and (2) researching structures that reflect those that young children say and hear.

Relative clauses in children with SLI

Building on findings from typical development (Diessel & Tomasello, 2001, 2005), Frizelle and Fletcher (2014a, 2014b) carried out a study of relative clause constructions in children with SLI. Children with SLI and two groups of children with typical development were asked to repeat relative clauses representing a range of syntactic roles. To represent two levels of matrix clause, each relative clause was attached to either the predicate nominal of a copular clause or the direct object of a transitive clause. The syntactic role of the post-modified noun phrase in the relative clause included not only *subject* and *object*, but also *oblique* (where the post modified noun functions as the object of a preposition, as in 4), *indirect object* (the post modified noun is the indirect object of the relative clause, as in 5) and *genitive* (where the relativizer *whose* and noun sequence functioned as either the *subject*, as in 6, or *object* as in 7, of the relative clause). As with previous papers we use the term 'relative clause' for the post-modifying clause itself (the embedded clause) whereas

'relative clause constructions' refer to the full sentence (i.e. the matrix and relative clause together).

(4) *Emma spoke to the [**man**]* $_{Oblique}$ *who the horse ran away from.*

(5) *Anne helped the [**girl**]* $_{indirect\ object}$ *who Eddie baked a cake for.*

(6) *Anne saw the [**farmer**]* $_{genitive\ subject}$ *whose cow fell in the shed.*

(7) *This is the [**cat**] whose [**tail**]* $_{genitive\ object}$ *Joe caught in the door.*

Frizelle and Fletcher (2014a, 2014b) found that children with SLI were significantly delayed in their ability to repeat all types of relative clause constructions. However it was also found that children with SLI had significantly less of a problem with those that express a single proposition (referred to as Presentational - PN relatives) than with the bi-clausal relative constructions (referred to as dual propositional - DP relatives), which were matched for length, and which appear later in the speech of children with typical development. This significant difference between PN and DP relative constructions was also evident for the other two control groups but to a lesser degree. With regard to the comparative difficulty of different types of relative clauses, representing a range of syntactic roles, the children with SLI demonstrated a similar difficulty index to that of the children with typical development but at a much lower performance level (even to those who were on average two years younger). Children with SLI performed best on subject relatives (intransitive), followed by subject relatives (transitive), object relatives, oblique relatives, indirect object relatives, genitive subject and lastly genitive object relatives (see Frizelle and Fletcher 2014a, for more detail).

The current study aims to increase our understanding of the syntactic recall abilities of children with SLI in relation to relative clause constructions, by investigating the role of memory in children's performance on the repetition task

(used in Frizelle & Fletcher 2014a, 2014b). By systematically controlling the two types of matrix clause we can explore the role of both pSTM and WM components in the children's ability to recall (easier) single and (more difficult) dual propositional relative clause constructions. In addition, the index difficulty shown by varying the syntactic role of the relative clause provides us with an index of complexity against which the influence of pSTM and WM can be further examined.

Baddeley Memory Model

Verbal working memory research on children with SLI has primarily been carried out with respect to two dominant models, that of Baddeley and Hitch (Baddeley, 2003; Baddeley & Hitch, 1974) and Daneman and Carpenter (1980). The current study is based on the Baddeley and Hitch model, in which working memory is a multidimensional system, composed of three separate but interactive components (Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005). There are two domain specific slave systems, the phonological loop and the visuo-spatial sketchpad. The short-term storage of verbal information is supported by the phonological loop (henceforth referred to as phonological short-term memory – pSTM), which is capacity limited and stores incoming speech temporarily. The information fades in 2-3 seconds if not processed in some way. The visuo-spatial sketchpad is responsible for the short-term storage of visuo-spatial information and is not the focus of the current study. The regulation and co-ordination of information into both slave systems is supported by a resource limited, domain general, central executive system. Jointly, the functions of the central executive and the phonological loop support the temporary storage and processing of verbal information, referred to as working memory (WM).

Memory and Syntax

Deficits in both memory components have been proposed to underlie receptive and expressive grammatical difficulties in SLI (Adams & Gathercole 2000; Montgomery, 2000a, 2000b; Montgomery & Evans, 2009). Many complex syntactic structures, such as relative clauses, require children to hold a considerable amount of linguistic material in their pSTM before processing and parsing each sentence. Given their embedded nature, relative clauses also have a higher processing load and are likely to invoke the use of WM to a greater degree than most simple non-embedded sentences. However, within relative clause types, children with SLI evince varying degrees of difficulty, in repeating these complex structures (Frizelle & Fletcher 2014a, 2014b). It seems likely that the involvement of memory is not constant across these different levels of difficulty.

This relationship between different memory components on one hand and different levels of syntactic complexity on the other is of significant clinical concern, particularly from an intervention perspective. How children engage with their pSTM and working memory may vary according to their level of competency with a given structure as well as the frequency of their exposure to that structure. Adopting a usage based approach, we assume that each time a child encounters a structure in the ambient language (1) it leaves a trace in memory which reinforces its mental representation and in turn facilitates the activation of the structure in future language use, and (2) children attempt to recognize structural similarities involving the recognition of shared attributes at a lexical level and shared structures or relationships at a grammatical level. Therefore the more frequently a grammatical construction occurs, the more entrenched its mental representation becomes and the easier it is to activate in language use (Bybee & Hopper, 2001). This syntactic activation (of

particular grammatical schemas) supports access to memory representations so that there may be no need to search through unrelated representations (McElree, Foraker & Dyer, 2003). This is suggestive of a synergistic relationship between components of memory and the degree of difficulty of the syntax that is being processed or produced. That is, the less problematic the structure, the more likely syntactic information is available to support access to representations in memory, requiring less inhibition of distracting information and resulting in a reduced processing load.

We might therefore hypothesise that in the case of PN relatives (those which children with SLI recalled with greater ease), the child can move more efficiently through the sentence parsing or formulation process, the linguistic material is less likely to decay, and the child can rely more heavily on pSTM than on WM in their understanding or production of the sentence. Furthermore, in the case of DP relative clause constructions (those which children with SLI recalled with more difficulty), we might consider that syntactic information is less likely to be available to support their representations in memory. This is likely to increase their need to search through unrelated structural configurations and the requirement for inhibition so intensifying the processing load of the sentence and the demands on their already reduced WM.

In relation to constructions which realize different syntactic roles in the relative clause, we might expect those in which the grammatical schema is most similar to simple sentences (following a noun-verb-noun pattern), those they recalled with greatest ease and those they are most frequently exposed to, to be parsed and formulated relying primarily on pSTM (i.e. intransitive and transitive subject relatives). However given their poor performance overall on the task it may be that all syntactic roles will make significant demands on these children's WM.

Memory in relation to sentence comprehension and production in children with SLI

Despite the proposition that impairments in pSTM and WM underlie receptive and expressive grammatical difficulties in children with SLI, there have been relatively few studies specifically investigating the relationship between these two memory components and children's comprehension or expression of constructions of varying complexity. Of the recent studies that have investigated the relationship between memory and the ability of children with SLI to recall sentences (e.g. Hesketh & Conti-Ramsden, 2013; Poll et al., 2013), results appear mixed and few have focused on relative clause constructions specifically. One study, which explicitly explores relative clauses, is Riches et al. (2010). Riches and colleagues investigated the role of memory in the ability of 14 adolescents with SLI to repeat relative clauses in four conditions, (i.e. subject and object relatives, with added adjectives in either the matrix or relative clause). They found a significant correlation between pSTM (indexed by *digit recall*) and the children's ability to repeat these complex syntactic structures (no breakdown between relative clause types was given), but no correlation was found between WM and sentence recall performance.

In the comprehension literature, Montgomery's work with children with SLI, largely investigates sentence length (Montgomery, 1995, 2000a, 2000b; Montgomery & Evans, 2009). In 1995 he investigated the relationship between pSTM and these children's comprehension of longer and shorter sentences of varying complexity, and in 2000, he explored the relationship between WM and similar sentence types. The sentences included long and short versions of simple active sentences with added adjectival and adverbial items (8), constructions with an embedded subject relative (9), and constructions with embedded subject and object relatives (10).

(8) The little car is going to hit the train.

(9) The little boy that is falling is kicking the big girl.

(10) The little boy who is standing is hitting the little girl who is sitting.

In 1995, Montgomery reported a positive correlation between the children's understanding of longer sentences and pSTM. In his 2000 studies he found no correlation between WM and sentence comprehension. However because the focus of each study was on the impact of sentence length, a breakdown of the children's understanding in relation to the structural characteristics was not provided. Norbury, Bishop and Briscoe (2002) also reported a weak but significant correlation between pSTM and the comprehension, by children with SLI, of active and passive sentences. Again, a breakdown between sentence types was not given.

A more recent study by Montgomery and Evans (2009) investigated the relationship between two components of memory, pSTM and attentional resource capacity / allocation (working memory), and the sentence comprehension of school aged children with SLI. In this study pSTM was indexed by non-word repetition and WM by the Competing Language processing task (Gaulin & Campbell, 1994). The sentence comprehension task included simple active sentences (11), (conforming to canonical word order and almost all containing two argument predicates) and more complex sentences modeled on those used by van der Lely and Stollwerck, (1997). An important distinction between the Montgomery and Evans' study (2009) and the current study is that complex sentences were defined as such because they required the children to compute a non-local syntactic dependency but they did not include embedded sentences (used in the current study). Their 'complex sentences' included semantically reversible verbal be passives, (12), pronominals, (13) and reflexives, (14).

(11) The old man is touching the blue haired woman.

(12) The monkey is bitten by the dog.

(13) Baloo bear says Mowgli is tickling him.

(14) Mr Pig says Winnie the Pooh is feeding himself.

Although Montgomery and Evans (2009) reported memory associations independently for the simple and more complex sentences investigated, a difficulty index is not available for the children with SLI, within the more complex sentence types. For the children with SLI, pSTM correlated significantly with simple sentences and WM correlated with complex sentences. They concluded that the comprehension difficulties of children with SLI are related to their limitations in WM and that even simple sentences require considerable pSTM resources. One recommendation from this study was to examine the influence of working memory on a wider range of sentence structures, specifically relative clauses. The current study therefore aimed to extend the work of Montgomery and Evans (2009), using a sentence recall task.

Sentence Recall

There is a considerable body of evidence suggesting that sentence recall requires both comprehension and production through reconstructing the target sentence. If the sentence is beyond the child's memory span they will remember the conceptual meaning of the sentence but the details are lost to auditory memory (Baddeley, Hitch & Allen, 2009). Sentence reconstruction is supported by lexical, conceptual and syntactic representations in long-term memory (Brown & Hulme, 1995; Potter & Lombardi, 1990, 1998; Schweickert, 1993) as well as by phonological short-term memory processes (Alloway & Gathercole, 2005). If the child does not understand the sentence then the syntactic and semantic representations are likely to differ from the original stimulus (Vinther, 2002). The requirement that the general

meaning of the sentence must be retained, while the child reconstructs the sentence, is hypothesized as making demands on their working memory capacity. Although the literature acknowledges a memory role in children's performance on a sentence recall task, to the best of our knowledge, nothing is reported on the relationship between both pSTM and WM, and levels of difficulty within a particular type of complex sentence in children's performance on sentence recall. Given that memory of sentences is supported by syntactic representations, it would seem reasonable to suggest that the relationship between memory variables and the recall of relative clause constructions may vary with the type and level of difficulty of the relative clause being processed and produced. As previously outlined, the current study aims to increase our understanding of the syntactic recall abilities of children with SLI in relation to relative clause constructions, by investigating the possible role of memory in how these children performed on the task.

The specific research questions addressed are:

- What is the association between two components of memory (pSTM and WM) with the ability of English-speaking school-aged children with SLI, to recall relative clause constructions of different degrees of difficulty?
    - Does the type of matrix clause influence these associations?
    - Are the associations influenced by the syntactic role of the relative clause?
- How do these associations compare with children who are age-matched and typically developing and with children who are on average two years younger, with typical development?
- What implications for clinical practice arise from the results?

Methodology

Participants

Thirty-five children with SLI (25 males and 10 females) and thirty-two aged matched children with typical development (AM-TD) were recruited for the study. The target recruitment age was between 6;0 and 7;11 years for both groups. Three of the children with SLI were subsequently excluded, due to an inability to complete the experimental task. Twenty younger children with typical development (YTD) were also recruited (12 male and 8 female), ranging in age for 4;7 to 4;11 years. This age range was chosen as children with SLI tend to perform at least two years behind their peers, for example in studies of morpho-syntactic development (see Rice, 1998) and children were required to be 4;7 years in order to complete subtests from the Working Memory Test Battery for Children (WMTB-C, Pickering & Gathercole, 2001). This allowed us to relate the abilities of children with SLI to the trajectory of development revealed by two groups of children with typical development, who are on average two years apart in age. The younger children were not language-matched to the children with SLI due to the inherent validity problems with language matching (Plante, Swisher, Kiernan & Restrepo, 1993), which are particularly evident when investigating children beyond preschool age.

Four children with SLI came from schools located within RAPID areas (*Revitalising Areas by Planning, Investment and Development;* Pobal, n.d.). These are locations in Ireland, identified as being socially and financially deprived. An equal number of children with typical development were also recruited from these areas. Participants came from homes where English was spoken as the first and only language. Written consent was given by the parents / guardian of each child who took part in the study.

The children with SLI were selected on the basis of their receptive language composite score identified by their performance on the Clinical Evaluation of Language Fundamentals – 4th Edition, UK standardization (CELF-4 UK) (Semel, Wiig & Secord, 2006). They were required to score below -1.25 standard deviations (SD) in order to be included. They also met all other usual exclusionary criteria for SLI, i.e. a diagnosis of Attention Deficit Hyperactivity Disorder, Autistic Spectrum disorder, major physical disabilities, intellectual disability or hearing impairment. Children with verbal articulatory dyspraxia or any significant phonological problems were also excluded.

Control children were required to score within 1 SD of the mean for their age on receptive and expressive language composite scores of the CELF-4, UK (AM-TD group - (Semel et al., 2006) and the CELF Preschool 2, UK (YTD group) (Wiig, Secord & Semel, 2006). All children had IQ scores within the typical range i.e. no less than 1 SD below the mean on the Raven's Test of Progressive Matrices. Ethical approval for the study was obtained from the Cork Teaching Hospitals Clinical Research Ethics Committee.

Test Measures – Working memory Test Battery for Children

Memory functioning was assessed using the Working Memory Test Battery for Children (WMTB-C, Pickering & Gathercole, 2001). The test comprises eight subtests, four measures of phonological loop function (pSTM), 2 measures of the visuo-spatial sketchpad (these are not reported in this paper) and three measures of central executive function (WM). Each subtest is standardized to a mean of 100 and SD of 15. All subtests were administered to the children with SLI and the age-matched group with typical development. However the lower age limit of 5;7 years

precluded the younger group from completing the *Listening recall* and *Counting recall* (WM) subtests.

pSTM was assessed using the four measures in the WMTB-C; *digit recall, Word List Matching, Word list recall* and *Non-word list recall*. Three of these measures (*Digit recall, Word list recall* and *Non-word list recall*) use the immediate serial recall paradigm. The fourth measure requires that the child judges whether two spoken word sequences are identical or not. All four subtests provide a composite score of pSTM.

WM was assessed using the *Listening Recall, Counting Recall* and *Backward digit* recall subtests from the WMTB-C – all of which require both storage and processing of information. The *Listening recall* subtest is an adaptation of the Competing Language Processing Task (Gaulin & Campell, 1994). The child is required to make a truth-value judgement about a short simple sentence presented auditorily (for example – *fish can swim*) while at the same time trying to recall the sentence-final word. The sentences are arranged in groups at six levels. In level 1 the child must only understand one sentence and recall the last word of that sentence. The groups increase by one sentence at each level so that for level six, the child makes a truth-value judgement about each of the six sentences in the group and when the sentence group has been completed they are asked to recall the last word of each previously presented sentence. The *counting recall* task (based on that by Case, Kurland and Goldberg, 1982) requires the child to count the number of randomly presented target dots in a series of displays and to remember the tally of each presentation. The *backward digit recall* subtest requires the child to repeat a list of digits in reverse order. The child's performance on the three subtests provides a composite score reflecting their WM.

Sentence Recall Task

The sentence-recall task was newly devised and included 52 complex sentences that contained relative clauses. Seventeen simple active declarative filler sentences were randomly inserted in the list of relative clause sentences, to reduce perseveration. All sentences were between 10 and 13 syllables in length. Children were asked to repeat verbatim one of seven different types of relative clause structure. With the exception of the genitive-subject (Gen-S) relatives (where there were two examples of each) – see example 6, there were four examples of each of the other relative clause types. Two were attached to a presentational copular construction (PN relative) and two to the direct object of a transitive clause (DP relative). In all sentences, the relative clauses were introduced by one of the relative markers, *who*, *that* or *whose*. Table 1 gives an example test sentence for each of the fourteen conditions.

Table 1 - *Example Test Sentence for each Condition*

	Presentational (PN)	Dual propositional (DP)
Subject intransitive (S)	This is the bird that slept in the box all night.	The girl cleaned up the milk that spilt in the fridge
Subject transitive (St)	There is the sheep that drank the water this morning.	Eddie met the girl who broke the window last week.
Object (O)	There is the picture that you drew on the wall last week.	The girl ate the sweets that you brought to the party.
Indirect object (Io)	There is the dog that the man kicked his football to.	Anne fed the baby who Emma sang a song to.
Oblique (Obl)	There is the tree that the car crashed into last night.	Anne painted the picture that the girl looked at today.

Genitive subject (GenS)	There is the girl whose juice spilt in the kitchen.	Anne saw the farmer whose cow fell in the shed.
Genitive object (GenO)	There is the girl whose toy Anne broke in the garden.	Emma met the girl whose bag Anne took to school.

Procedure

The assessment procedures were administered to the participants over two sessions. The WMTB- C (Pickering & Gathercole, 2001) was administered and scored according to the standardized instructions. The sentence-recall task was divided into three batteries and administered in one session. The sequence of sentences was randomized so that there were two orders of presentation for each battery. The procedure for the sentence recall task was an adaptation of that used by Diessel and Tomasello in their 2005 study and is outlined in more detail in Frizelle and Fletcher (2014a). All responses were recorded using a Zoom H4 audio recorder and stored on computer for transcription and analysis. Transcriptions were carried out orthographically and included mazes and hesitations. An independent analyst re-transcribed 5% of the transcripts from each group. Agreement, assessed via word-level accuracy, was 98.5%.

A comprehensive scoring system was devised to allow for a detailed description of both correct and incorrect responses. Children's responses were assigned a score ranging from ten to zero, with a higher score representing a more accurate performance. The summation of these scores resulted in a total sentence recall score and those reflecting each of the matrix clause types resulted in a total PN score and a total DP score, on which the groups could be compared. The highest possible raw score, within PN and DP relatives, for each child, was 260. Sentences repeated without error received a score of 10. Sentences with a lexical substitution but

which otherwise maintained the syntactic structure of the target sentence received a score of 9. Sentences in which there was an inflectional error or a combination of a lexical and an inflectional error were given a score of 8, depending on the type of error (see Frizelle and Fletcher 2014a for specific examples). The assignment of a score of 10, 9 or 8 allowed us to compare each group, on the total number of sentences that accurately maintained the structure of the matrix clause and that of the relative clause, even though the wording of the sentence might not be accurate in all respects. This was referred to as the total syntactic accuracy score and allowed us uncover a syntactically driven index of difficulty across relative clause types.

Our detailed scoring system (from 10 to 0) also allowed for an analysis of errors, which did not maintain the structure of the target relative clause construction. An analysis of other error categories is not central to this paper and is provided in Frizelle and Fletcher (2014b). Inter-rater reliability measures were obtained for the scoring scheme for the sentence-recall data, with 5% of all responses randomly selected for re-analysis. For all scored responses, the agreement rate between the original scoring and an independent rater was 92.7%.

Results

Data preparation procedures

Each groups' task performance on the variables of interest was examined for normal distribution. It was noted that the syntactic accuracy and WM scores for the children with SLI were not normally distributed. Given the language level necessary in order to understand what is required in the *listening recall task* – there were a number of children who did not understand the task requirements and were therefore unable to complete it. They were attributed the lowest possible score on this subtest. Log transformation did not normalize either data set. As a result Spearman's rho non-

parametric correlation was carried out, however the results were similar to the Pearson product moment correlation co-efficient. Therefore only the Pearson correlation co-efficients are reported.

Children's performance on the experimental tasks

A descriptive summary for each group on the memory variables is presented in Table 2. Memory variables are reported as raw scores. The performance of each group on the overall sentence recall task, the PN and DP constructions, and each of the relative clause types has been reported in Frizelle and Fletcher (2014a).

Table 2: *Summary of Memory Scores for each of the Three Groups*

	SLI (n = 32)		**AM-TD (n = 32)**		**YTD (n = 20)**		**Comparison of means**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	***F/t***	***p***	**η2**
pSTM									
(Composite Raw Score)	57.56	10.67	83.84	11.51	68.10	9.07	(*F*) 49.1	< .001**	.54
Digit recall	21.75	3.12	28.5	3.91	24.4	9.03	(*F*) 33.3	< .001**	.45
Word list Matching	12.84	6.31	22.31	4.01	16.6	4.91	(*F*) 26.8	< .001**	.40
Word List Recall	13.41	2.26	19.22	2.81	15.3	3.39	(*F*) 36.3	<.001**	.47
Non –word recall	9.56	2.79	13.81	2.63	11.8	1.82	(*F*) 22.5	< .001**	.36
WM									
(Composite Raw Score)	20.03	5.78	38.03	8.02	----	----	(*t*) 10.3	<.001*	.61
Listening Recall	3.41	2.95	10.97	2.04	----	----	(*t*) 11.93	<.001*	.70
Counting Recall	10.31	2.63	16.88	4.41	----	----	(*t*) 7.23	<.001*	.46
Backward digit Recall	6.3	1.89	10.19	3.01	6.0	1.62	(*F*) 29.01	< .001*	.42 (not significant between YTD and SLI)

**Differences significant between all three groups

* Differences significant between two groups only

Phonological short-term memory (4 subtests).

Analysis was initially carried out comparing groups on the component phonological memory raw scores. A one-way analysis of variance (ANOVA) indicated that the groups differed significantly (F (2, 81) = 49.1, p < .001, η2 = .54). Post hoc tests (Tukey-B) showed that the differences between all three groups were significant, p < .001 for the age-matched and SLI group differences, and for the two control group differences, and p <.002 for the SLI and younger control group differences. Further analyses on the phonological memory subtests revealed significant differences between the groups on *digit recall* (F (2, 81) = 33.28, p < .001, η2 = .45), *word-list matching* (F (2, 81) = 26.8, p < .001, η2 = .40), *word-list recall* (F (2, 81) = 36.25, p < .001, η2 = .47) and *non-word repetition* (F (2, 81) = 22.53, p < .001, η2 = .36). Post hoc tests (Tukey- B) showed that the significant differences were between all three groups. The performance of the children with SLI and younger group with typical development was closest on the *word list recall* measure (p = .049).

Working Memory (3 subtests)

Working memory was analysed by initially comparing the SLI and age-matched control groups on the *central executive* composite raw scores. Due to the age profile of the younger children with typical development it was not possible to obtain a composite score for this group. An independent sample t test was performed and showed significant differences between the SLI and age-matched control groups (t (62) = 10.3, p <.001). Analysis of the subtests showed that for both *listening recall* and *counting recall* the children with SLI performed significantly worse than the age-matched children with typical development (t (62) = 11.93, p <.001, η2 = .70 – *listening recall*), (t (62) = 7.23, p <.001, η2 = .46 - *counting recall)*. The final subtest

analysed (reflecting working memory capacity) was *backward digit recall*. Group performance was compared using a one-way analysis of variance (ANOVA) and results revealed a significant difference between the groups (F (1, 82) = 29.01, p < .001, η2 = .42). Post hoc tests (Tukey B) showed that the children with SLI performed significantly worse than the age-matched group with typical development (p < .001) but not the younger group with typical development (p = .89). Differences between the two control groups were also significant (p < .001).

Correlational /Regression Analysis:

Component Memory Scores and the Matrix clause (PN v's DP).

The relationship between the children's performance on the sentence recall task and each of the predictor variables was initially explored using total PN score and total DP score (as the dependent variables) and the composite memory scores, pSTM and WM (as the independent variables). The relationship was investigated for each group using Pearson product-moment correlation co-efficient. The correlation matrices for all children are shown in Table 3.

Table 3: *Correlations between Memory Scores and Each Group's Performance on PN and DP Relative Clause Constructions*

	SLI – Correlation (P value)		**AM-TD – Correlation (P value)**		**YTD – Correlation (P value)**	
	PN	DP	PN	DP	PN	DP
Phonological Memory	**.36(.046*)**	.27(.138)	**.63(<. 001**)**	**.59(<. 001**)**	**.53(.017*)**	**.65(.002*)**
Digit Recall	**.48(.006*)**	**.38(.030*)**	**.47(.006*)**	**.35(.047*)**	**.58(.008*)**	**.62(.004*)**
Word list matching	.22(.233)	.17(.361)	.27(.142)	.18(.313)	.37(.110)	.38(.094)
Word list Recall	.20(.271)	.21(.252)	**.45(.009*)**	**.40(.025*)**	.31(.191)	.31(.188)
Non-word recall	.22(.238)	.12(.525)	**.46(.008*)**	**.31(.086)**	.20(.406)	**.50(.025*)**
Working Memory	.18(.306)	.24(.187)	.34(.061)	.27(.130)	-----	-----
Listening Recall	.31(.087)	**.49(.004*)**	.24(.189)	.17(.366)	-----	-----
Counting Recall	-.14(.430)	-.13(.465)	**.38(.031*)**	.26(.148)	-----	-----
Backward digit recall	.15(.430)	06(.747)	.254(.162)	.09(.629)	.08(.723)	-.03(.907)

* Significant at $p < 0.05$.

** Significant at $p < 0.001$.

As can be seen, for the children with SLI, there was a significant correlation between pSTM and the simpler PN relative clause constructions. No such correlation was evident for the more complex DP relative clause constructions and no significant correlations evident between the WM component score and either relative clause sentence type. Further analysis was completed using enter multiple regression. Phonological memory was entered into the equation and explained 12.6% of the variability in total PN score for the children with SLI. This was significant (F (1,30) = 4.337, p = .046).

In contrast, for the age-matched children with typical development, there was a strong positive correlation between the pSTM component score and both PN and DP relative clause constructions but no significant association between the WM component score and either of the sentence types. Using enter multiple regression phonological memory explained 39.7% of the variance in total PN score and 35.1% in total DP score. Both regression equations were statistically significant (F (1, 30) = 19.73, $p < .001$) for PN and (F (1, 30) = 16.20, $p < .001$), for DP.

Similarly, for the younger children with typical development, there was a strong positive correlation between pSTM and their performance on both PN and DP sentences. Further analysis using enter multiple regression showed that pSTM accounted for 27.7% (F (1,18) = 6.908, p = .017) of the variability in total PN score and 42.5% (F (1,18) = 13.311, p = .002) of variability in total DP score, for this group of children.

Memory subtest Scores and the Matrix clause (PN v's DP).

A more detailed investigation in to the possible contribution of both mechanisms of working memory was carried out for each group through analyses of the subtests of each component (see table 3). Interestingly, for the children with SLI,

there was a significant correlation between *digit recall* and both the simpler PN and more complex DP relative clause constructions (accounting for 22.7% of the variance in the former and 14.7% in the latter). Both regression equations were significant (F (1, 30) = 8.786, p = .006) for PN and (F (1, 30) = 5.179, p = .030) for DP. No correlations were evident for the other three subtests representing pSTM. This analysis also revealed a significant correlation between *listening recall* (a measure of WM) and the more complex DP relative clause constructions but no correlation between *listening recall* and the simpler PN relatives. Regression analysis revealed that *Listening recall* accounted for 24.2% of the variability in DP scores and the regression equation was highly significant (F (1, 30) = 9.570, p = .004).

For the age-matched group of children with typical development, there were significant associations between, both the *digit recall* and *word list recall* subtests, and both PN and DP sentences. There was also a significant correlation between *non-word recall* and the simpler PN sentences. Using enter multiple regression *digit recall* explained 22.5% of the variance in total PN score compared to 12.5% in total DP score. *Word list recall* accounted for 20.4% of the variability in children's performance on the simpler PN sentences compared to 15.7% on the DP sentences and *non-word recall* explained 21.3% of the variance on PN constructions. All regression equations were statistically significant. Although there were no significant correlations between *listening recall* and either of the dependent variables, a significant correlation between *counting recall* (also a measure of WM) and the simpler PN sentences did emerge. Regression analysis showed that it accounted for 14.6% of the variance in total PN score, which was statistically significant (F (1, 30) = 5.14, p = .031).

For the younger children with typical development analyses of the subtests of pSTM show strong significant correlations between *digit recall* and the children's performance on both the PN and DP sentences. *Digit recall* accounted for 33.1% (F (1, 18) = 8.89, p = .008) of the variability in total PN score and 38.3% (F (1, 18) = 11.19, p = .004) of the variability in total DP score – both regression equations were significant. A significant correlation also emerged between *non-word recall* and the more complex DP relative clause types (25% shared variance). The regression equation was statistically significant (F (1, 18) = 5.988, p = .025). The only subtest carried out by the younger group, which represented WM, was *backward digit recall*. There were no significant correlations observed between this component of working memory and the children's performance on either simple or more complex relative clause types.

In summary, all three groups of children showed a significant association between *digit recall* (a measure of pSTM) and their performance on both PN and DP relative clause constructions. However, the children with SLI were the only group to demonstrate a significant association between *listening recall* (a measure of working memory) and the more difficult DP constructions.

Memory and the syntactic role of the relative clause

The relationship between the children's performance on the sentence recall task and memory variables was further explored according to the syntactic role of the relative clause, using syntactic accuracy scores as the dependent variable. Based on the fact that *digit recall* (a measure of pSTM) was the strongest correlate for all three groups across PN and DP relative constructions, this was investigated as the first independent variable, followed by *listening recall*, as the only measure of working

Table 4: *Correlations between Memory Subtests and Each Group's Performance on Relative Clause Types*

	SLI – Correlation (P value)		**AM-TD – Correlation (P value)**		**YTD – Correlation (P value)**
	Digit recall	Listening recall	Digit recall	Listening recall	Digit recall
Subject intransitive	**.51 (.003**)**	.27 (.133)	-.09 (.622)	-.02(.909)	**.61(.004**)**
Subject transitive	**.38 (.032*)**	**.48 (.006**)**	.10(.571)	.15(.427)	**.46(.044*)**
Object	.35 (.053)	**.39 (.028*)**	**.**27(.131)	.14(.455)	.41(.075)
Oblique	**.41 (.019*)**	**.44 (.013*)**	.33(.062)	.25(.163)	**.58(.007**)**
Indirect object	**.36 (.041*)**	**.38 (.031*)**	.35(.053)	.13(.493)	**.54(.014*)**
Genitive subject	.29 (.108)	.17(.353)	**.46(.009**)**	-.07(.724)	.27(.256)
Genitive object	.16 (.390)	-.21(.241)	**.50 (.004**)**	.20(.285)	-.11(.633)

* Significant at $p < .05$ level

** Significant at $p < .01$ level

memory that showed significant correlations for DP relative clause constructions, in children with SLI. The correlation matrices for each group are shown in Table 4. As can be seen for the children with SLI and the younger children with typical development there is a strong significant correlation between *digit recall* and the subject (intransitive), subject transitive, oblique and indirect object relatives. Although not significant, associations between *digit recall* and object relatives are approaching significance for the children with SLI (p = .053) Neither group show any associations with either of the genitive relative clause types (which were most difficult for each group). In contrast these were the only associations shown between *digit recall* and the relative clause types for the age-matched children with typical development. Further analysis was completed using enter multiple regression. For the children with SLI *digit recall* explained the highest amount of variability in subject intransitive relatives (25.7%), followed by oblique relatives (17.1%) subject transitive (14.5%), indirect object relatives (13.1%) and object relatives (11.9%). For the younger children with typical development, *digit recall* again explained the highest amount of variability in subject intransitive relatives (37.1%) followed by oblique relatives (33.9%). Digit recall explained 29% of variability in indirect object relatives, 20.7% of variability in subject transitive relatives and 16.5% of variability in object relatives. With the exception of those relating to the object relatives all other regression equations were significant. For the age-matched children with typical development, *digit recall* explained 20.9% of the variability in genitive (subject) relatives and 24.8% of the variability in genitive (object) relatives.

Further examination of table 4 shows a significant correlation between *listening recall* and transitive subject, object, oblique and indirect object relative clauses in the children with SLI. Using enter multiple regression *listening recall*

accounted for the most variability in subject transitive relatives (22.6%) (F (1, 30) = 8.75, p = .006), followed by oblique relatives (18.9%) (F (1, 30) = 6.995 p= .013), object relatives (15%) (F (1,30) = 5.309 p= .028) and lastly indirect object relatives (14.6%) (F (1, 30) = 5.138 p = .031). *Listening recall* did not correlate within any relative clause type for the age-matched children with typical development.

In summary, the children with SLI and the younger children with typical development showed a similar profile in the associations that emerged between *digit recall* and their performance across a range of relative clause types – both groups showing strong significant associations between *digit recall* and each relative clause type (with the exception of object relatives which was close to significance for the children with SLI, and the genitive relatives in which both groups showed flooring effects). In contrast, for the age-matched children with typical development, the only associations that emerged between *digit recall* and relative clause types were in relation to the genitive relatives (with which they had the greatest difficulty). These children performed almost at ceiling level (in relation to syntactic accuracy score) on most other relative clause types.

Discussion

This study aims to add to the literature underlining the close relationship between components of memory and syntactic knowledge in children with SLI, by refining our view of that association. Firstly, we examined the role of memory in the recall of two general types of relative clause construction, which are differentiated by the form of the matrix clause and whose comparative difficulty is empirically established. Secondly, we investigated the role of memory in the recall of relative clauses defined by a range of syntactic roles, again where an index of difficulty has been established. We then compared the associations that emerged for children with

SLI to those that manifested in both age-matched and younger children with typical development. We will discuss each point in turn.

Memory and the complexity of the matrix clause (single and dual propositional RC constructions)

The first research question asked whether the role of memory, in the ability of children with SLI to repeat relative clause constructions, would be influenced by the complexity of the matrix clause. Given that the recall of these relative clause constructions (averaging 11 words in length) required the children to hold a appreciable amount of verbal material in their pSTM before processing and parsing each sentence, we expected a significant association between pSTM and the children's performance recalling both types of relative clause construction. This was borne out by the *digit recall* data with significant associations emerging for both matrix clause types and is in keeping with that reported by Riches et al. (2010) in relation to DP relatives recalled by adolescents with SLI. However, given that Frizelle & Fletcher (2014a) established that children with SLI found single propositional PN relative clause constructions easier to recall than their dual propositional counterparts, (which were matched for length), we expected that the role of memory might be influenced by the type of relative clause construction being recalled. This clearly was the case. Although associations emerged between *digit recall* and both relative clause constructions, only the more complex DP constructions were significantly associated with *listening recall* (a measure of WM). Although PN constructions are considered complex, they are not fully bi-clausal and can be paraphrased by a simple sentence. The role of the matrix clause in these structures is merely to introduce the noun and in that sense could be omitted e.g. *There is the sheep that drank the water this morning,*

could be represented as *The sheep drank the water this morning*. Propositionally these sentences are therefore similar to simple sentences. The fact that children with SLI find PN relatives easier to recall than DP relatives, the frequency of PN relatives in young children's speech (Diessel, 2004 p.131) and the similarity of PN relatives to simple sentences, leads us to believe that these structures are more entrenched than their DP counterparts and therefore more easily activated. This syntactic activation supports access to representations in memory, reducing the need to search through unrelated structural representations and thereby reducing the processing load of the sentence. It appears that when recalling PN relatives the child can move more efficiently through the sentence formulation process and can therefore produce the sentence by relying more heavily on their pSTM than on their WM. In contrast, DP relative clause constructions are fully bi-clausal and place higher demands on the memory systems of children with SLI: if the syntactic information is not available to support representations in memory, a search through unrelated representations is required, thereby increasing the processing load of the sentence to be recalled. Lack of syntactic knowledge in the cohort with SLI, therefore demands the use of already reduced working memory, in recalling these sentences. In turn, reduced working memory impacts on their ability to generate accurate linguistic representations in a timely fashion[3]. This supports the concept of a synergistic relationship between syntactic knowledge and components of memory.

There are interesting comparisons here with the work of Montgomery and Evans' (2009), while acknowledging that we used different types of complex sentences. Broadly speaking if we align our PN relatives with their simple sentences and our DP relatives with their complex sentences, our results are somewhat similar,

[3] This result was in contrast to Riches et al. (2010) who reported no such association in adolescents but who used only one measure of WM (*backward digit recall*) a variable with which we did not find any association either.

and serve to strengthen these associations further. However one difference between our results, in relation to children with SLI, is the absence of an association between pSTM and complex sentences in Montgomery and Evan's (2009) study. They suggest that this may be to do with the types of complex sentences investigated and their relatively short length. It is also worth noting that their measure of pSTM was *non-word recall*, a variable with which we did not find an association either.

Memory and the complexity of the relative clause

The second research question addressed whether associations that emerged between memory and the recall of relative clause sentences would be influenced by the syntactic role of the embedded clause. The data suggests that this is the case. The strongest association emerged between *digit recall* and the relative clauses with which the children with SLI had the least difficulty (intransitive subject relatives), while no association was evident between *listening recall* and this relative clause type. These relative clauses are similar to their transitive subject counterparts, in that they follow the canonical sentence sequence frequently used in simple sentences and are therefore considered easier to activate and easier to process, than relative clauses that do not match this schema [4]. However, Diessel, (2004, p.138) notes that transitive relatives are very infrequent among the early relative constructions produced by children with typical development and the majority of children's early relatives contain an intransitive verb (73%). Although matched for length, these structures have one less argument than other relative clause types again making them easier to process. It seems that when children with SLI are recalling these sentences, they are relying heavily on their phonological short-term memory but not invoking the use of working memory. However other relative clauses with which children with SLI showed a

[4] Although recent research (Frizelle & Fletcher, 2014a) suggests that in the case of object relatives, specific lexical choices can override processing difficulties arising from a non-canonical structural configuration

lower level of recall ability (transitive subject, object, oblique and indirect object) appeared to call on the use of both components of memory (showing significant relationships with *digit recall* and *listening recall*). With the exception of the transitive subject relatives, the other types are considered more difficult to interpret because they involve a sequence of nouns and verbs that do not match the noun-verb-noun schema to which children are frequently exposed. It is also the case that young children tend not to produce oblique and indirect object relatives, as they are rarely exposed to them in child directed speech (Diessel, 2004, p.136, p.146). Applying a usage-based account, this lack of exposure results in these structures being more difficult to activate and makes it more difficult for children to recognize structural similarities between sentences. This in turn increases the processing load of the relative clause, the need to search through unrelated structural representations in memory, and the demand on both pSTM and WM. No associations emerged between either memory component, and the relative clauses with which children with SLI had the greatest difficulty. It is suggested that their performance was so low on the genitive relative clause types no relationships could emerge.

Memory and the performance of children with typical development

Our third research question asked how the associations that emerged for children with SLI compared with those that emerged for age-matched children and children who were on average two years younger with typical development.

In contrast to the children with SLI, the complexity of the matrix clause did not influence the role of memory in recalling the relative clause constructions for either group of children with typical development. These children showed significant associations between phonological short-term memory and both PN and DP relative clause constructions. In further contrast, they did not invoke the use of working

memory (based on only one measure for the younger children) when recalling the more complex DP relative clause constructions. It seemed that for age-matched children with typical development their level of syntactic knowledge, regarding PN and DP relative clause constructions, was such that they did not depend heavily on their working memory to recall these sentences. Although the absence of an association between working memory and complex sentences is in contrast to what has been documented in the adult literature (Just & Carpenter, 1992; King & Just, 1991) this can be explained by their near ceiling performance on both sentence types. In contrast, adult studies tend to involve highly complex sentences (including multiple-embedded clauses) that push the individuals to their processing limits.

For the younger group the picture is less clear, as due to age restrictions in the administration of the WMTB-C (Pickering & Gathercole, 2001), we have only one measure of working memory (*backward digit recall*) and this measure did not correlate with sentence recall for any group. Given their performance on the sentence recall task, and the fact that their *backward digit recall* performance was not significantly different from that of the children with SLI, it is likely that the DP sentences are taxing the working memory abilities of the younger children with typical development but we cannot be sure of this relationship, as we do not have a reliable measure on which to base our conclusions.

In relation to the syntactic role of the relative clause, the younger children with typical development showed a similar profile to the children with SLI, in the relationships that emerged between *digit recall* and relative clause types. This provides further support for the concept that there is a synergistic relationship between syntactic knowledge and components of memory. Although these children performed better than the children with SLI on the sentence recall task, they

performed significantly worse than the older control group (Frizelle & Fletcher, 2014a). Their syntactic knowledge was such that they relied heavily on their phonological short-term memory to repeat these structures.

In contrast, the only relationships between *digit recall* and relative clause types for the older group of children with typical development were with both types of genitive relative clause i.e. those with which these children had the greatest difficulty. With the exception of the genitive relatives it seems that the other relative clause structures are so easily activated by these children they are not relying heavily on either memory component.

Clinical Implications

Our final research question asked what implication for clinical practice could we draw from our results. Our results suggest that the issue of, which components of memory are associated with the ability of children to recall syntactic structures, depends on both the syntactic abilities of the individuals carrying out the task, and the degree of difficulty of the structure to be recalled. Structures with which children with SLI have a greater degree of control, (in this case PN relative constructions and intransitive subject relatives), can be parsed and processed by relying more prominently on pSTM. Whereas those that are less stable and are therefore more difficult to activate (DP constructions, subject transitive, object, oblique and indirect object), invoke the use of children's WM skills.

This information, which is suggestive of a synergistic relationship between memory and syntax, builds on that presented in Frizelle & Fletcher (2014a). As a result, PN relatives should serve as the point of entry for any therapeutic intervention on relative clauses. In order to minimise the effect of reduced WM in children with SLI each syntactic role should be approached and consolidated within the context of a

PN matrix clause. Clinicians should be cognisant of the difficulty index that exists within relative clause types and reduce the effect of pSTM by shortening the length of the more difficult types in particular. Clinicians should also be aware that full bi-clausal relatives are invoking the use of these children's WM and given that WM intervention training programmes have been found to be ineffective in relation to skill transfer, (Mervy-Lervag & Hulme, 2012) clinicians would be best advised to focus specifically on the syntactic structures in any intervention approach.

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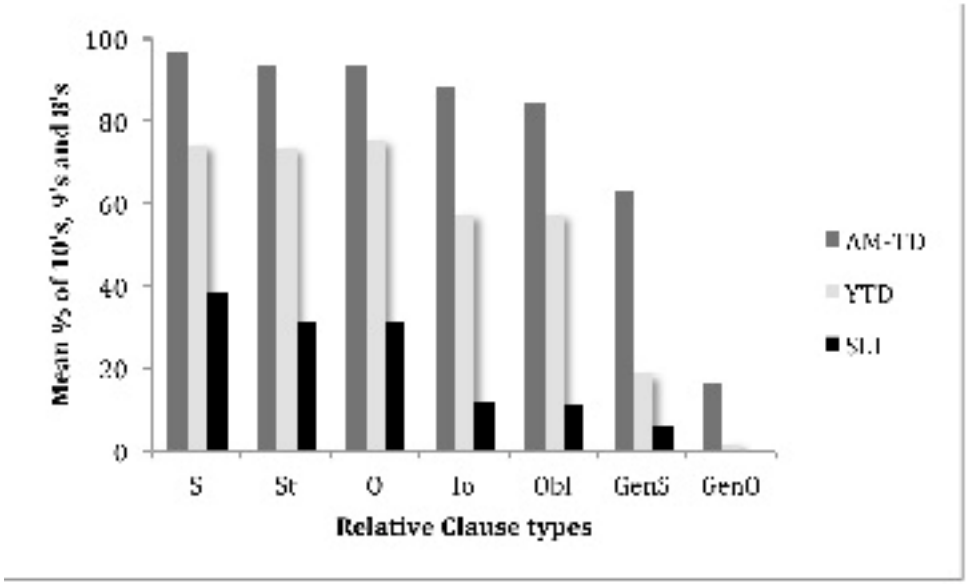
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Supplementary Figure 1.

Mean % of 10's, 9's and 8's Produced in each Relative Clause Type



Supplementary Table 1: *Summary of Cognitive and Language Profiles for each of the Three Groups*

	SLI (n = 32)			AM-TD (n = 32)			YTD (n = 20)		
	M	**SD**	**Range**	**M**	**SD**	**Range**	**M**	**SD**	**Range**
Age	6;10	7.12	6;0 –7;11	6;11	6.5	6;0 – 7;11	4;9	1.5	4;7 –4;11
RLS	68.4	8.52	46 - 81	107.8	8.8	92 - 125	108.5	6.2	96 - 120
IQ	97.1	7.61	85 - 115	104.7	10.2	90 - 130	110.8	7.8	95 – 130

RLS = Receptive Language Score

Supplementary Table 2 – *Examples of syntactically accurate RC constructions with and without minor errors*

Score - Error type	Target Sentence	Sentence Produced
10 No errors	The cat caught the mouse that ran around the garden.	The cat caught the mouse that ran around the garden.
9 Lexical error	Eddie met the girl who broke the *window* last week.	Eddie met the girl who broke the *thing* last week.
8 Lexical and Grammatical error (change in tense)	The *girl ate* the sweets that you *brought* to the party.	The *boy eat* the sweets you *brung* to the party.