TALITA MARIA FORTUNATO-TAVARES

Syntactic structural assignment in children with specific language impairment, autism and Down syndrome

[Designação sintática estrutural em crianças com distúrbio específico de linguagem, autismo e síndrome de Down]

Tese apresentada à Faculdade de Medicina da Universidade de São Paulo para obtenção do título de Doutor em Ciências

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To my greatest blessings...

Às minhas grandes bênçãos...

Presentation

This doctoral dissertation was conducted in collaboration with Dr. Richard G. Schwartz, Professor at the Speech -Language - Hearing Department, The Graduate Center, City University of New York.

The research project included two phases. The first was composed by the investigation of Brazilian children with Specific Language Impairment and their typically developing peers. This first study - presented in the dissertation as Study I - was accepted for publication in the Journal of Speech, Language and Hearing Research [Fortunato-Tavares, T., Andrade, C. R. F., Befi-Lopes, D. M., Hestvik, A., Epstein, B., Tornyova, L., & Schwartz, R. G. (in press). Syntactic structural assignment in Brazilian Portuguese-speaking children with specific language impairment. *Journal of Speech, Language, Hearing Research*; doi:10.1044/1092-4388(2011/10-0215)]. The second phase consisted on the expansion of Study I, covering the investigation of syntactic structural assignment in children with Specific Language Impairment, Autism and Down syndrome. This study is presented in the dissertation as Study 2.

This dissertation is presented in English as it is the result of an international collaboration.

Apresentação

A pesquisa que envolve esta Tese foi realizada em parceria com o Dr. Richard G. Schwartz, Professor do *Speech-Language-Hearing Department, The Graduate Center, City University of New York.*

O projeto de pesquisa contemplou duas etapas. A primeira consistiu na investigação de crianças Brasileiras com diagnóstico de Distúrbio Especifico de Linguagem e seus pares com desenvolvimento típico. Este primeiro estudo, apresentado na Tese como Estudo I, foi aceito para publicação no *Journal of Speech, Language and Hearing Research* [Fortunato-Tavares, T., Andrade, C. R. F., Befi-Lopes, D. M., Hestvik, A., Epstein, B., Tornyova, L., & Schwartz, R. G. (in press). Syntactic structural assignment in Brazilian Portuguese-speaking children with specific language impairment. *Journal of Speech, Language, Hearing Research*; doi:10.1044/1092-4388(2011/10-0215)]. A segunda etapa consistiu na ampliação do Estudo I, contemplando a investigação da designação sintática estrutural em crianças com diagnóstico de Distúrbio Especifico de Linguagem, Autismo e Síndrome de Down. Este estudo está apresentado na Tese como Estudo II.

Devido ao fato desta Tese ser fruto de parceria internacional, a mesma é apresentada na língua inglesa.

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So many people have helped me in so many ways to get me from where I started to where I am today that I hardly know how to start - and how to stop is even more challenging. Let me first just make the statement that I know, both as a professional and a person, that I am a work in progress who is a sum of all she has learned and experienced. I owe everything to the people who have taught me, helped me, and supported me and I thank God for the incredibly amazing life I have.

A very special thanks goes to the children and their parents who participated in this study. I thank each of you for your willingness (and patience!) to devote your time to contribute to this work. Child language research would not exist if it were not for people like you!

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It has been a great privilege to spend several years in the Department of Physical Therapy, Communication Sciences and Disorders and Occupational Therapy (Departamento de Fisioterapia, Fonoaudiologia e Terapia Ocupacional) at FMUSP. It all started during my years as an undergraduate student. I would like to take this opportunity to thank each member of my two classes, 27 and 28, for the countless incredible moments we spent discovering a completely new world together.

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This work would not have existed without the support of Professor Richard G. Schwartz, my doctoral mentor at the CUNY Graduate Center. I am forever indebted to you, not only for the countless ways you contributed to this particular project, but also for the myriad ways you have supported me in all of my professional goals. You have taught me more than how to do research; you taught me how to live with humility, curiosity, conviction and to always find a place for joy. For all of these reasons this dissertation is dedicated in part (and a very great part!) to you.

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I have to say that acknowledging family is not an easy task. I start with a special thanks to my “family through marriage”, especially Gilda and Naylor, for giving me a place where the door is always open.

My grandparents made growing up so much fun! My childhood memories are composed of them. I especially thank my two grandmas, Nair (*in memoriam*) and Deolinda (*in memoriam*), for their invaluable companionship. I am very grateful I could have you by my side for so long. I lost both of you during this “dissertation process” and I feel very sorry I was not able to finish early so you could see me here.

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I would not be anything without the love and support of my mother, my father, my brother, and the joy of my little nephew, Gustavinho. My mother, Marilena, is my example in everything I do. I have no idea how to express how grateful I am for EVERYTHING you have done for me. You always find a way to make things in life easy for us even in our most difficult times. My father, Arnaldo (*in memoriam*), will always be my deepest inspiration. I lack words to describe how much I miss you. There is no need to say that I wished you were here to see how far I have come; I know you have never truly left. I am grateful to have my brother, Arnaldo Jr., by my side. You are the most intelligent person I know and it has been great sharing life with you. Thank you for bringing Gustavinho into our lives. Gustavinho, thank you for teaching me how to be a child again and for taking me away from the “grown up world” whenever you are around!

Finally, this dissertation is dedicated to my greatest blessing, Gustavo, my husband, the most loving, brilliant and decent person I have ever known.

All of us who have you in our lives know just how amazing you are in everything that you do. You make me proud every day. Thank you for all your unconditional love and support in absolutely everything. A lifetime with you will always be too short…

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If you can dream it, you can do it.

Walt Disney

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Study II – Syntactic Assignment in Children with Specific Language Impairment, Autism and Down Syndrome

Abbreviations

ANOVA	Analysis of Variance
ASD	Autism Spectrum Disorders
C	Correct
CCEB	Brazilian Economic Classification Criterion *[Critério de Classificação Econômica Brasil]*
C-command	Constituent command
CGC	Computational Grammatical Complexity
dB HL	Decibel Hearing Level
DS	Down Syndrome
H	Hierarchical
HOD	Hierarchical Ordering Deficit
Hz	Hertz
IQ	Intelligence Coefficient
ISI	Interstimulus Interval
MLU	Mean Length of Utterance
MLU_m	Mean Length of Utterance - morpheme
ms	Millisecond
NP	Noun Phrase
P	Preposition
PP	Prepositional Phrase
R	Reverse
S	Sentence
SES	Socioeconomic Status
SLI	Specific Language Impairment
STOP	Syntactic Test of Pronominal Reference
TLD	Typical Language Development
TONI	Test of Nonverbal Intelligence
VP	Verbal Phrase
WM	Working Memory

Abstract

Purpose: to study the hierarchical syntactic structuring in children with language disorders. The research involved children with Specific Language Impairment (SLI), Autism Spectrum Disorders (ASD), and Down Syndrome (DS). The main purpose of this dissertation was to examine and compare the syntactic structural assignment, through the comprehension of sentences with predicates and reflexives that are linked to a non-adjacent noun, as a test of the Hierarchical Ordering Deficit Hypothesis (HOD). That hypothesis posits that children with language impairment have difficulty in establishing non-adjacent (hierarchical) relations among elements of a sentence. This dissertation also tested whether additional working memory demands in constructions containing reflexives affected the syntactic assignment of children with SLI, ASD and DS. **Method:** Sixty-two Brazilian Portuguese-speaking children (40 boys and 22 girls) between 7;0 and 14;2 years of age participated in two studies that investigated the syntactic assignment of predicates and reflexives. Study I compared performance of children SLI to children with typical language development (TLD). Study II compared the performance of children with SLI, ASD, DS and TLD peers. The experiment consisted on a computerized sentence comprehension task designed on E-Prime software. Each child responded to 72 trials which were randomly presented to avoid order or familiarization effects. For each trial, the child was presented with a context sentence (maximum duration of 5500 ms) and, after an interstimulus interval of 1000 ms, the target sentence (maximum

duration of 5000 ms) and the visual stimuli (four pictures) were presented simultaneously. **Results:** In Study I, children with SLI were significantly less accurate on all conditions. Different error distributions were observed on the two working memory conditions. Both groups made more errors resulting in incorrect syntactic construction in the long working memory condition.
In Study II, children with SLI, ASD, and DS exhibited poorer overall performance than TLD children. The groups of ASD and DS exhibited similar response patterns across conditions. Children with SLI exhibited similar performance to the DS and ASD children only when working memory demands were higher. **Conclusion:** The HOD hypothesis was not confirmed. Children with SLI, ASD and DS differ from children with TLD on the comprehension of predicate and reflexive structures where knowledge of syntactic structural assignment is required. There are similarities between children with ASD and DS on the comprehension of these structures. Working memory has different effects in syntactic comprehension depending on the language disorder.

Descriptors: Child language; Language development disorders; Working memory; Autism; Down syndrome.

Resumo

Objetivo: Estudar a estruturação hierárquica da sintaxe em crianças com distúrbios de linguagem. Foram pesquisados os quadros de Distúrbio Específico de Linguagem (DEL), Distúrbios do Espectro Autístico (DEA) e Síndrome de Down (SD). O objetivo principal desta pesquisa foi avaliar e comparar a designação sintática estrutural, por meio da compreensão de sentenças com predicativos e pronomes reflexivos ligados a um substantivo não adjacente, de modo a testar a hipótese do Déficit de Ordenação Hierárquica (DOH). Essa hipótese postula que crianças com distúrbios de linguagem têm dificuldade em estabelecer relações não adjacentes (hierárquicas) entre os elementos de uma frase. Esta pesquisa também avaliou se uma demanda adicional de memória de trabalho, em construções contendo pronomes reflexivos, afeta a designação sintática estrutural em crianças com DEL, DEA e SD. **Método:** Sessenta e duas crianças falantes do Português Brasileiro (40 meninos e 22 meninas) entre 7; 0 e 14; 2 anos de idade participaram de dois estudos que investigaram a designação sintática de predicativo e de pronome reflexivo. O Estudo I comparou o desempenho de crianças com DEL e crianças com desenvolvimento típico de linguagem (DTL). O Estudo II comparou o desempenho de crianças com DEL, DEA, SD e seus pares com DTL. O experimento consistiu em uma tarefa computadorizada de compreensão de sentenças desenvolvida no software *E-Prime*. Cada criança respondeu a 72 ensaios apresentados aleatoriamente, de modo a evitar efeitos de ordem ou familiarização. Em cada ensaio, a criança foi apresentada a uma frase contextual (duração máxima de 5500 ms) e, após um intervalo entre estímulos de 1000 ms, a frase alvo (duração máxima de 5000 ms) e o estímulo visual (quatro figuras) foram apresentados simultaneamente. **Resultados:** No Estudo I, as crianças com DEL foram significativamente menos precisas em todas as condições. Diferentes distribuições de erro foram observadas nas duas condições de memória de trabalho. Ambos os grupos apresentaram mais erros acarretando em construções sintáticas incorretas na condição de longa demanda de memória de trabalho. No Estudo II, crianças com DEL, DEA e SD apresentaram pior desempenho quando comparadas às crianças com DTL. Os grupos DEA e SD apresentaram padrões de resposta semelhantes entre si em diferentes condições. As crianças com DEL apresentaram desempenho similar ao de crianças com DEA e SD apenas quando as demandas de memória de trabalho foram maiores. **Conclusões:** A hipótese DOH não foi confirmada. Crianças com DEL, DEA e SD se diferenciam de crianças com DTL na compreensão de sentenças com predicativos e reflexivos onde o conhecimento da designação sintática estrutural é necessário. Existem semelhanças entre as crianças com DEA e SD na compreensão destas estruturas. Diferentes efeitos de memória de trabalho na compreensão sintática são encontrados de acordo com o distúrbio de linguagem.

Descritores: Linguagem infantil; Transtornos do desenvolvimento da linguagem; Memória de trabalho; Autismo infantil; Síndrome de Down.

Study I

Syntactic Structural Assignment in Brazilian Portuguese-Speaking Children with Specific Language Impairment

Abstract

Purpose: This study examined the comprehension of sentences with predicates and reflexives that are linked to a non-adjacent noun as a test of the Hierarchical Ordering Deficit Hypothesis (HOD). That hypothesis and more modern versions posit that children with Specific Language Impairment have difficulty in establishing non-adjacent (hierarchical) relations among elements of a sentence. It also tested whether additional working memory (WM) demands in constructions containing reflexives affected the extent to which children with SLI incorrectly structure sentences as indicated by their picture-pointing comprehension responses. **Method:** Sixteen Brazilian Portuguese-speaking children (8;4-10;6) with SLI and 16 children with typical language development (TLD) matched for age (±3 months), gender, and socioeconomic status participated in two experiments (Predicate and Reflexive interpretation). In the Reflexive Experiment, we also manipulated WM demands. Each experiment involved a four choice picture selection sentence comprehension task. **Results:** Children with SLI were significantly less accurate on all conditions. Both groups made more hierarchical syntactic construction errors in the long as compared to the short WM condition. **Conclusion:** The HOD hypothesis was not confirmed. For both groups, syntactic factors (structural assignment) were more vulnerable than lexical factors (prepositions) to WM effects in sentence miscomprehension.

One characteristic of Specific Language Impairment (SLI) is a deficit in the comprehension and production of sentences, particularly those that involve long distance relationships. Several proposals have focused on the computational grammatical complexity (CGC) hypothesis, which posits deficits in the computational grammatical system that affect hierarchically complex structures in one or more components (syntax, morphology, phonology) of language (Gallon, Harris, & van der Lely, 2007; Marinis & van der Lely, 2007; Marshall & van der Lely, 2006; van der Lely, 2005; van der Lely & Stollwerck, 1997).

The hierarchical ordering deficit (HOD) account (Cromer, 1978), an historical predecessor of CGC, suggests that children with language impairment do not assign structure to sentences in the same way as their typically developing peers. According to this account, children with language impairment represent sentences as *flat* instead of hierarchically organized structures and the absence of hierarchical relations within the sentence structure would account for their overall difficulties with sentence comprehension. Although the HOD account concerns children with language disorders as the discussion and definition of SLI had not yet emerged by the late 1970s, this hypothesis has not been directly studied in children with SLI.

Bishop (1982) examined the HOD hypothesis in children with Landau-Kleffner syndrome who may exhibit some similar language deficits to children with SLI (Billard, Fluss, & Pinton, 2009; Deonna & Roulet, 2005; Overvliet et al., 2010). In that study, Bishop tested the relation between a predicate and the syntactic position of the nominal to which the predicate applies (attachment). An offline sentence comprehension task was used, in which children heard a sentence and then pointed to a picture in an array of four. Ten sentences with the following structure were devised: *The X in/on/under/in front of/behind the Z is Y*, where X and Z were nouns and Y was a color term. For each sentence, the corresponding of four pictures were: correct picture (C); sequential error where X and Y are reversed (S); P: prepositional error, corresponding to a sentence with a different preposition (P); and hierarchical error, corresponding to the type of error discussed above where the complement applies to Z rather than X (H). The actual group and individual scores were never presented. Instead, Bishop classified the children as C-, S-, P- or H- responders according to the most frequent type of response given to the ten sentences. Children who did not show a preference for selecting one type of picture were classified as *mixed*. More children with Landau-Kleffner syndrome were classified as having a hierarchical error preference than for any other response. In contrast, children with typical language development (TLD) did not show a particular preference for one type of distractor. Although Bishop concluded that these findings supported the HOD hypothesis as a cause for the deficit in comprehending sentences with hierarchical long-distance dependencies, the small number of stimuli, and the unusual data analyses render the conclusion uncertain.

Several studies have investigated the ability of children with SLI to comprehend and produce sentences with long distance dependencies. Although there seems to be an agreement that children with SLI do have an overall difficulty with a variety of syntactic structures, such as relative clauses (Friedman & Novogrodsky, 2004, 2007; Hestvik, Schwartz & Tornyova, 2010; Schuele & Tolbert, 2001) and wh-questions (Deevy & Leonard, 2004; Hansson & Nettelbladt, 2006; Marinis & van der Lely, 2007), the overall source of these difficulties is not yet clear. Among the candidate deficits that might explain these difficulties are specific grammatical deficits (e.g., Cromer, 1978; van der Lely, 2005; van der Lely & Stollwerck, 1997) and working memory processing limitations (e.g., Deevy & Leonard, 2004; Hestvik, Schwartz & Tornyova, 2010; Marton, Schwartz, Farkas, & Katsnelson, 2006). In the present study, we examined the HOD hypothesis and the effects of working memory demands on syntactic structural assignment of children with SLI and their chronologically matched controls.

Syntactic Aspects of the Hierarchical Ordering Deficit Hypothesis

The HOD hypothesis (Cromer, 1978) is based on the dependency among elements of a syntactic arrangement. When two or more elements co-occur in a syntactic arrangement, some type of dominance exists between or among them. Typically, there is one dominant element, the *head,* which is the primary determinant of the properties of the arrangement. The other elements are its *dependent(s)* (Van Valin, 2001). C-command (deriving from *constituent command*) is a relationship between phrasal nodes (elements of syntactic structure) in grammatical trees. Originally defined by Reinhardt (1976), it corresponds to the idea of *siblings and all their descendants* in a hierarchical relationship.

To illustrate, when a sentence like *The chicken on the ball is brown* is heard, a hierarchical representation (Figure 1a) of the sentence is incrementally built as each word is processed. However, suppose that children with SLI fail to build the correct syntactic structure during on-line sentence processing. The same sentence would then be represented as a sequence of units in a *flat* structure (Figure 1b) and the absence of hierarchical relations results in an indeterminant attachment. It also leads to an absence of structural differentiation information among the elements of the syntactic tree resulting in comprehension errors with discourse consequences.

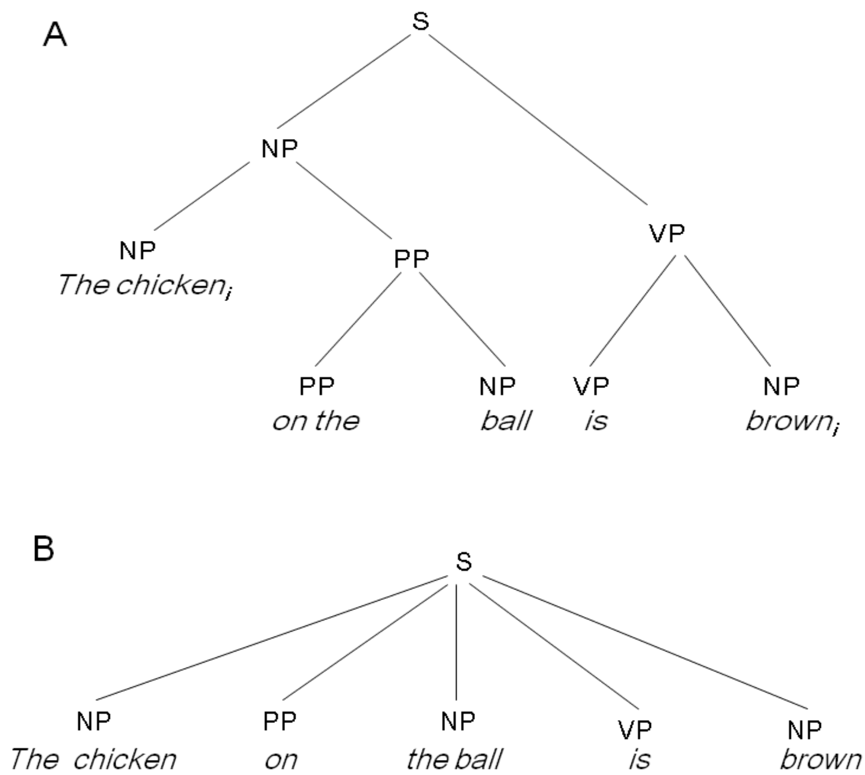

Figure 1: A. Hierarchical structure representation of the sentence with predicate attachment *The chicken on the ball is brown*. B. Incorrect (*flat*) structure representation of the sentence *The chicken on the ball is brown*.

In Figure 1a, the subject NP (*the chicken*) is positioned higher in the tree than the predicate (*brown*). Therefore, the interpretation of this hierarchically built structure would be that *the chicken is on the ball, and the chicken is brown* because the subject (*the chicken*) c-commands the predicate (*brown)*. In Figure 1b, this differentiation is not present and is not expressed by the structure. This lack of hierarchical structure results in ambiguity; the predicate (*brown*) could be attached either to the nearest NP (*the ball*) or to the furthest NP (*the chicken*). In case a recency strategy is employed, the predicate (*brown*) is applied to the nearest NP (*the ball*). In the latter, the interpretation of this flat structure would be that *the chicken is on the ball, and the ball is brown -* in other words, *the chicken* is not higher than *brown* in this incorrect syntactic structure.

The supposed incorrect structure assignment proposed by Cromer (1978) should have the same effects on predication relationships and on reflexive interpretation. Reflexive interpretation, like predication, relies on structure assignment because a reflexive pronoun must agree with the antecedent that c-commands it in person, gender and number. C-command essentially means that the antecedent must be asymmetrically higher in the tree representation than the reflexive. For example, in the following syntactic representation (Figure 2a), the reflexive pronoun can only refer to *the dad*, not *the grandpa.* The reason for this is that the NP *the dad* is the head of the subject. Only *the dad* c-commands the reflexive, and thus, only this NP can provide reference for the reflexive. If SLI children do not correctly represent these structural relations (as in Figure 2b), their rules for reflexive interpretation would not apply correctly, and they might allow *the grandpa* to be the antecedent of the reflexive, yielding the interpretation: *the dad is in front of the grandpa, and the grandpa is scratching himself*.

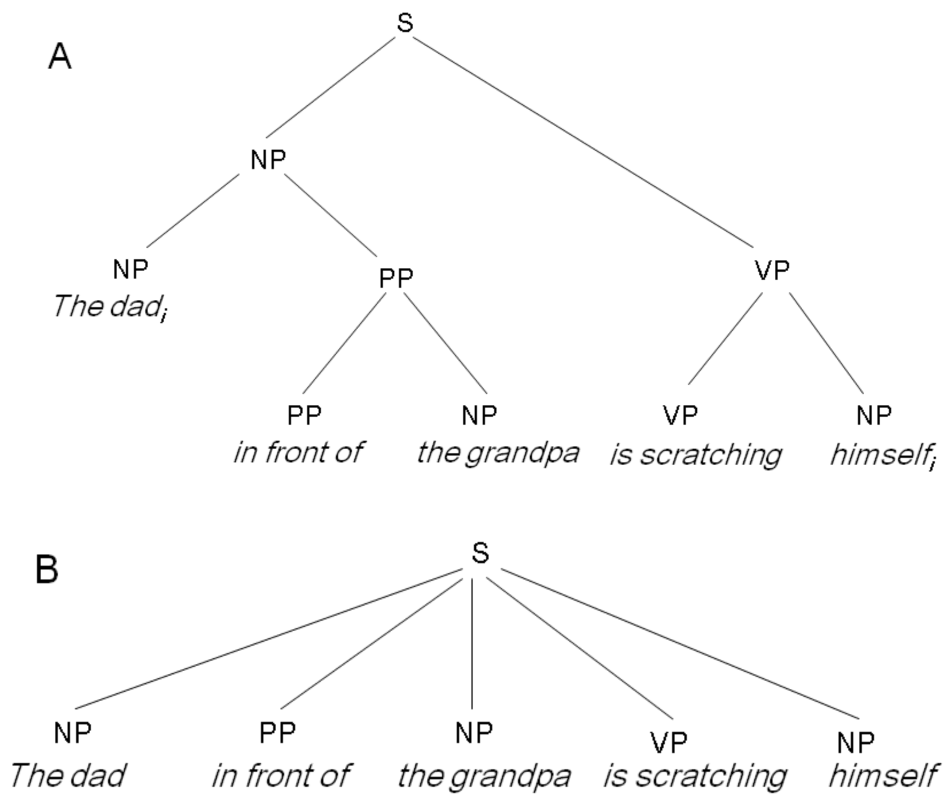

Figure 2: A. Hierarchical structure representation of the sentence with a reflexive dependency *The dad in front of the grandpa is scratching himself*. B. Incorrect (*flat*) structure representation of the sentence *The dad in front of the grandpa is scratching himself.*

Syntactic Structural Assignment and Reflexives

Studies have examined whether deficits in the syntactic structural assignment affect reflexive-antecedent relations in the SLI population using the Syntactic Test of Pronominal Reference (STOP) (e.g., van der Lely, 1998; van der Lely & Stollwerck, 1997). The STOP analyzes syntactic assignment of pronouns and reflexives in the following relations: name-pronoun; quantifier-pronoun; name-reflexive; and quantifier-reflexive. The test consists of 108 sentences being 48 experimental and 60 fillers. Each sentence is presented twice. In one presentation, the picture matched the target sentence and, in the other presentation, the picture did not match with the target sentence. In a study (van der Lely & Stollwerck, 1997) using the STOP, 12 children with grammatical SLI (9;3 to 12;10 years of age) were near ceiling on the name-reflexive conditions in which semantic-conceptual lexical knowledge was sufficient to identify the correct antecedent. In contrast, SLI children had significantly lower accuracy scores than their language-matched controls (5;5 to 8;9 years of age) in mismatch conditions with lexical information that was insufficient to determine the antecedent and the children had to rely only on syntax. A subsequent study (van der Lely, 1998) reported similar findings on a case study of a boy with SLI but much less details of findings were provided. On these two studies, the authors concluded that children with SLI have sufficient knowledge of the semantic conceptual properties of reflexives and theta role assignment but they do not have the syntactic knowledge characterized by the Binding Theory.

However, some facts about these studies should be noted. The test included syntactic constructions with subordinate clauses and question structures, which might have added greater complexity to the reflexives. Furthermore, a limited number of different sentences per condition (only six as each sentence was presented twice) were used. Children with SLI were up to 5.5 SDs below the mean on standardized tests, an atypical study group, which also resulted in a very young group of language-matched controls. Moreover, in van der Lely and Stollwerck (1997), no between-group differences were observed on the match condition in which children had to rely only on syntax. Processing limitations such as working memory deficits may also play a significant role on the construction of hierarchical syntactic structures and none of these studies had taken that into account. The role of structured syntactic assignment and the influence of working memory on sentence comprehension of children with SLI still remain unclear.

Working Memory and Sentence Comprehension

Although domain specific perspectives of SLI like the CGC account predict a pervasive deficit in grammatical components determined by structural complexity, they reject the influence of working memory. Working memory is critical for processing language because the building of syntactic and discourse structures requires relating linguistic units across a number of intervening words and syllables in a lengthy time span (Martin & McElree, 2009; Marton et al., 2006; McElree, Foraker, & Dyer, 2003).

Most investigations of the relation between working memory and sentence comprehension have analyzed the correlation between independent working memory measures (e.g., nonword and real word repetition, repetition of word lists, etc.) and performance on a sentence comprehension task. For example, Just and Carpenter (1992) used a sentence list recall task to classify subjects as having high or low sentence memory spans and then found that their memory span was related to their performance on an independent comprehension task. In contrast, Waters and Caplan (1996) found that sentence list recall span was not a major determinant in the processing of garden path sentences. This latter finding led to a proposal of multiple working memory capacities that subserve language processing and to the suggestion that the sentence span task does not assess the working memory used for language comprehension in adults.

Montgomery and his colleagues have examined the influence of working memory on sentence comprehension by children with SLI. An early study (Montgomery, 1995) provided evidence of a relation between phonological working memory deficits and sentence comprehension difficulties for some children with SLI. More recent studies (Montgomery, 2000, 2004; Montgomery & Evans, 2009) provided evidence that sentence comprehension is associated with working memory and claimed that deficits in comprehending complex sentences cannot be explained by a syntax-specific representational deficit. These conclusions were also based primarily on the correlation of independent working memory measures and sentence comprehension performance. The working memory tasks typically employed reflect the temporary storage of verbal material that plays only a secondary role in higher level language comprehension. It is not surprising that performance on these tasks are correlated, but to understand the role of working memory in sentence comprehension tasks that manipulate working in sentence comprehension tasks may be more informative.

The few studies that have used such a direct manipulation of working memory load in sentences have posited working memory as one of the underlying causes of sentence comprehension problems in children with SLI. In a study of Wh-question comprehension with direct manipulation of sentence working memory demands (Deevy & Leonard, 2004), children with SLI performed similarly to the TLD group on short questions, but showed poorer performance on long object questions than on long subject questions. The combination of a more difficult structure with additional length posed more problems for children with SLI. The authors then concluded that working memory places demands on linguistic processing and thus plays an important role in the difficulties experienced by children with SLI. However, the actual difference between conditions was quite small (one to two items) despite the significant statistical findings.

Marton and her colleagues (2006) reported that the increasing the number of words in a sentence, without an increase in grammatical complexity, did not influence performance accuracy to the same extent as the increase in morphological complexity. In that study, children correctly recalled more words and answered more questions following sentences with simple morphological structures when compared to sentences with complex morphology. These results and previous findings (Marton & Schwartz 2003) suggest an influence of linguistic processing on working memory demands, with a larger impact of linguistic complexity than sentence length on working memory performance accuracy.

Summary

In the present study we examined whether children with SLI have a deficit in their structural assignment. According to the HOD hypothesis (Cromer, 1978), children with language impairment construct a *flat* rather than a hierarchical representation of sentences leading to comprehension errors. If the HOD is correct, children with SLI will exhibit lower accuracy and select more errors reflecting a non-hierarchical construction than children with TLD.

We conducted two experiments to examine two types of structural assignment in comprehension: predicates and reflexives. The first experiment focused on predicate-NP relations as in Bishop (1982). The second focused on reflexives and their antecedent nouns. If the HOD hypothesis is true, it should be valid for both predicates and reflexives.

If the deficit is domain specific as in the CGC and the HOD accounts, working memory effects on sentence comprehension would not occur. We examined this in the second experiment by manipulating sentence length without adding structural complexity. By examining error patterns, we also expected to be able to tease apart syntactic and lexical factors from working memory effects.

Cross-linguistic Issues

Although the hierarchical structure of the phrases is assumed to be universal, the linear ordering between the head and its complements, as well as between the intermediate level and the specific position, is language specific. The latter is considered a parameter of Universal Grammar, giving rise to various word orders across languages. Brazilian Portuguese is a head-initial language (as are English, French, Hebrew and many others) in which the head (for example the verb *ate*) precedes the complement (for example the NP *an apple* in the sentence *John ate an apple,* from Botwinik-Rotem & Friedmann, 2009). There is a high attachment preference in Brazilian Portuguese (Miyamoto, 1998) for both structures under investigation in this study (predicate attachment and reflexive assignment). Thus, it is reasonable to generalize findings from the present study to other head-initial languages and languages with high attachment preference for predicates and reflexives.

Brazilian Portuguese primarily uses reflexive pronouns as clitics attached to the verb as in other Romance languages. Unlike English reflexive pronouns, reflexive clitics in Brazilian Portuguese are unstressed. They have person and number markers (but no gender markers) and cannot be used in isolation. The basic pattern for clitic placement in modern Brazilian Portuguese is preverbal. The Brazilian Portuguese third person reflexive clitic used in the current study is *se,* as exemplified in (a):

(a) O pai$_i$ na frente do avô <u>se</u>$_i$ coçou.

[*The dad$_i$ in front of the grandpa scratched <u>himself</u>$_i$.*]

Bedore and Leonard (2001) observed that Spanish-speaking children with SLI performed more poorly than both age and MLU matched controls in marking gender and number of clitics. As no studies have examined clitic production by Brazilian Portuguese-speaking children with SLI, we aimed to exclude the possible bias of clitic morpheme agreement by presenting only one clitic form: both possible antecedents of clitics in the present study were third person singular.

Typically developing children have problems in acquiring certain clitic forms in some languages. Frequent clitic omissions in obligatory contexts and late onset of clitics in the object position have been observed for languages like Brazilian (Lopes, 2003) and European (Silva, 2008) Portuguese, Italian (Guasti, 1993; Schaeffer, 1997), French (Jakubowicz & Rigaut, 2000; Van der Velde, Jakubowicz & Rigaut, 2002), and Catalan (Wexler, Gavarró & Torrens, 2003). However, determinants with the same morphological form of third person clitics are not omitted. For these languages, clitic omission does not occur because of perceptual or prosodic production factors but because of their syntactic roles.

Although reflexive clitics are less problematic for children than other clitics (Costa & Lobo, 2007; Jakubowicz & Rigaut, 2000; Silva, 2008), the presence of clitics, and not full pronouns like reflexives in English for example, still may pose additional difficulties for children other than the pure reflexive assignment examined here. If the presence of clitics posed an additional challenge, we should observe lower accuracy for the Reflexive than for the Predicate experiment with similar (short) working memory demands.

General Method

Participants

Thirty-two Brazilian Portuguese-speaking children (19 boys and 13 girls) participated in the two experiments. Children were between 8;4 and 10;6 and composed two, aged-matched, equally sized groups (TLD and SLI). All children were paired by age within a three-month maximum interval, by gender (with the exception of one pair), and by social economic status (SES) according to the Brazilian Economic Classification Criterion questionnaire (CCEB - *Critério de Classificação Econômica Brasil* [ABEP, 2008]). Children were also matched by educational level: the same number of children was enrolled in Third (four children), Fourth (nine children), and Fifth (three children) grades in each group. All children came from homes in which Brazilian Portuguese was the only language spoken.

SLI group

These 16 children (10 boys and six girls) were recruited through the Investigation on Specific Language Impairment Laboratory at the Department of Physical Therapy, Communication Sciences and Disorders and Occupational Therapy of the Medical School of Universidade de São Paulo (*Faculdade de Medicina da Universidade de São Paulo* – FMUSP), Brazil. The children with SLI were between 8;4 and 10;6 years old (M = 9;4 years; SD = 9 months). All of the families were identified as C2 (lower middle class) on the CCEB (ABEP, 2008). These children had no history of neurological impairments, no evidence of oral motor disabilities, and no social or emotional difficulties. They all had been diagnosed by a group of Speech-Language Pathologists as having SLI. There is no comprehensive standardized language test in Brazilian Portuguese. The most comprehensive language test available is the ABFW Child Language Test (Andrade, Befi-Lopes, Fernandes, & Wertzner, 2004), which evaluates Vocabulary, Phonology, Fluency, and Pragmatics. The ABFW (Andrade et al., 2004) is the most widely used language test in Brazil and it is also used in Portugal. All children from the SLI group had scores on the ABFW at least 1.25 standard deviations below the mean on Vocabulary, and Fluency measures within normal limits regarding number of stuttering like disfluencies and percentage of stuttered syllables. Children that had only liquid simplification, cluster simplification or distortions were included in the study. Other phonological processes (e.g., stopping, deaffrication) were considered as exclusion criteria. All children exhibited a predominance of use of verbal as compared to gesture and nonverbal communication means (see Table 1 for more detailed information on test scores). All children had MLU_m in spontaneous speech samples of at least 150 utterances below at least 1 standard deviation of reference values available for Brazilian Portuguese (Araujo, 2007). The group mean for MLU_m was 4.84 (SD = 0.48).

Additional criteria for children with SLI selection included normal nonverbal IQ performance (score above 85) as measured by the Test of Non-Verbal Intelligence III (Brown, Sherbenou & Johnsen, 1997) and normal hearing as measured by hearing screening at 25dB HL for the frequencies of

500, 1000 and 2000 Hz. All SLI children had persistent histories of language impairment after more than two years of speech and language intervention and were receiving speech-language services at the time of testing.

Table 1: Mean (standard deviations) of age, non-verbal IQ and language test performance of participants.

	SLI Mean (SD)	**TLD Mean (SD)**	***p***
Age	9.4 (9)	9.4 (8)	0.293
TONI-3	97 (5.8)	101 (5.5)	0.079
ABFW Child Language Test			
Vocabulary raw score	52 (3.6)	77 (3.8)	<.001*
Fluency			
Stuttering like disfluencies	1.4 (1.0)	1.3 (0.9)	0.580
Percentage of stuttered syllables	0.7 (0.5)	0.7 (0.4)	0.580
Pragmatics			
Number of communicative acts per minute	8.8 (0.9)	10.6 (1.1)	<.001*
Percentage of verbal communicative acts	67.5 (3.8)	74.5 (6.6)	<.001*

Note: SLI = specific language impairment; TLD = typical language development; Age expressed in years.months (months); TONI-3 = Test of Non-Verbal Intelligence - 3. Statistically significant p values for t-tests are marked with an *.

TLD group

Children in this group were recruited from Public Schools of São Paulo. The 16 children (nine boys and seven girls) were between 8;5 and 10;6 (*M* = 9;4; *SD* = 8 months). According to the SES questionnaire, all families of children of this group were classified as C2 on the CCEB (ABEP, 2008) with the exception of one family, which was classified as C1 (middle class). These children had scores on the four sections of the ABFW Child Language Test (Andrade et al., 2004) within normal limits. The MLU was not computed in this group due to limits on testing imposed by most of the schools from which children were recruited. Their teachers were questioned about academic performance related to syntax and morphosyntax and none of the teachers reported difficulties in these areas for any participant. All children from this group had no history of language impairment, normal nonverbal IQ performance (score above 85) as measured by the Test of Non-Verbal Intelligence III (Brown et al., 1997), and normal hearing as measured by a hearing screening.

Experiment 1

This experiment tested the comprehension of predicate-NP relations (attachment) by children with SLI and their matched peers.

Stimuli

There were 26 trials in this experiment. Each trial consisted of one context sentence, one target sentence, and an array of four pictures. Context sentences had the following structure: *Here is a(an) X and a(an) Z (Aqui estão a(o) X e a(o) Z),* where X and Z were the nouns of the target sentence (e.g., *Here is a chicken and a ball* - *Aqui estão a galinha e a bola*). Target sentences of this experiment had the following structure: *The X in/on/under/in front of/behind the Z is Y (O X na(o)/acima/abaixo/na frente/atrás de Z é Y)*, where X and Z were nouns and Y was a color term (e.g., *The chicken on the ball is brown* - *A galinha acima da bola é marrom*). Each visual stimulus included four pictures presented on a computer screen: correct picture (correct attachment or antecedent and correct spatial relation), hierarchical error picture (incorrect attachment or antecedent testing for a hierarchical structural error), preposition change error picture (correct attachment or antecedent with a lexical error on the prepositional relation), and reverse error picture (incorrect attachment or antecedent and spatial relations testing for a complete reversal of relations). Figure 3 illustrates the visual (picture) stimuli for the above trial.

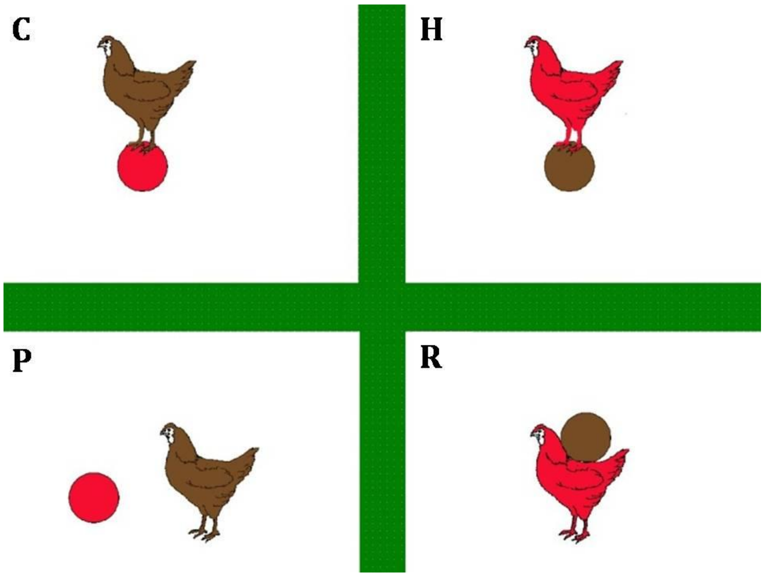

Figure 3: An example of the visual (picture) stimuli from Experiment 1 for the target sentence *A galinha em cima da bola é marrom* (*The chicken on the ball is brown*); C=correct picture; H= hierarchical error picture; P= preposition change picture; R=reverse error picture.

Procedure

The picture stimuli were presented via E-Prime Experimental Control Software (PST software, 1996-2006) on a laptop computer. The auditory (context and target sentences) stimuli were digitally recorded by a female Brazilian Portuguese native speaker on the PRAAT software (Boersma & Weenink, 2006) and presented through the computer speakers at a comfortable audible level.

The trials were randomly presented to avoid length, order or familiarization effects. The experimenter verbally provided the following instructions and they were also presented in written form on the computer screen before the beginning of the experiment: *First you are going to listen to a sentence introducing the characters. Four pictures with those characters will appear on the computer and you will listen to another sentence. You will have to point to the picture that shows what the sentence is about.* Five practice trials were conducted. Although we planned to present the practice trials again if a child did not seem to understand the task, all of the children successfully completed the practice trials.

For each trial, the child was presented with a context sentence followed by the visual (four-picture array) stimulus and the target sentence. For example, on a single trial they heard a context sentence (e.g., *Here is a circle and a star - Aqui estão um círculo e uma estrela)*. Each context sentence had a maximum duration of 5500 ms. After an interstimulus interval (ISI) of 1000 ms, the target sentence and an array of four pictures were presented simultaneously. The target sentences had the maximum duration of 5000 ms (e.g., *The circle in the star is blue - O círculo dentro da estrela é azul).* The picture position in the four quadrants of the computer screen was randomly selected for each trial. The four pictures remained on the computer screen until a response was detected. The child then had to select (by pointing) the picture that corresponded to the sentence (the experimenter pushed the corresponding response button). The responses were classified and analyzed according to picture selection (correct, hierarchical error, preposition error, or reversed error).

Data Analysis

A widely used approach to analyze data from picture selection tests is to consider the responses as continuous data using methods such as t-test and ANOVA. However, this ignores the fact that these responses are categorical data. The validity of using t-tests and ANOVAs for categorical response types is questionable (Ennisi & Bi, 1999; Stevens, 1946). The practical implication of this approach is that an inflated Type I error can result in an erroneous conclusion.

The categorical responses of the current study follow a multinomial distribution (in each trial, the child had to select one picture among the four presented). The observed response patterns exhibited heterogeneity among children, especially in the SLI group, and many null responses, especially for the TLD group. An appropriate, although less commonly used statistical model for this type of data is the Dirichlet-Multinomial model (Molenberghs & Verbeke, 2005; Paulino & Singer, 2006). In our analysis, we fitted the Dirichlet-Multinomial model via maximum likelihood methods and compared the expected response frequencies between and within groups via Wald statistics.

Results

Figure 4 illustrates the responses (in percentage) according to picture type selection (correct, hierarchical, preposition change, and reversed) for both groups (TLD and SLI). Children with SLI had a notably lower percentage of correct responses and selected more of each error type picture when compared to their TLD chronologically matched controls.

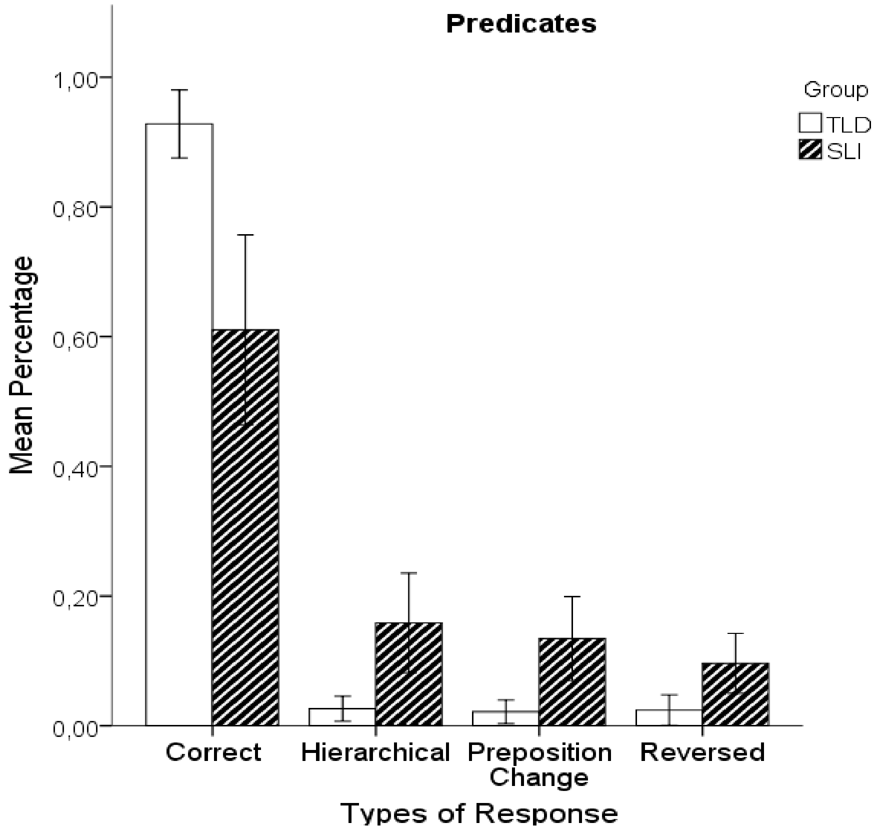

Figure 4: Mean percentage of responses according to picture selection for both groups (TLD and SLI) on Experiment 1 (Predicates). Error bars denote 95% Confidence Interval.

We employed the Dirichlet-Multinomial model to estimate the probabilities of each response category (correct, hierarchical, preposition change, reversed) for each group (Table 2).

Table 2: Dirichlet-Mutinomial model estimated mean (Standard Error) percentage of picture selection for both groups (SLI and TLD) on Experiment 1 (Predicates) and on Experiment 2 (Reflexives) by working memory condition.

Experiment	Group	Working Memory Condition	Picture Selection			
			Correct	Hierarchical	Preposition Change	Reversed
	TLD	Short	93.0 (3.0)	3.0 (2.0)	2.0 (1.0)	2.0 (1.0)
Predicates	SLI	Short	59.0 (7.0)	16.0 (5.0)	14.0 (4.0)	11.0 (1.0)
		Short	83.0 (3.0)	4.0 (1.0)	6.0 (2.0)	7.0 (1.0)
	TLD	Long	57.0 (5.0)	10.0 (6.0)	6.0 (2.0)	26.0 (2.0)
		Short	60.0 (5.0)	10.0 (3.0)	15.0 (4.0)	15.0 (1.0)
Reflexives	SLI	Long	33.0 (4.0)	20.0 (4.0)	13.0 (3.0)	34.0 (2.0)

The analysis via Wald statistics revealed an overall effect for group (χ^2 (3, N = 32) = 117.31, p < .001) indicating that the response distributions for TLD and SLI children were in general different on the comprehension of syntactic constructions involving a predicate attachment.

To further investigate this effect, between-group comparisons examined each response type. Children with TLD were significantly more accurate than children with SLI (χ^2 (1, N = 32) = 19.41, p < .001). Moreover, the differences on selection of incorrect pictures presented by the two groups were statistically significant for each of the three types of error (hierarchical: χ^2 (1, N = 32) = 7.85, p = .005; preposition change: χ^2 (1, N = 32) = 7.28, p = .007; and reversed: χ^2 (1, N = 32) = 83.82, p < .001). Thus, the overall lower accuracy of the children with SLI compared to their TLD peers was distributed across the error types.

For the within-group error analysis, there were no significant differences in the selection of the three error response types for any of the groups (SLI: χ^2 (2, N = 16) = 2.08, p = .35; TLD: χ^2 (2, N = 16) = 0.33, p = .84). This indicates that neither children with SLI nor children with TLD exhibited a dominant error response. Although children with SLI made more errors than TLD children, their error distribution is no different than those of TLD children.

Discussion

In this experiment, we examined the structural assignment of predicates of children with SLI and their matched controls. Children with SLI performed more poorly than their TLD peers, indicating an overall deficit on the comprehension of sentences with non-adjacent predicate-NP relations in this group. However, a preference for the hierarchical error was not observed. Factors other than a hierarchical ordering deficit also influenced accuracy of these children. Thus, taken together, these findings do not support the HOD account (Cromer, 1978) as an explanation for the sentence comprehension deficit in SLI.

Experiment 2

This experiment tested the comprehension of reflexives and their antecedent nouns by children with SLI and their chronologically matched peers. We also examined whether working memory demands affected the extent to which children with SLI incorrectly comprehended sentences.

Stimuli

There were 28 trials for the short working memory condition and 28 for the long working memory condition. Each trial consisted of one context sentence, one target sentence, and an array of four pictures.

Context sentences had the same structure as those in Experiment 1 (e.g., *Here is a grandpa and a dad - Aqui estão um pai e um avô)*. Target sentences had the following structure: *The X in/on/under/in front of/behind the Z* ***[modifier]*** *is Y (O X na(o)/acima/abaixo/na frente/ atrás de Z* ***[modifier]*** *está Y)*. In this experiment, X and Z were nouns and Y was verbal phrase with a reflexive pronoun. In addition, each target sentence was presented in a short and a long version, produced by adding a modifier phrase between the subject and the reflexive without increasing structural complexity (e.g., *The dad in front of the grandpa* ***with the yellow shirt*** *is scratching himself* - *O pai na frente do avô* ***de camisa amarela*** *está se coçando).*

As in Experiment 1, the four visual stimuli were designed to address the configurations of the target sentence (correct picture), the hierarchical error, the preposition change error, and the reverse error. Figure 5 illustrates the picture stimuli of the trial of Experiment 2 exemplified above.

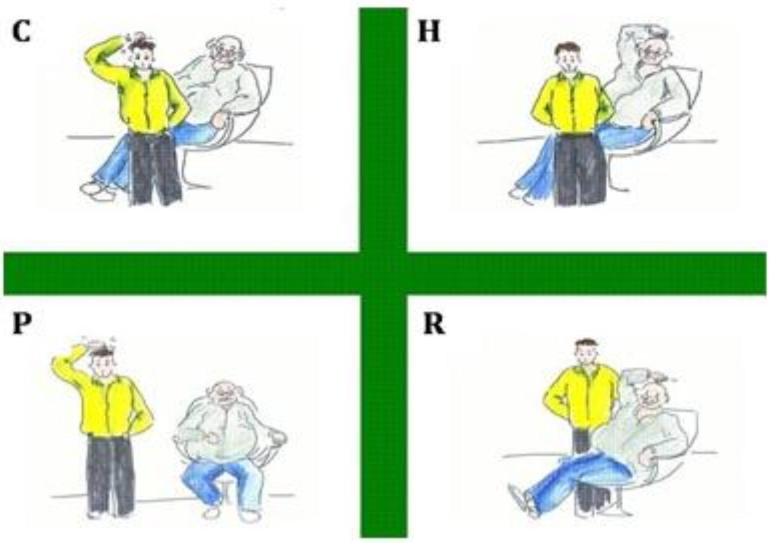

Figure 5: An example of the visual (picture) stimuli from Experiment 2 for the target sentence *"O pai na frente do avô está se coçando"* (*The dad in front of the grandpa is scratching himself*); C=correct picture; H= hierarchical error picture; P=preposition change picture; R=reverse error picture.

Procedure

The procedure of Experiment 2 was identical to that of Experiment 1. Trials of Experiments 1 and 2 were randomly mixed together in a single session to avoid length, order or familiarization effects. The duration of the study (Experiments 1 and 2) was approximately 40 minutes. The session was divided into three blocks. Breaks were provided between the blocks.

Results

Means (in percentage) of responses according to picture type selection (correct, hierarchical, preposition change, and reversed) for both groups (TLD and SLI) on the short working memory condition are displayed in Figure 6.

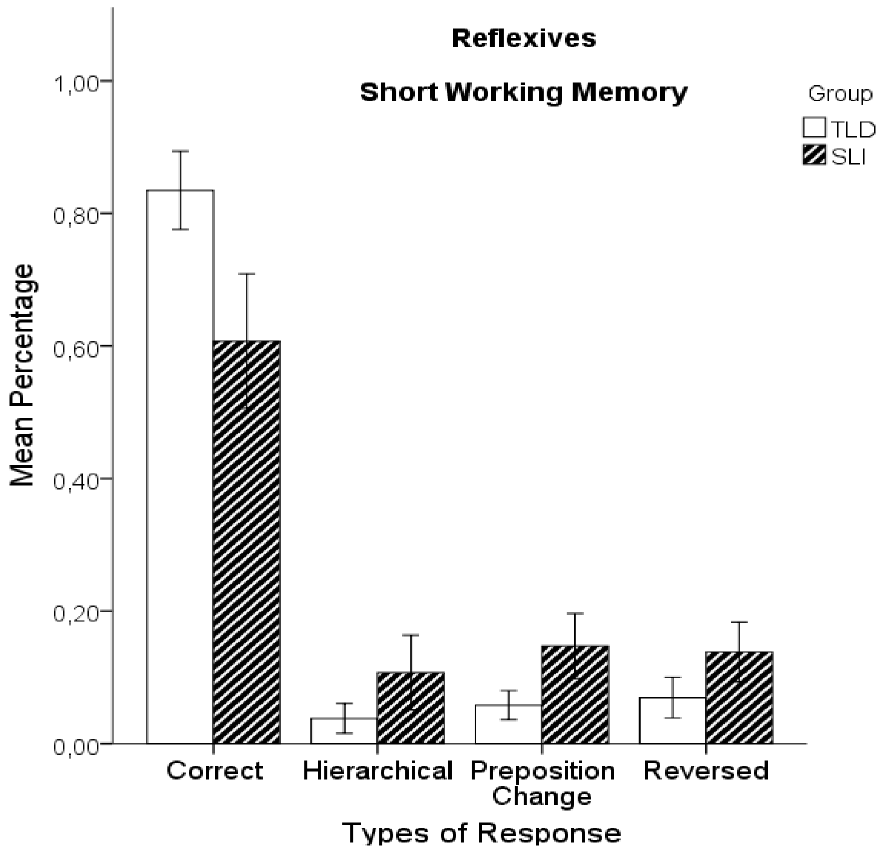

Figure 6: Mean percentage of responses according to picture selection for both groups (TLD and SLI) on Experiment 2 (Reflexives) on the short working memory condition. Error bars denote 95% Confidence Interval.

The Dirichlet-Multinomial model was employed to estimate the probabilities of each response type (Table 2) and the Wald statistic to examine between and within-group differences.

Figure 7 illustrates the results for the long working memory condition.

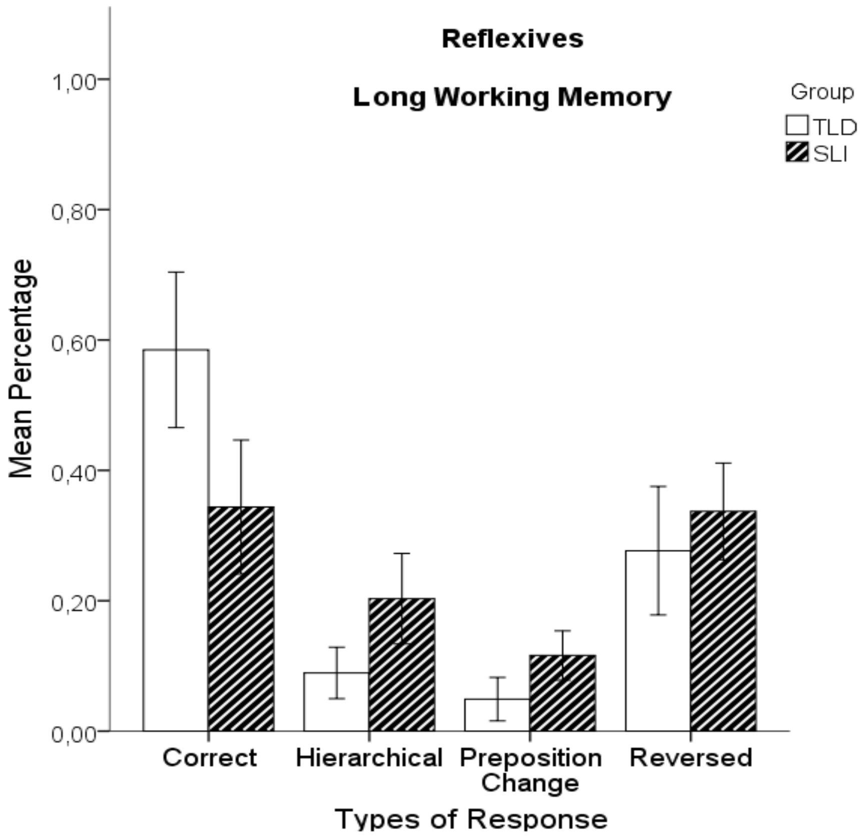

Figure 7: Mean percentage of responses according to picture selection for both groups (TLD and SLI) on Experiment 2 (Reflexives) on the long working memory condition. Error bars denote 95% Confidence Interval.

Short Working Memory Condition

The Dirichlet-Multinomial model revealed via Wald statistics an overall effect for group (χ^2 (3, N = 32) = 44.74, p < .001) indicating that response distributions for TLD and SLI children were different for the comprehension of constructions involving reflexive-antecedent assignment with low working memory demands.

To further investigate this effect, between-group comparisons were carried out for each of the four response types. Children with TLD were significantly more accurate than children with SLI (χ^2 (1, N = 32) = 14.27, p < .001). Moreover, the group differences in selection of incorrect pictures were statistically significant for each of the three types of error (hierarchical: χ^2 (1, N = 32) = 4.67, p = .032; preposition change: χ^2 (1, N = 32) = 5.92, p = .015; reversed: χ^2 (1, N = 32) = 38.91, p < .001).

In the within-group error analysis, there were no significant differences among the three error types for the SLI group (χ^2 (2, N = 16) = 4.24, p = .12), indicating that the children with SLI did not exhibit a dominant error response. In contrast, the distribution of errors on the TLD group was not homogenous (χ^2 (2, N = 16) = 13.68, p < .001); children with TLD exhibited differences according to the categories of error. These findings indicate a different pattern of error response distributions for children with SLI and children with TLD for the comprehension of reflexive constructions with low working memory demands.

Additional analyses investigated whether children with SLI and children with TLD had a preference for errors involving an incorrect syntactic assignment. The preposition change picture represents choices in which the child has constructed a hierarchal structure for the sentence (only making an error in the prepositional relation of the pictured items). The remaining two error choices, hierarchical and reversed, represent incorrect syntactic assignment. Therefore, on the next set of analyses, we combined the responses in order to obtain two categories: correct structural assignment (correct response and preposition error response) and incorrect structural assignment (hierarchical and reversed error responses).

When we analyzed the correct (correct and preposition error pictures) and incorrect (hierarchical and reverse error pictures) structural assignment by combining the responses, the model revealed within-group differences for each of the groups (TLD: χ^2 (1, N = 16) = 471.43, p < .001; SLI: χ^2 (1, N = 16) = 62.93, p < .001). In the comprehension of reflexive constructions with low working memory demands, children exhibit a preference for responses with correct structural assignment regardless of language status.

Long Working Memory Condition

The Wald statistical analysis of the Dirichlet-Multinomial model revealed an overall effect for group (χ^2 (3, N = 32) = 13.00, p = .005) in the comprehension of sentences containing reflexive antecedent relations with increased working memory demands. This finding indicates that responses of TLD and SLI children were in general different on this condition.

To further investigate this effect, between-group comparisons were carried out for each of the response types. Children with TLD were significantly more accurate than children with SLI (χ^2 (1, N = 32) = 12.45, p < .001). Moreover, the groups differed in their selection of incorrect pictures for each of the three types of error (hierarchical: χ^2 (1, N = 32) = 4.33, p = .040; preposition change: χ^2 (1, N = 32) = 3.84, p = .050; reversed: χ^2 (1, N = 32) = 7.91, p = .005).

The within-group error analysis revealed significant differences for the SLI (χ^2 (2, N = 16) = 57.48, p < .001) and for the TLD group (χ^2 (2, N = 16) = 95.03, p < .001). Both groups exhibited a heterogeneous error distribution for the comprehension of reflexive constructions with increased working memory demands.

When we analyzed the correct (correct and preposition error pictures) and incorrect (hierarchical and reverse error pictures) syntactic structural assignment by combining the responses, the model revealed within-group difference for the TLD group (χ^2 (1, N = 16) = 9.45, p = .002). However, children with SLI did not exhibit such difference (χ^2 (1, N = 16) = 1.09, p = .29). This finding indicates that, when working memory demands were higher, children with SLI exhibited no difference between correct and incorrect syntactic assignment on the comprehension of sentences involving a reflexive-antecedent relation.

Working Memory Effect

The Wald statistics applied to the statistical model indicated significant differences on accuracy between the two working memory conditions for the TLD (χ^2 (1, N = 16) = 18.48, p < .001) and for the SLI group (χ^2 (1, N = 16) =

14.88, $p < .001$). Both groups exhibited a decrease in accuracy with an increase in working memory demands.

A set of analyses examined whether children were more likely to make syntactic (hierarchical and reverse) and lexical (preposition) errors in the long working memory condition. In these analyses, we compared the selection of each error type across the two conditions of working memory. Children with SLI exhibited increased selection of hierarchical (χ^2 (1, N = 16) = 5.04, p = .025) and reverse (χ^2 (1, N = 16) = 98.83, p < .001) pictures in the long working memory condition. In contrast, children with SLI exhibited a non-significant decrease in the selection of the preposition error picture on the long working memory condition (χ^2 (1, N = 16) = 0.37, p = .540). The same pattern was observed for children with TLD: a significant increase in the selection of the hierarchical (χ^2 (1, N = 16) = 4.31, p = .037) and reverse (χ^2 (1, N = 16) = 71.33, p < .001) types of error, and no change in the selection of the preposition error (χ^2 (1, N = 16) < 0.001, p = .99). The selection of the preposition change picture was the only type of error not responsible for the decreased accuracy noted for both groups on the long working memory condition.

Discussion

In this experiment, we examined the structural assignment for sentences with reflexives and the effect of a greater working memory demand on accuracy and error types. As expected, the children with SLI had lower accuracy than their typically developing peers in both working memory conditions. The poorer performance of the children with SLI in assigning the correct antecedent to reflexives are in agreement with findings reported by van der Lely (1998) and van der Lely and Stollwerck (1997). In those earlier studies, the authors reported that children with SLI exhibited deficits on the assignment of the correct antecedent name to reflexive anaphora when syntactic knowledge was required. However, the smaller number and the increased complexity of stimuli on the Syntactic Test of Pronominal Reference (STOP), the use of clitics rather than full pronouns in the current experiment, the differences in subjects (the children in the previous study have very severely impaired children with SLI and very young language-matched controls), and the different tasks employed make comparisons difficult.

Syntactic deficits were not the only factors that affected comprehension of hierarchically complex structures. The CGC hypothesis (van der Lely, 2005) posits that only deficits in the computational grammatical system affect hierarchically complex structures and rejects the notion that working memory plays a role in comprehension of such structures. The increase in working memory demands in the present experiment significantly affected the comprehension accuracy for both groups. Working memory demands interfered with hierarchical structure assignment regardless of language status.

Although our work provides converging evidence that children with SLI have working memory limitations affecting their comprehension (Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1990; Mainela-Arnold & Evans, 2005; Marton & Schwartz, 2003; Montgomery, 2004; Schwartz, 2009), the two groups exhibited similar decrease in accuracy (approximately 26%) and similar error patterns with increased working memory demands. Both groups made more syntactic errors (i.e., assignment of incorrect antecedent) in the long than in the short working memory condition. Both the hierarchical and the reversed error type involved structural deviations either in the absence of hierarchical relations or reversed syntactic tree components. These errors increased with a more demanding working memory load. In contrast, preposition errors only involved a lexical error and were selected less frequently in response to the longer sentences. The fact that the lexical error choices decreased, whereas the syntactic ones increased in the long working memory condition for both groups indicates that working memory has differential effects on language comprehension regardless of language status.

General Discussion

We conducted two experiments designed to examine the ability of children with SLI to establish long distance relationships between predicates and nouns as well as between reflexives and their antecedents. According to the HOD (Cromer, 1978) hypothesis, children with language impairment have a deficit in hierarchical sentence structuring that causes comprehension errors. The comprehension performance and the influence of different working memory demands on two syntactic constructions that require hierarchy knowledge on their elements for a correct comprehension was compared between a group of children with SLI and an age-matched group of children with TLD in order to examine this proposal.

The results of Experiment 1 are not consistent with findings reported by Bishop (1982). These between-study inconsistencies may reflect methodological differences (e.g., fewer trials and no statistical analyses). Furthermore, the participants in the Bishop´s study were children with Landau-Kleffner syndrome and, although some similarities in language profiles with children with SLI are expected (Billard et al., 2009; Deonna & Roulet, 2005; Overvliet et al., 2010), there do not appear to be any studies that have examined syntactic aspects of comprehension in these children. Although we did observe a syntactic structural assignment influence on sentence miscomprehension of children with SLI, the selection of the hierarchical picture was not the dominant error response as observed by Bishop. Instead, both groups of children exhibited no apparent preference among the three error types (hierarchical, preposition change, or reversed) on Experiment 1. This contradicts the HOD hypothesis and the CGC account that the most common cause of miscomprehension of children with language impairment is a deficit in structuring the syntactic hierarchical representation of the sentence resulting in incorrect attachment or antecedent selection.

Although children with SLI made more errors than their typically developing matched controls, they still got the majority of trials correct in Experiment 1 and in the short condition in Experiment 2. This suggests that other factors (e.g., issues in processing) may underlie sentence comprehension deficits in children with SLI. Previous investigations have shown that children with SLI are influenced by semantic and pragmatic factors when these factors are related to syntactic constraints (Precious & Conti-Ramsden, 1998; van der Lely & Dewart, 1986). Although plausibility might affect attachment and antecedent-reflexive relations, this factor was controlled in our study (in all situations both characters were possible antecedents; both the dad and the grandpa could be scratching themselves). Moreover, semantic and pragmatic factors may have different effects on attachment and on antecedent-reflexive relations. Predicates and reflexives differ in that the adjective used in the attachment is an open-class word whereas the reflexive pronoun is a closed-class word and in this case is a clitic. Although such effects could have influenced the two experiments, this was not observed on the response patterns. Similar accuracy and similar error type distributions were observed on Experiment 1 and on the short working memory condition of Experiment 2.

Other cognitive abilities could also have influenced the performance of children with SLI in the present study. Studies have shown that children with SLI exhibit difficulties with certain cognitive tasks besides having non-verbal IQs near the low end of normal (Hick, Botting & Conti-Ramsdem, 2005; Kamhi, Catts, Mauer, Apel & Gentry, 1988; Marton, 2008). Hick and colleagues (2005) found that children with SLI exhibit a visuo-spatial deficit, but only when the tasks also involve working memory demands. Our tasks did not involve visuo-spatial working memory; pictures were presented simultaneously and remained in view until a response was detected.

In Experiment 2, although children with SLI did get a number of trials correct, they were less accurate than their age-matched peers. Although the deficit in syntactic assignment of antecedent nouns to reflexives is consistent with findings from van der Lely (1998) and van der Lely & Stollwerck (1997), some differences between our study and these studies should be noted. In the current study, the reflexives were marked by a clitic pronoun and there has been evidence for a deficit in clitic acquisition for many Romance languages including Brazilian Portuguese (Lopes, 2003). Furthermore, it is noteworthy that clitics are unstressed and the lack of perceptual salience could also have caused an additional difficulty when compared to full pronouns. Although the clitics in the reflexive constructions could have caused additional problems for children with SLI, this does not seem to have occurred. When working memory demands were more limited, the children with SLI were similarly accurate in the Predicate and the Reflexive experiments. Van der Lely employed a forced choice judgment task (children saw only one picture and judged whether it matched a sentence they heard), which may have been easier than making a selection from a set of four pictures. However, in a yes/no judgment, guessing may have had a greater effect on the results. Although the three studies examined the assignment of an antecedent noun to a reflexive, three different syntactic constructions were used. Our study involved sentences with a NP with a complex subject followed by a verbal phrase (VP) with a reflexive pronoun (e.g. *The dad in front of the grandpa is scratching himself*). van der Lely and Stollwerck (1997) and van der Lely (1998) used a subordinate structure (e.g. *Mowgli says Baloo Bear is tickling himself*) and a question structure (e.g. *Is Mowgli tickling himself?*). The complex subjects in our study might have been more challenging than the simple subjects in the other two studies. Furthermore, the questions used on van der Lely studies involved verb movement and only included one possible antecedent, whereas the sentences with subordinate clauses added substantial syntactic complexity that may have confounded the comprehension of reflexives. In our study, the control of the syntactic construction, the analysis of the error types presented by children, and the analysis of working memory demands are an important advance.

A different pattern of response was observed in both groups across the working memory demands. With an increased working memory demand, the likelihood of a syntactic representational error also increased. In contrast, with the increased working memory demand, we observed a decrease in the number of lexical (prepositional) errors. Thus, there appears to be a working memory effect on structuring syntactic representations that was not predicted by HOD (Cromer, 1978) or by the CGC (van der Lely, 2005; van der Lely &

Stollwerck, 1997) proposals. Clearly, sentence comprehension difficulties are not only a matter of structural assignment and importantly, children with TLD also exhibit working memory effects.

Marton and colleagues (2006) have found that working memory deficits are related to increases in morphosyntactic or syntactic complexity rather than to absolute capacity. However, when we controlled for syntactic complexity (long working memory condition sentences of the current study had no additional structural complexity), working memory still plays an important role on sentence comprehension. This supports the view that the effect of working memory demands on linguistic processing, and not just linguistic complexity, plays an important role in the sentence comprehension difficulties experienced by children with SLI (Deevy & Leonard, 2004). This was also true for children with TLD. Thus, there seems to be a direct effect of working memory demand on sentence comprehension in children rather than simply an association of measures reflecting working memory and sentence comprehension performance as suggested by Montgomery and Evans (2009) and Just and Carpenter (1992).

Waters and Caplan (1996) proposed that at least two different working memory capacities subserve language processing. Although we did not examine this directly, we found evidence of different working memory effects for syntactic (hierarchical structure) and lexical (preposition) factors in sentence comprehension. In our study, the hierarchical relations of the syntactic tree components were affected by the high working memory demand to a greater extent than the preposition use. McElree and colleagues

(1998, 2000, 2003) have proposed that sentence comprehension is subserved by content-addressable memory structures in which syntactic and semantic constraints provide direct access to relevant representations. Although according to this view both syntactic and semantic constraints seem to be available, there might be different effects on sentence comprehension for each of these constraints. Moreover, if linguistic comprehension is related to the central executive component of Baddeley's model (1986) as suggested by Marton (2006), the model may also need to account for these differential effects across language features.

Although there are mixed findings regarding which working memory measure and component are most closely associated with language comprehension, it is clear from our data that direct manipulation of working memory on sentences does have a general effect on syntactic structural assignment. Furthermore, working memory, as measured by direct manipulation of sentences without adding syntactic structural complexity, has differential effects on comprehension errors (syntactic vs. lexical) regardless of language status.

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Study II

Syntactic Assignment in Children with Specific Language Impairment, Autism and Down Syndrome

Abstract

Purpose: Despite the increasing number of studies examining syntax in children with various types of language disorders, most have focused on Specific Language Impairment (SLI) and cross-population studies are still relatively scarce. The purpose of this study was to investigate the syntactic structural assignment of predicates and reflexives, as well as working memory effects, in comprehension of four different groups of children: SLI, Down syndrome (DS), Autism Spectrum Disorder (ASD), and Typical Language Development (TLD). **Methods:** Sixty children (38 boys and 22 girls) participated. Children were between 7;0 and 14;2 years of age and composed four groups (SLI, DS, ASD, TLD) of 15 children each. Children underwent a computerized picture-selection sentence comprehension task. Predicate attachment and reflexive antecedent assignment (short and long working memory conditions) were investigated. **Results:** SLI, ASD, and DS children exhibited poorer overall performance than TLD children. The groups of ASD and DS exhibited similar response patterns across conditions. Children with SLI exhibited similar performance to the DS and ASD children only when working memory demands were higher. **Conclusion:** Children with SLI, ASD, and DS differ from children with TLD on the comprehension of predicate and reflexive structures where knowledge of syntactic structural assignment is required. There are similarities between children with ADS and DS on the comprehension of these structures. Working memory has different effects in syntactic comprehension depending on the language disorder.

After decades of research, we have a reasonable framework of phonological, semantic, and pragmatic features as characterization of several developmental language disorders. However, the same is not observed for more complex linguistic contexts such as syntax. Despite the increasing number of studies examining syntax in children with various types of language disorders most have focused on Specific Language Impairment (SLI) and cross-population studies are still relatively scarce (e.g. Bol & Kasparian, 2009; Laws & Bishop, 2004). Understanding the characteristics of the syntactic abilities and their differences and overlaps among populations with language disorders will allow a better characterization of each disorder and it may also help evidence causal connections between language impairments and underlying capacities or processes.

Rice, Warren and Betz (2005) argued that there is a great need for systematic comparisons across disorders at greater levels of specificity than is currently available and the need for careful linguistic description is immediate, for the dual intention of scientific investigation and clinical application. In the current study, we compared the syntactic assignment of groups of children with SLI, Autism Spectrum Disorder (ASD), and Down syndrome as a test of the Hierarchical Ordering Deficit Hypothesis (HOD). That hypothesis posits that children with language impairment have difficulty in establishing non-adjacent (hierarchical) relations among elements of a sentence. This study also investigated whether additional working memory demands in constructions containing reflexives affected the syntactic assignment of children with SLI, ASD and Down syndrome.

The linguistic profiles of these three populations have been compared so far mostly by literature reviews (e.g., Laws & Bishop, 2004; Rice, Warren & Betz, 2005; Williams, Botting & Boucher, 2008; Ypsilanti & Grouios, 2008) of studies analyzing one or pairs of these disorders. These reviews have reported that there are relative areas of strengths and weaknesses across the various populations, suggesting that some language aspects warrant differentiation in descriptions of symptoms of language disorders. However, most studies have used only standardized language tests or simple language measures and focus on expressive language, making language comprehension an even more under-researched area.

The need for more controlled experimental conditions is clear, especially for the area of syntax in which standardized tests generally group a variety of structures and only an overall measure is provided. So far we are not aware of descriptions and comparisons among these three groups on syntactic assignment. Deficits in structuring hierarchical syntactic representation cause problems for learning, processing, and application of syntactic rules, which often leads to comprehension impairments. In this study, we experimentally compared the syntactic hierarchical structural assignment in the comprehension of children with SLI, ASD and Down syndrome of specific syntactic structures (predicate and reflexive) and we also investigated the influence of working memory on the correct comprehension and error patterns of these children.

Syntax and Working Memory in SLI

Although there seems to be an agreement that children with SLI have an overall deficit in the comprehension and production of sentences, the range of syntactic structures studied is not very broad. There is evidence that these children exhibit difficulties particularly with syntactic structures that involve long distance relationships but this claim have been mostly studied in constructions involving relative clauses (Friedman & Novogrodsky, 2004, 2007; Hestvik, Schwartz & Tornyova, 2010; Schuele & Tolbert, 2001), wh-questions (Deevy & Leonard, 2004; Hansson & Nettelbladt, 2006; Marinis & van der Lely, 2007) and reflexives (Fortunato-Tavares, et al., in press; van der Lely, 1998; van der Lely & Stollwerck, 1997).

In their studies of pronoun and reflexive assignment, van der Lely and colleagues (1997, 1998) claimed that children with SLI have sufficient knowledge of the semantic conceptual properties of reflexives and theta role assignment, but they do not have the syntactic knowledge characterized by the Binding Theory. However, some methodological questions should be noted such as increased complexity of structures presented, limited number of sentences, and young age of language ability match controls. Another study (Fortunato-Tavares et al., in press) that investigated the assignment of predicates and reflexives on a group of Brazilian Portuguese-Speaking children with SLI and a group of age-matched controls found that children with SLI exhibited deficits related to structural assignment but these deficits were not limited to the Hierarchical Ordering Deficit (HOD) as proposed by Cromer (1978). According to the HOD, children with language disorders would construct flat instead of hierarchically organized structures and this lack of hierarchy in the syntactic tree would account for their overall language difficulties (for more detailed explanation of the HOD hypothesis and SLI see Study I). Taken together, these studies suggest that children with SLI have a deficit in assigning the correct antecedent to reflexives and attaching a predicate to its respective noun in comparison to chronological and language ability matched controls.

Although a number of studies suggest that children with SLI have more limited working memory capacity than age-matched controls (e.g., Marton & Schwartz, 2003), only few studies have investigated the direct association between working memory and sentence comprehension through direct manipulations of sentence working memory demands. Deevy and Leonard (1994), in a study of wh-question comprehension with direct manipulation of sentence working memory demand found that children with SLI performed similarly to the TLD group on short questions, but showed poorer performance on long object questions than on long subject questions. The authors concluded that working memory demands on linguistic processing, and not just linguistic complexity, play an important role in the difficulties experienced by children with SLI. Marton and colleagues (2006) reported that increasing the number of words in a sentence, without an increase in grammatical complexity, did not influence performance accuracy to the same extent as the increase in morphological complexity. In that study, children correctly recalled more words and answered more questions following sentences with simple morphological structures when compared to sentences with complex morphology. These results and previous findings

(Marton & Schwartz 2003) suggest an influence of linguistic processing on working memory demands, with a larger impact of linguistic complexity than sentence length on working memory performance accuracy. Fortunato-Tavares and colleagues (in press) found a clear influence of working memory on syntactic structural assignment of children with SLI and their age-matched controls, contradicting domain specific theories of SLI - like the HOD (Cromer, 1978) and the computational grammatical complexity (CGC) hypothesis (i.e. Gallon, Harris, & van der Lely, 2007; Marinis & van der Lely, 2007) - which reject the influence of processing limitations on the syntactic deficit of children with SLI.

Syntax and Working Memory in Autism Spectrum Disorder

There has not been a similar in-depth exploration of syntactic abilities in ASD and little is known about their syntactic skills beyond morphosyntax. Recent studies on morphosyntax have indicated a morphosyntactic deficit in language production of children with autism (e.g., Eigst, Bennetto, & Dadlani, 2007) or in a subgroup of children with autism who have a language delay similar to SLI (e.g., Roberts, Rice, & Tager–Flusberg, 2004). However, only few studies have aimed to investigate the syntax knowledge of children with autism beyond morphosyntax. In general these studies suggest the presence of more substantive syntactic impairments in autism (Rapin & Dunn, 2003), or in a subgroup of individuals with autism (Kjelgaard & Tager-Flusberg, 2001) in, for example, formulating sentences (Landa & Goldberg, 2007), responding to wh-questions (Oi, 2008, 2010), and repeating sentences with complex syntax (Riches, Loucas, Baird, Charman, & Simonoff, 2010).

The two studies that investigated responses of autistic children to wh-questions (Oi, 2008, 2010) found that the rate of inadequate response to wh-questions was higher than to yes/no questions in the group of children with autism. Although this pattern was not specific to autistic children and was also seen for children with typical development, the rate of inadequate responses to wh-questions in children with autism was higher than in typically developing children. Such a difference was not observed for yes/no questions, which consist on sentences with less complex syntax.

Landa and colleagues (2007) reported a significant difference between the performance of participants with autism compared to controls on the Clinical Evaluation of Language Fundamentals-Revised (CELF-R; Semel, Wiig, & Secord, 1987) Formulated Sentences test which measures the ability to form grammatically and semantically intact simple, compound, and complex sentences. However, no detail is provided regarding the types of errors and structures that posed more difficulty to the children, limiting, therefore, our understanding of specific deficits.

In a study on repetition of sentences with complex syntax (subject and object relative clauses with varying adjective positions), Riches and colleagues (2010) found that the children with autism and language impairment, and children with SLI, presented higher error rates than the typically developing controls. Greater errors were made for object relatives versus subject relatives, and sentences with adjectives in the relative clause versus adjectives in the main clause. The profiles of the two clinical groups were qualitatively similar, with error rates increasing in response to both syntactic complexity and adjective position. In that study, participants with autism and language impairment exhibited a syntactic impairment affecting structures with long-distance dependencies and non-canonical word order such as object relatives. However, children with SLI were significantly more affected by syntactic complexity, and were significantly more likely to make complete changes to syntactic structure. The authors also observed high correlations between Sentence Repetition error rates and difference scores, and the raw scores from working memory tests as Children's Test of Non-word Repetition and the Digit Recall, Backward Digit Recall and Listening Recall from the Working Memory Test Battery for Children (Gathercole & Pickering, 2001). Although the authors claim that this could possibly indicate a processing effect on syntactic processing, a simple correlation analyses may not the best measure to indicate a direct association between these two capacities.

Working memory deficits in ASD have been inconsistently reported. Some studies found deficiency in working memory (Luna, Minshew, & Garver 2002; Joseph, Steele, Meyer, & Tager-Flusberg, 2005) while others reported normal performance (Dawson, Munson, & Estes, 2002; Koshino, Carpenter, Minshew, Cherkassky, Keller, & Just, 2005). This discrepancy in findings could be attributed to several factors. First, a wide range of different tasks are employed (e.g. digit-span, n-back, non-word repetition, non-word comparison) ranging from tasks that might involve working memory itself and tasks which characteristics apart from working memory might interfere with the task execution. Second, different matching procedures are employed including typically developing and developing delayed children, nonverbal, verbal ability, and chronological age matched controls.

Most studies investigating syntax in the Autistic Spectrum population concern production thus making our knowledge about syntactic comprehension even scarcer. To the best of our knowledge, no study experimentally analyzing syntax (especially comprehension) that has not made use of language samples and standardized tests is found. There is no consensus on a working memory deficit in children with ASD, and the direct effects of working memory demands on sentence comprehension in this population still remains unclear.

Syntax and Working Memory in Down Syndrome

Language deficits in Down syndrome are not consistent across all components of language; vocabulary development has been described as a relative strength, whereas syntax and morphology appear to more affected (e.g., Chapman, Kay-Raining Bird, & Schwartz, 1990; Fowler, 1990; Naigles, Fowler, & Helm, 1993). In conversational language samples, measures of utterance length and syntactic complexity reveals that individuals with Down syndrome produce shorter, less complex noun phrases, verb phrases, sentence structures, questions/negations than typically developing individuals (Price et al., 2008). Subordinate and relative clauses, negated and passive constructions were not observed on speech samples of a group of French speakers with Down syndrome (Rondal & Comblain, 1996), while deficient production of passives in both children and adult English speakers with Down syndrome has been reported (Bridges & Smith, 1984; Eriks-Brophy, Stojanovic, & Goodluck, 2002; Fowler, 1990; Ring & Clahsen, 2005). It is important to point out that the studies on syntax and morphosyntax in Down syndrome most often focus on the observation of spontaneous language, with just a few exceptions for language comprehension.

The syntactic assignment of reflexives in children with Down syndrome has been investigated with a Picture Truth Value Judgment task eliciting yes/no answers to questions accompanied by picture stimuli (Perovic, 2004, 2006; Ring & Clahsen, 2005), using similar experiments and materials employed on studies with children with SLI (van der Lely, 1996; van der Lely & Stollwerck, 1997). In those studies, four different types of experimental questions are included (name-reflexive, name-pronoun, quantifier-reflexive and quantifier-pronoun) and presented in two different conditions (picture match and mismatch). These studies have shown consistent findings of a difficulty in Down syndrome on the syntactic binding of reflexives but not of pronouns. In the studies by Perovic, individuals with Down syndrome presented near ceiling performance in sentences with non-reflexive pronouns and performed significantly poorer than controls on conditions involving a reflexive. Similar findings were obtained by Ring and Clahsen (2005) in which children with Down syndrome exhibited significantly lower accuracy on reflexives than on non-reflexive pronouns and showed significantly lower accuracy than controls only on sentences involving reflexives.

There is some evidence that the difficulties presented by individuals with Down syndrome in the syntactic domain are somewhat different than other language disorders. With respect to syntactic assignment, we are not aware of any study directly comparing Down syndrome to other populations with language disorders. However, when comparing independent studies on Down syndrome to those on the SLI population (van der Lely; 1996; van der Lely & Stollwerck, 1997) we observe a different response pattern. In the studies by van der Lely and colleagues, children with SLI achieved lower accuracy than controls on quantifier-pronoun (match) and name-pronoun (mismatch) conditions showing that difficulties of these children in syntactic assignment of pronouns is not restricted to reflexives as the observed in Down syndrome (Perovic, 2004, 2006; Ring & Clahsen, 2005). However, more studies are needed as no direct comparison between the two populations was carried out. Furthermore, there is evidence for a working memory effect on syntactic assignment (Fortunato-Tavares et al., in press) and none of these studies has taken that into account.

Several studies that examined working memory in Down syndrome revealed a specific deficit in verbal working memory (Jarrold & Baddeley, 1997; Jarrold, Baddeley, & Hewes, 2000; Lanfranchi, Cornoldi, & Vianello, 2004; Miolo, Chapman, & Sindberg, 2005; Seung & Chapman, 2004) and the studies that have examined relationships between overall language measures and memory deficits of individuals with Down syndrome point to connections between language and working memory (Chapman & Hesketh, 2001; Miolo et al., 2005; Laws, 2004; Laws & Gunn, 2004).

Associations between working memory and language are reported when comparisons are made using sentence comprehension performance. Laws (1998) reported significant relationships, in children and adolescents with Down syndrome between verbal working memory, as measured by a nonword repetition task, and word span, reading, and language comprehension. A longitudinal study (Chapman, Hesketh, & Kistler, 2002) showed that syntax comprehension in Down syndrome is best predicted by not only verbal working memory but also by visual working memory. In the study by Miolo and colleagues (2005) verbal working memory accounted for almost half of the variation in semantic role assignment, indicating that sentence comprehension, in terms of semantic role assignment, placed substantial demands on working memory in this group. Although the authors claim that these associations might suggest that in Down syndrome working memory and language abilities are not completely independent, these relationships could also only be suggesting comorbidities of these two deficits.

In summary, most studies investigating syntax in Down syndrome concern production. Furthermore, there is no clear picture on the comparison of individuals with Down syndrome and different populations with language disorders concerning syntax. Although there seems to be a consensus on a correlation between verbal working memory and some language aspects in children with Down syndrome, only studies analyzing correlations or predictions have been conducted, limiting our understanding of the direct association between these two areas.

Summary

The findings of research concerning syntax and different developmental language disorders are extremely limited. This fact raises the question of whether the similarities between language profiles in fact exist, are superficial, or whether common underlying mechanisms could be implicated. Moreover, structural aspects of syntax have been little investigated in language disorders other than SLI. The main interest in cross-population research has been in the area of morphosyntax and there is an urgent need for more information on complex syntax. Thus, the current study consists on a carefully designed experiment, previously successfully applied in both typically and atypically developing populations, to investigate the syntactic structural assignment of predicates and reflexives (Fortunato-Tavares et al., in press). We here examined whether children with SLI, ASD, and Down syndrome differ from typically developing children and from each other on the comprehension of syntactic structures in which knowledge of hierarchical syntactic assignment for a correct comprehension is required. This provided us a mean to test the HOD hypothesis (Cromer, 1978) as a possible cause of sentence miscomprehension in children with SLI, ASD, and Down syndrome. In the Predicate Attachment experiment, we examined the comprehension of structures containing a noun phrase - predicate relation. In the Reflexive Assignment experiment, in addition to the examination of comprehension of structures containing an antecedent - reflexive relation, we also examined the effects of different working memory demands in the comprehension of such structures. Furthermore, in the two experiments, we

compared effects of syntactic and lexical (preposition) causes of miscomprehension by examining their error types.

Method

Participants

Sixty children (38 boys and 22 girls) participated. Children were between 7;0 and 14;2 (years;month) years of age and composed four equally sized groups (SLI, DS, ASD, and TLD). Although participants were not individually matched, there were no between-group differences on age. All of the children came from homes in which Brazilian Portuguese was the only language spoken.

Specific Language Impairment Group

These 15 children (nine boys and six girls) were between 8;4 and 10;6 years old (M = 9;4 years; SD = 9 months). This group is a subsample of a SLI group of a previous study (Fortunato-Tavares et al., in press). These children had no history of neurological impairments, no evidence of oral motor disabilities, and no social or emotional difficulties. They all had been diagnosed by a group of Speech-Language Pathologists as specific language impaired. All children from this group had scores on the ABFW Child Language Test (Andrade, Befi-Lopes, Fernandes, & Wertzner, 2004) at least 1.25 standard deviations below the mean on Vocabulary. Additional criteria for children with SLI selection included normal nonverbal IQ performance as measured by TONI-III (Brown, Sherbenou & Johnsen, 1997) and normal hearing as measured by hearing screening at 25dBHL for the frequencies of 500, 1000 and 2000 Hz. All SLI children presented persistent history of language impairment after more than two years of speech and language intervention and were all receiving speech-language services at the time of testing.

Autism Spectrum Disorders Group

These 15 children were between 7;0 and 13;5 years old (M = 9;8; SD = 2;2). As expected, boys outnumbered girls (13 boys and two girls). The vocabulary of these children tested with the ABFW Child Language Test (Andrade et al., 2004) and non-verbal reasoning ability and fluid intelligence were tested with the Ravens Coloured Progressive Matrices (Raven, 1993). Children from this group presented at the moment of testing normal hearing as measured by hearing screening at 25dBHL for the frequencies of 500, 1000 and 2000 Hz and were all receiving Speech-Language services at the moment of data collection.

Down Syndrome Group

These 15 children (eight boys and seven girls) were between 7;0 and 14;2 years old (M = 10;3; SD = 2;7). They all had abnormalities associated with Trisomy 21. All participants were relatively healthy, free of sensory impairments that would interfere with language development, and had relatively good speech intelligibility. The vocabulary of these children was tested with the ABFW Child Language Test (Andrade et al., 2004). All children from this group underwent complete audiometry at the moment of testing and the mean threshold for the frequencies of 500, 1000 and 2000 Hz for the group was 16.9 (SD = 9.0) dB for the right and 18.9 (12.3) dB for the left ear. All children were all receiving Speech-Language services and intelligence was tested with the WISC-III (Wechsler, 2004).

Typical Language Development Group

The 15 children (eight boys and seven girls) with TLD were between 8;5 and 10;5 years old (*M* = 9;5 years; *SD* = 7 months). Although the children with TLD were not individually matched to the clinical groups, there were no significant differences on age among the four groups (p = .308). Children in this group were recruited from Public Schools of the city of São Paulo. These children all had scores on the vocabulary section of the ABFW Child Language Test (Andrade et al., 2004) within normal limits. All children from this group presented no history of language impairment, normal nonverbal IQ performance as measured by the Test of Non-Verbal Intelligence III (Brown et al., 1997), and normal hearing as measured by hearing screening at 25dBHL for the frequencies of 500, 1000 and 2000 Hz.

Table 1 displays detailed the demographic information of participants of all four groups and results on vocabulary test and intelligence measure.

Table 1: Mean (standard deviations) of age, intelligence measure, vocabulary test performance and gender distribution of participants.

	SLI	ASD	DS	TLD	*p*-value
Age [range]	9,4 (0,9) [8,4 - 10,6]	9,8 (2,2) [7,0 - 13,5]	10,3 (2,7) [7,0 - 14,2]	9,5 (0,7) [8,5 - 10,5]	.308
Gender (M:F)	09:06	13:02	08:07	08:07	
Intelligence Measure	97 (5.8)[a]	92 (16.2)[b]	54.5 (6.9)[c]	101 (5.5)[a]	.001*
Vocabulary	53 (3.2)	70.5 (13.8)	56 (17.1)	56 (17.1)	.029*

Note: age expressed in years,months; b – IQ equivalent scores of the Raven Matrices Test percentile a - TONI-3; c – WISC. Statistically significant p-values for one-way ANOVAs are marked with an *.

Stimuli

Each trial consisted of one context sentence, one target sentence, and an array of four pictures. Context sentences of both experiments (Predicate Attachment and Reflexive Antecedent) had the following structure: *Here is a(an) X and a(an) Z (Aqui estão a(o) X e a(o) Z),* where X and Z were the nouns of the target sentence (e.g. *Here is a cup and a box; Aqui estão a xícara e a caixa*).

The Predicate Attachment Experiment consisted of 26 trials. The target sentences of this experiment had the following structure: *The X in/on/under/in front of/behind the Z is Y (O X na(o)/acima/abaixo/na frente/ atrás de Z é Y)*, where X and Z were nouns and Y was a color term (e.g., *The box in the cup is white; A caixa dentro da xícara é branca*).

The Reflexive Assignment Experiment consisted of 56 trials (28 for each working memory condition). Target sentences of this experiment had the following structure: *The X in/on/under/in front of/behind the Z **[modifier]*** *is Y (O X na(o)/acima/abaixo/na frente/ atrás de Z* ***[modifier]*** *está Y)*. In this experiment, X and Z were nouns and Y was verbal phrase with a reflexive pronoun. In addition, each target sentence was presented in a short and a long version, produced by adding a modifier phrase between the subject and the reflexive without increasing structural complexity (e.g., *The doctor in front of the patient* ***[with the green shirt]*** *is dressing himself; O médico na frente do paciente* ***[de camisa verde]*** *está se vestindo).*

The visual stimuli each included four pictures that were presented on a computer screen: correct picture (correct attachment or antecedent and correct spatial relation); hierarchical error picture (incorrect attachment or antecedent testing for a hierarchical structural error); preposition change error picture (correct attachment or antecedent with a lexical error on the prepositional relation); reverse error picture (incorrect attachment or antecedent and spatial relations testing for a complete reversal of relations).

Procedure

The picture stimuli were presented via E-Prime Experimental Control Software (PST software, Pittsburgh, PA, USA, 1996-2006) and run on a laptop computer. The auditory (context and target sentences) stimuli were digitally recorded by a female Brazilian Portuguese native speaker on the PRAAT software (Boersma & Weenink, 2006) and presented through the speakers of the computer at the same audible level for all participants.

The trials of the two experiments were randomly presented to avoid length, order, or familiarization effects. The experimenter verbally provided instructions and they were also presented in written form on the computer screen before the beginning of the experiment. Five practice trials were presented. For each trial, the child, in silent room, was presented with a context sentence followed by the visual (four-picture array) stimulus and the target sentence. Each context sentence had a maximum duration of 5500 ms. After an interstimulus interval (ISI) of 1000 ms, the target sentence and an array of four pictures were presented simultaneously. The target sentences had the maximum duration of 5000 ms.

The position of the picture types on the four quadrants of the computer screen was randomly selected for each trial by E-Prime. The four pictures remained on the computer screen until a response was detected. The child then had to select (by pointing) the picture that corresponded to the sentence (the experimenter pushed the corresponding response button). The responses were classified and analyzed according to picture selection (correct, hierarchical error, preposition error, reversed error).

Figure 1 displays the timeline design of stimuli presentation on a single trial.

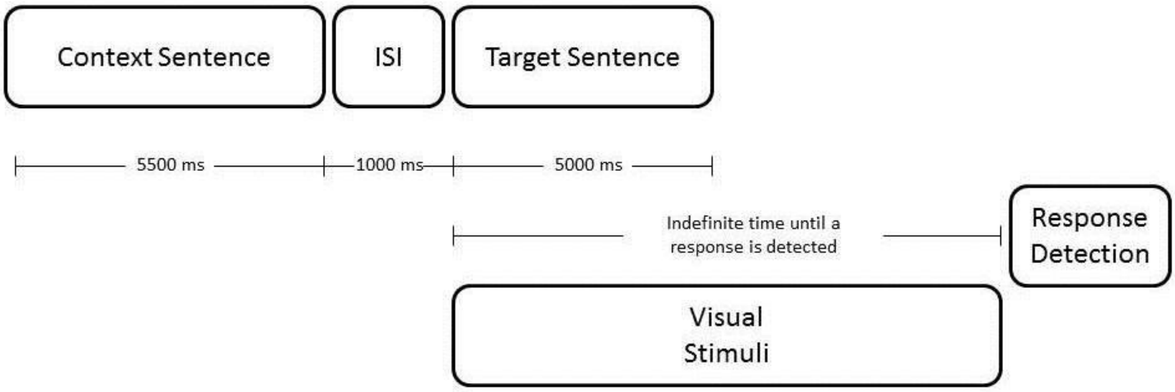

Figure 1: Timeline illustration of auditory, visual stimuli and interstimulus interval (ISI) of a single trial.

Data Analysis

The observed frequencies in each response category (correct, hierarchical, preposition change and reverse) revealed individual variability and also several null frequencies. An appropriate model for this analysis is the Dirichlet-Multinomial model (e.g. Paulino & Singer, 2006) which is a generalization of the Beta-Binomial model (Molenberghs & Verbeke, 2005).

The Dirichlet-Multinomial model assumes that the frequencies in each response category are generated by a multinomial model with a specific probability vector for each child and that these probability values constitute a random sample of a Dirichlet distribution. In our study, maximum likelihood methods were used to obtain the estimative of expected frequencies through a Dirichlet-multinomial model and these frequencies were compared between and within groups via Wald statistics and confidence intervals.

Results

Predicate Attachment

Figure 2 illustrates the response accuracy (in percentage) of the four groups (TLD, SLI, ASD, and DS) on the Predicate Attachment experiment. Children with SLI had a notably lower percentage of correct responses when compared to their TLD controls. In contrast, children with SLI exhibited higher accuracy when compared to both children with ASD and Down syndrome.

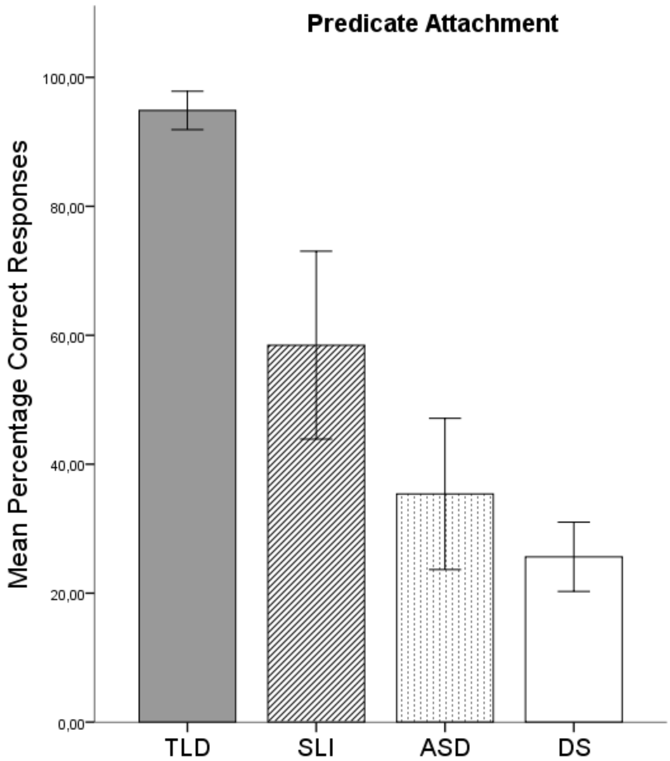

Figure 2: Mean percentage accuracy for the four groups (TLD, SLI, ASD, and DS) on the Predicate Attachment experiment. Error bars denote 95% Confidence Interval.

Between-group differences were also observed on the error analysis. Figure 3 exhibits the responses (in percentage) according to error type (hierarchical, preposition change, and reversed) for each of the groups.

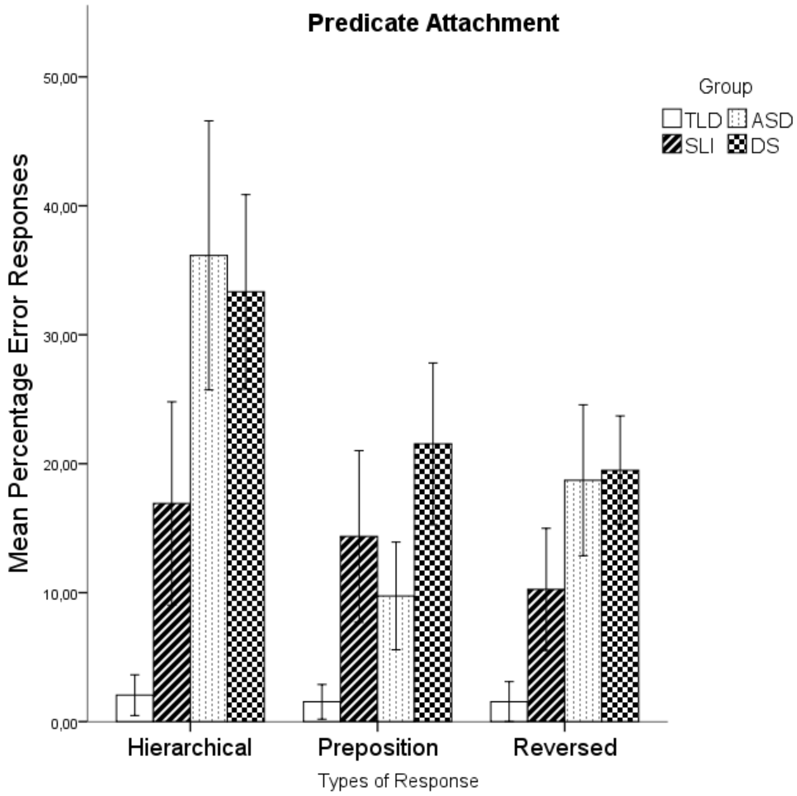

Figure 3: Mean percentage of error responses (hierarchical, predicate, reversed) for the four groups (TLD, SLI, ASD, and DS) on the Predicate Attachment experiment. Error bars denote 95% Confidence Interval.

For the inferential analysis, we employed the Dirichlet-Multinomial model to estimate the probabilities of each response category (correct, hierarchical, preposition change, reversed) for each group (Table 2).

Table 2: Dirichlet-Mutinomial model estimated mean (Standard Error) percentage of picture selection for the four groups (TLD, SLI, ASD, DS) on the Predicate Attachment Experiment.

	Picture Selection			
Group	**Correct**	**Hierarchical**	**Preposition Change**	**Reversed**
TLD	95.0 (2.0)	2.0 (1.0)	2.0 (0.5)	1.0 (0.3)
SLI	56.0 (7.0)	17.0 (5.0)	15.0 (2.0)	12.0 (1.0)
ASD	35.0 (5.0)	35.0 (5.0)	11.0 (2.0)	19.0 (1.0)
DS	26.0 (3.0)	33.0 (4.0)	21.0 (2.0)	20.0 (1.0)

The analysis via Wald statistics revealed an overall effect for group (χ^2 (9, N = 60) = 417.53, p < .001) indicating that the response distributions for the groups were in general different on the comprehension of syntactic constructions involving a predicate attachment.

To further investigate this effect, between-group comparisons examined each response type. Significant effects were observed for the correct responses, indicating that, in general, the four groups differed on accuracy (Correct: χ^2 (3, N = 60) = 352.28, p < .001). Moreover, significant effects were also observed on the selection of incorrect pictures presented by the groups for each of the three types of error (Hierarchical: χ^2 (3, N = 60) = 97.44, p < .001; Preposition: χ^2 (3, N = 60) = 118.00, p < .001; Reversed: χ^2 (3, N = 60) = 854.19, p < .001).

As statistical analysis revealed significant group effects for each response type, confidence intervals were constructed to investigate the difference in proportion of correct responses of the SLI, ASD and Down syndrome groups in comparison to the TLD group (Figure 4). The CI analysis indicated that the group of children with SLI was more accurate than children with ASD and Down syndrome. In turn, the ASD and Down syndrome groups did not exhibit differences between each other with respect to accuracy. A similar pattern is observed for errors involving syntax (hierarchical and reversed): similar hits of these errors are observed for children with ASD and Down syndrome, with SLI children exhibiting fewer syntactic errors than these two groups.

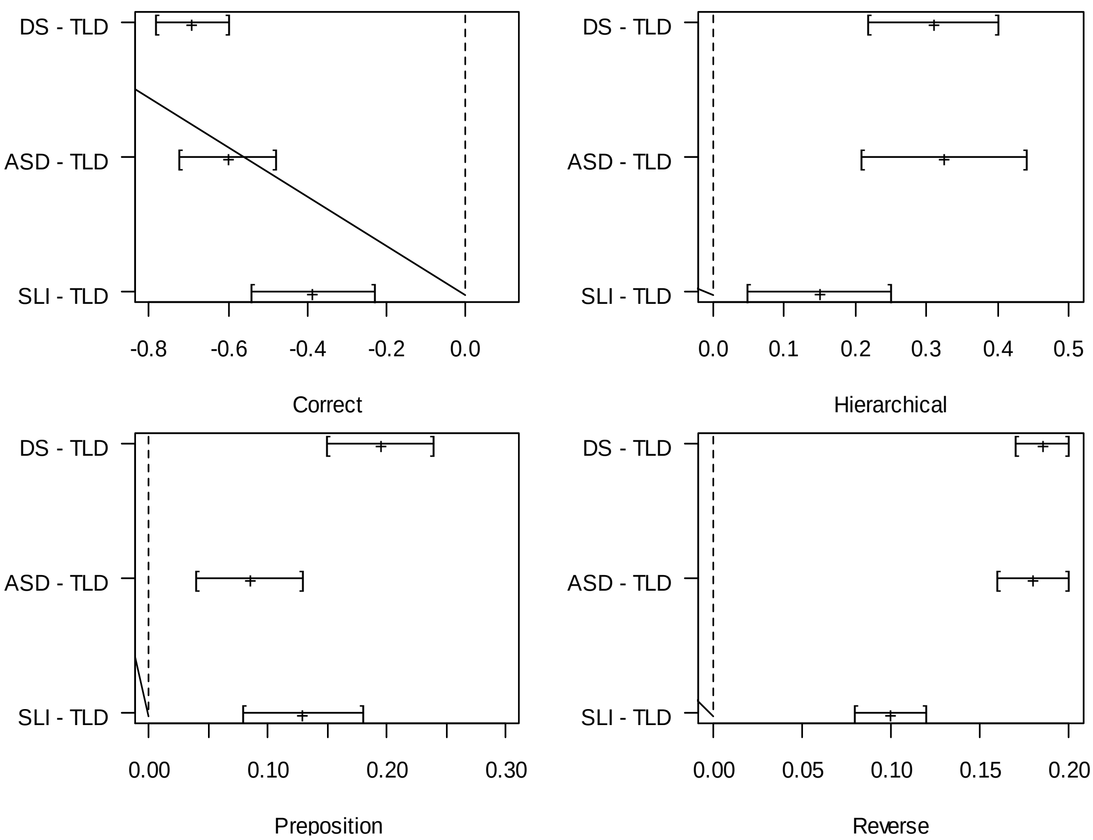

Figure 4: Confidence Intervals of the difference in proportions according to each response type (Correct, Hierarchical, Preposition, and Reverse) for the SLI, ASD, and DS groups in comparison to the TLD group on the Predicate Attachment experiment.

For the within-group error analysis, we observed two different patterns of error distributions. For the TLD and SLI groups, no effect of error type was observed (χ^2 (2, N = 15) = 1.03, p = .598; χ^2 (2, N = 15) = 4.79, p = .091 respectively), indicating that these children did not exhibit a significant preference for any of the error types. In contrast, error type effects were observed for children with ASD (χ^2 (2, N = 15) = 21.36, p < .001) and Down syndrome (χ^2 (2, N = 15) = 11.22, p = .004), both presenting a preference for the hierarchical error.

Reflexive Assignment

The results of the Reflexive Assignment experiment are presented according to the working memory condition.

Short Working Memory Condition

Figure 5 illustrates the response accuracy (in percentage) of the four groups (TLD, SLI, ASD, and DS) on the short working memory condition of the Reflexive Assignment experiment. Similarly to the Predicate Attachment experiment, children with SLI had lower percentage accuracy when compared to their TLD controls and higher accuracy when compared to both children with ASD and Down syndrome.

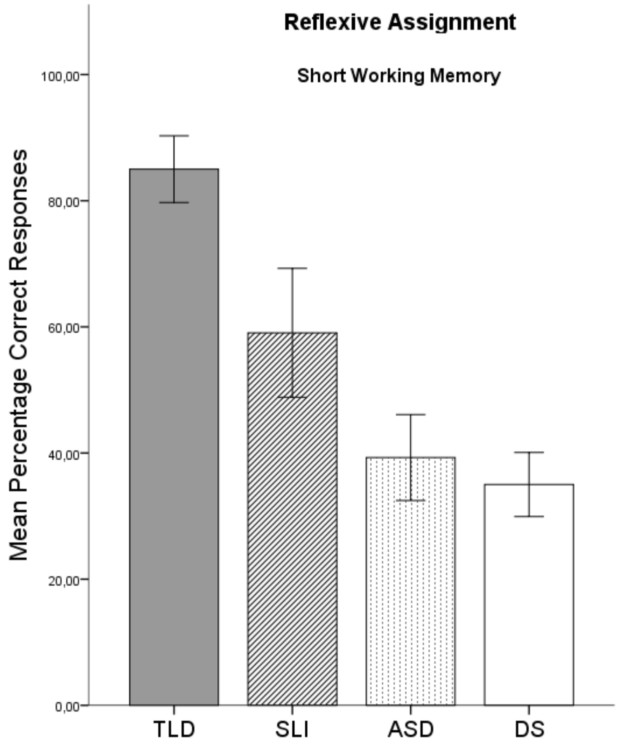

Figure 5: Mean percentage accuracy for the four groups (TLD, SLI, ASD, and DS) on the Short Working Memory condition of the Reflexive Assignment experiment. Error bars denote 95% Confidence Interval.

Figure 6 exhibits the responses (in percentage) according to error type (hierarchical, preposition change, and reversed) for each of the groups. The error analysis of the Reflexive Assignment experiment with short working memory demand revealed a more homogenous distribution across the clinical groups in comparison to the Predicate Attachment experiment.

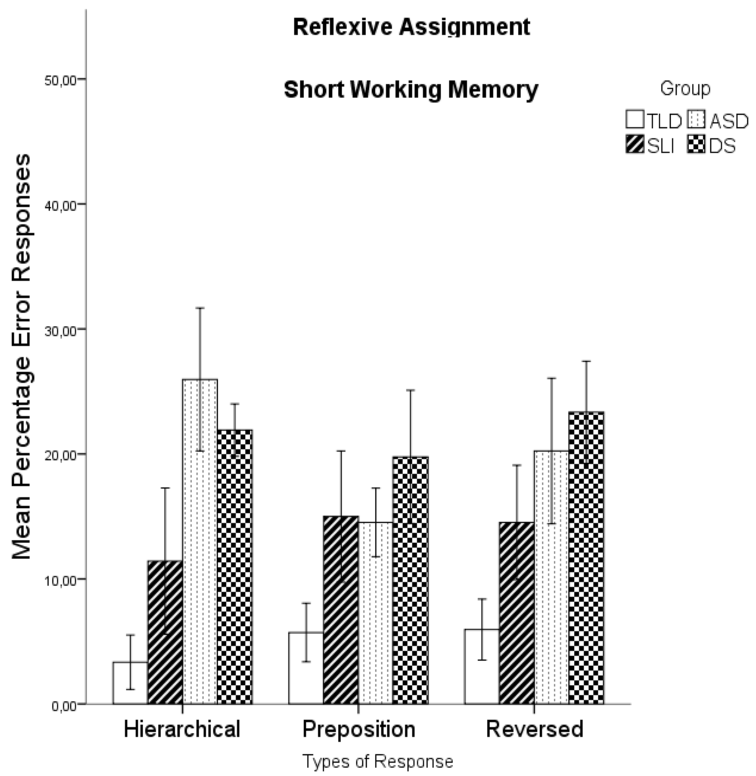

Figure 6: Mean percentage of error responses for the four groups (TLD, SLI, ASD, and DS) on the Long Working Memory condition of the Reflexive Assignment experiment. Error bars denote 95% Confidence Interval.

For the inferential analysis, we employed the Dirichlet-Multinomial model to estimate the probabilities of each response category (correct, hierarchical, preposition change, reversed) for each group (Table 3).

Table 3: Dirichlet-Mutinomial model estimated mean (Standard Error) percentage of picture selection for the four groups (TLD, SLI, ASD, DS) on the Reflexive Assignment Experiment with short working memory condition.

	Picture Selection			
Group	**Correct**	**Hierarchical**	**Preposition Change**	**Reversed**
TLD	85.0 (3.0)	3.0 (1.0)	6.0 (1.0)	6.0 (1.0)
SLI	58.0 (5.0)	11.0 (3.0)	16.0 (2.0)	15.0 (1.0)
ASD	39.0 (4.0)	26.0 (3.0)	15.0 (2.0)	20.0 (1.0)
DS	35.0 (2.0)	22.0 (2.0)	20.0 (1.0)	23.0 (0.5)

The analysis via Wald statistics revealed an overall effect for group (χ^2 (9, N = 60) = 257.27, $p < .001$) indicating that the response distributions for the groups were in general different on the comprehension of syntactic constructions involving the assignment of a reflexive with short working memory demands.

To further investigate this effect, between-group comparisons examined each response type. Significant effects were observed for the correct responses, indicating that, in general, the four groups differed on accuracy (Correct: χ^2 (3, N = 60) = 186.61, $p < .001$). Moreover, significant effects were also observed on the selection of incorrect pictures presented by the groups for each of the three types of error (Hierarchical: χ^2 (3, N = 60) = 91.00, $p < .001$; Preposition: χ^2 (3, N = 60) = 83.39, $p < .001$; Reversed: χ^2 (3, N = 60) = 439.83, $p < .001$).

As statistical analysis revealed a significant effect for group on each response type, confidence intervals were constructed to investigate the difference in proportion of correct responses of the SLI, ASD and Down syndrome groups in comparison to the TLD group (Figure 7). Similarly to the

Predicate Attachment experiment, the CIs indicated that the children with SLI were more accurate than children with ASD and Down syndrome on the assignment of reflexives with short working memory demands. In turn, the ASD and Down syndrome groups did not exhibit important differences between each other with respect to accuracy. For errors involving syntax (hierarchical and reversed), similar hits of these errors are observed for children with ASD and Down syndrome with SLI children exhibiting fewer syntactic errors than these two groups.

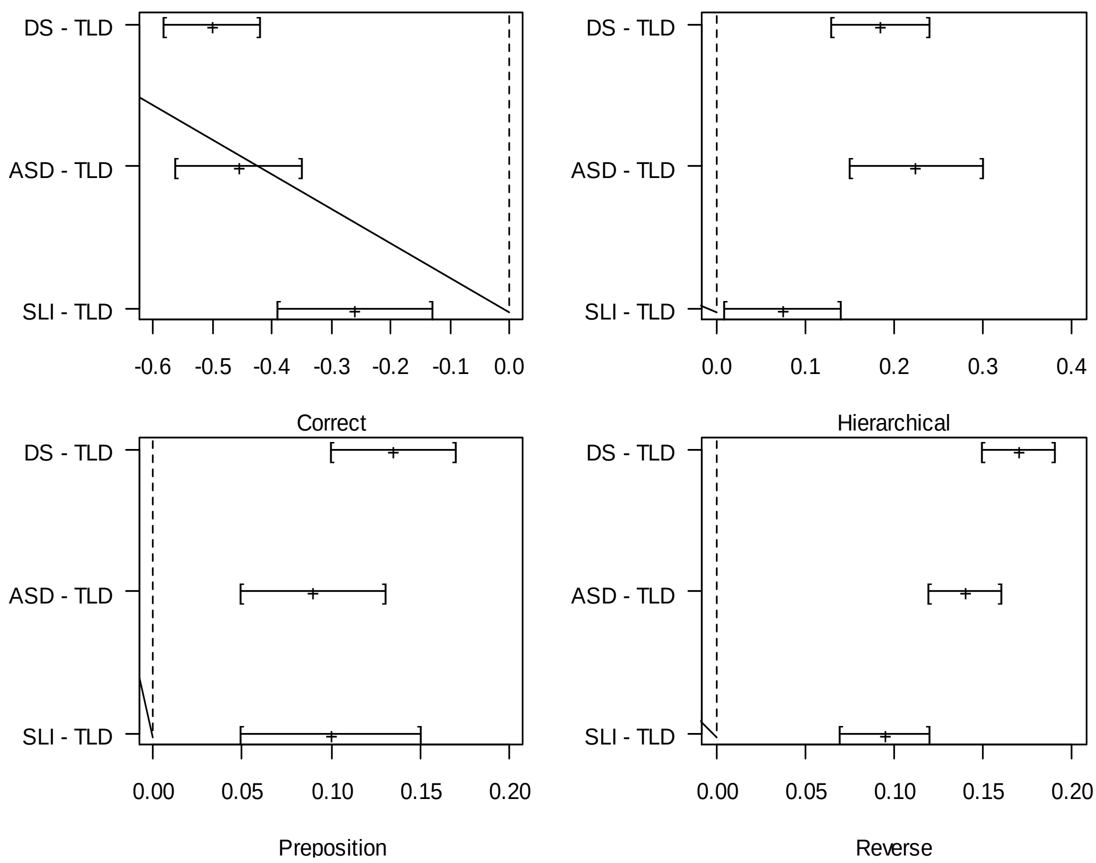

Figure 7: Confidence Intervals of the difference in proportions according to each response type (Correct, Hierarchical, Preposition, and Reverse) for the SLI, ASD, and DS groups in comparison to the TLD group on the Short Working Memory Condition of the Reflexive Assignment experiment.

For the within-group error analysis, the SLI and the Down syndrome groups did not exhibit a significant preference for any of the error types (χ^2 (2, *N* = 15) = 3.57, *p* = .168; χ^2 (2, *N* = 15) = 5.17, *p* = .075, respectively). The other two groups exhibited error type effects (TLD: χ^2 (2, *N* = 15) = 11.38, *p* = .003; ASD: χ^2 (2, *N* = 15) = 8.57, *p* = .014), indicating that for these children error type distribution was not homogeneous.

Long Working Memory Condition

Figure 8 illustrates the response accuracy (in percentage) of the four groups (TLD, SLI, ASD, and DS) on the Long Working Memory Condition of the Reflexive Assignment experiment. Here a different pattern of responses is observed in comparison to the Predicate Attachment experiment and to the short working memory condition of the Reflexive Assignment experiment. With higher working memory demands, children with SLI present similar accuracy to children with ASD and Down syndrome.

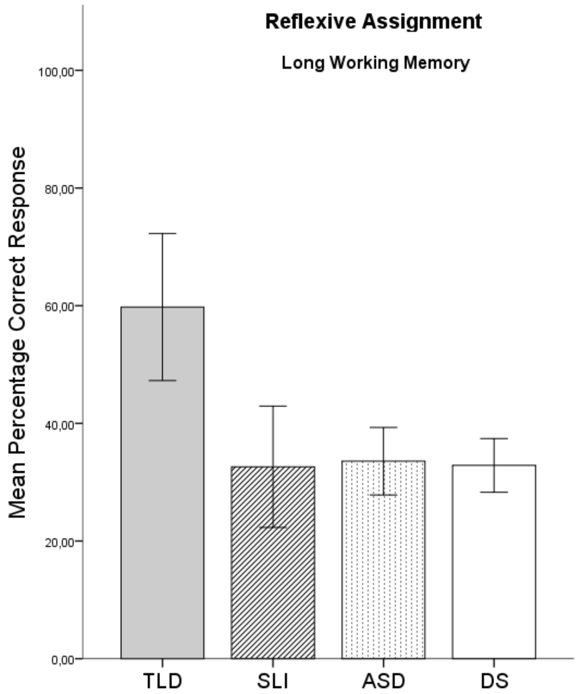

Figure 8: Mean percentage accuracy for the four groups (TLD, SLI, ASD, and DS) on the Long Working Memory condition of the Reflexive Assignment experiment. Error bars denote 95% Confidence Interval.

Figure 9 exhibits the responses (in percentage) according to error type (hierarchical, preposition change, and reversed) for each of the groups. The error analysis of Reflexive Assignment with long working memory demand revealed a homogenous distribution across groups of SLI, ASD and Down syndrome. Interestingly, the hits of the reversed type of error were similar across the four groups, including the TLD children.

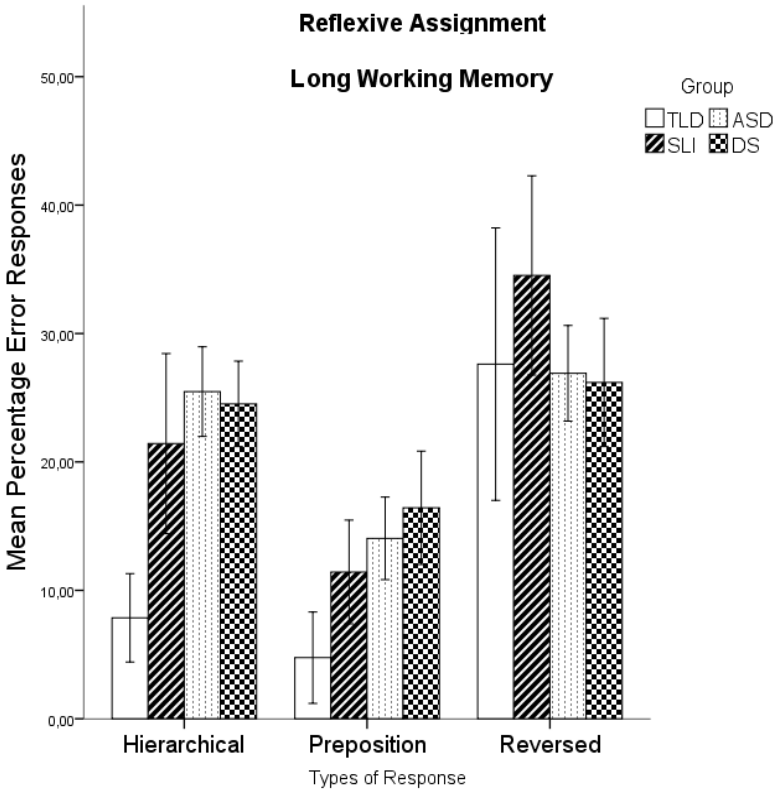

Figure 9: Mean percentage of error responses for the four groups (TLD, SLI, ASD, and DS) on the Long Working Memory condition of the Reflexive Assignment experiment. Error bars denote 95% Confidence Interval.

For the inferential analysis, we employed the Dirichlet-Multinomial model to estimate the probabilities of each response category (correct, hierarchical, preposition change, reversed) for each group (Table 4).

Table 4: Dirichlet-Mutinomial model estimated mean (Standard Error) percentage of picture selection for the four groups (TLD, SLI, ASD, DS) on the Reflexive Assignment Experiment with long working memory condition.

	Picture Selection			
Group	**Correct**	**Hierarchical**	**Preposition Change**	**Reversed**
TLD	58.0 (5.0)	10.0 (3.0)	6.0 (2.0)	26.0 (2.0)
SLI	32.0 (4.0)	21.0 (4.0)	12.0 (2.0)	35.0 (2.0)
ASD	34.0 (3.0)	25.0 (2.0)	14.0 (1.0)	27.0 (1.0)
DS	33.0 (3.0)	25.0 (3.0)	16.0 (2.0)	26.0 (1.0)

The analysis via Wald statistics revealed an overall effect for group (χ^2 (9, N = 60) = 58.49, p < .001) indicating that the response distributions for the groups were in general different on the comprehension of syntactic constructions involving the assignment of a reflexive with long working memory demands.

To further investigate this effect, between-group comparisons examined each response type. Significant effects were observed for the correct responses, indicating that, in general, the four groups differed on accuracy (Correct: χ^2 (3, N = 60) = 20.30, p < .001). Moreover, significant effects were also observed on the selection of incorrect pictures presented by the groups for each of the three types of error (Hierarchical: χ^2 (3, N = 60) = 21.55, p < .001; Preposition: χ^2 (3, N = 60) = 23.28, p < .001; Reversed: χ^2 (3, N = 60) = 21.72, p < .001).

As statistical analysis revealed a significant effect for group on each response type, confidence intervals were constructed to investigate the difference in proportion of correct responses of the SLI, ASD and Down syndrome groups in comparison to the TLD group (Figure 10). The CI analysis indicated similar accuracy of children with SLI, ASD and Down syndrome on the assignment of reflexives with long working memory demands. A similar pattern is observed for the hierarchical and the preposition errors, indicating the three clinical groups did not differ according to the selection of these response types.

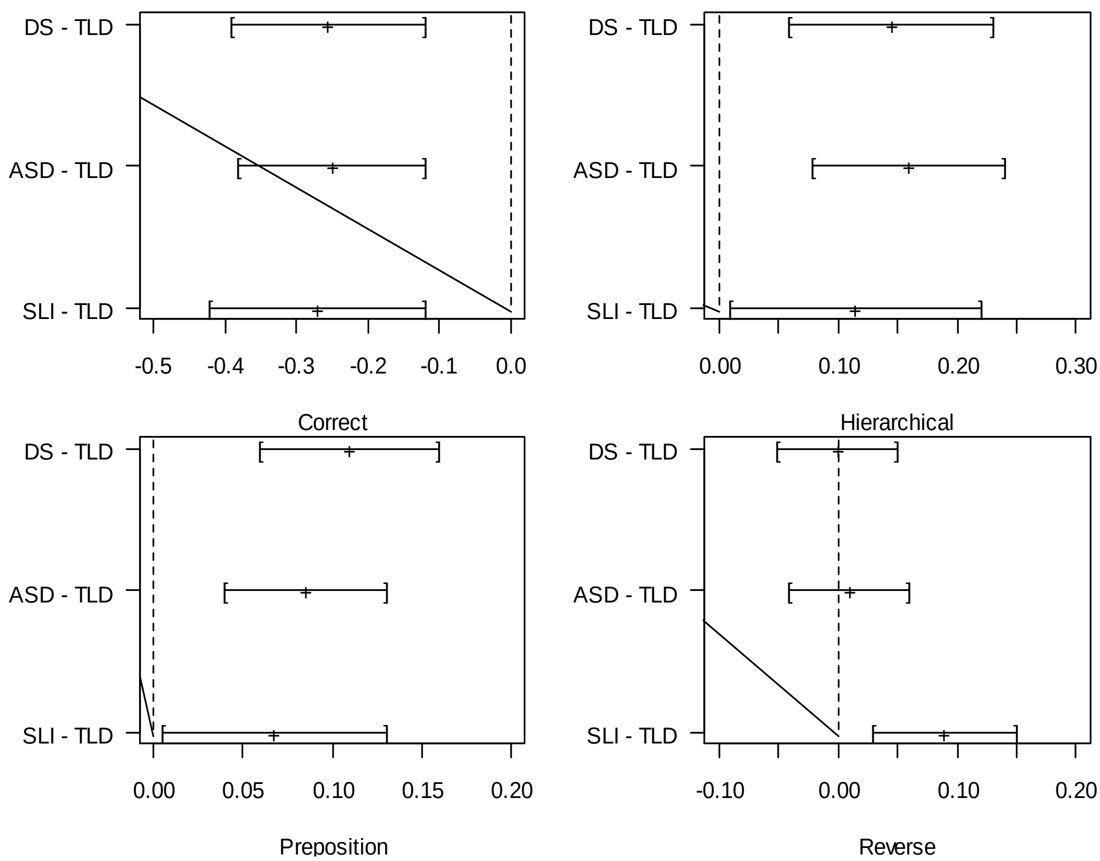

Figure 10: Confidence Intervals of the difference in proportions according to each response type (Correct, Hierarchical, Preposition, and Reverse) for the SLI, ASD, and DS groups in comparison to the TLD group on the Long Working Memory Condition of the Reflexive Assignment experiment.

For the within-group error analysis, error type effects were observed on all the four groups (TLD: χ^2 (2, N = 15) = 61.43, p < .001; SLI: χ^2 (2, N = 15) = 46.85, p < .0001; ASD: χ^2 (2, N = 15) = 51.11, p < .001; DS: χ^2 (2, N = 15) = 22.79, p < .0001), indicating that error type distribution was not homogeneous in any of the groups. A preference for the reverse error is observed.

Working Memory Effect

The Wald statistics applied to the Dirichlet-Multinomial model revealed significant working memory effects for the TLD, SLI and ASD groups (χ^2 (3, N = 15) = 212.06, p < .001); χ^2 (3, N = 15) = 427.93, p < .001; and χ^2 (3, N = 15) = 10.09, p = .039 respectively), indicating that for these groups the increase in working memory affected the overall response patterns. In contrast, no significant working memory effect was observed for the Down syndrome group (χ^2 (3, N = 15) = 0.929, p = .335). This finding indicates that the responses of the children from the Down syndrome group were not affected by an increase in working memory demands.

A set of analyses were carried out to further investigate the working memory effect on the TLD, SLI and ASD groups. In these analyses, we compared the selection of each response type (correct, hierarchical, preposition, and reverse) across the two conditions of working memory (short and long) in each group. Differences on accuracy between the two working memory conditions were found for the TLD (χ^2 (1, N = 15) = 18.61, p < .001) and for the SLI group (χ^2 (1, N = 15) = 14.88, p < .001). Both groups exhibited a decrease in accuracy with an increase in working memory demands. In contrast, the ASD group did not show a change in accuracy according to different working memory demands (χ^2 (1, N = 15) = 1.41, p = .235). As for the error types, children with TLD exhibited increased selection of hierarchical (χ^2 (1, N = 15) = 4.10, p = .043) and reverse (χ^2 (1, N = 15) = 69.55, p < .001) syntactic errors in the long working memory condition. In contrast, children with TLD exhibited no significant change in the selection of the preposition error picture according to working memory condition (χ^2 (1, N = 15) < .001, p = .990). The same pattern was observed for children with SLI: a significant increase in the selection of the hierarchical (χ^2 (1, N = 15) = 5.01, p = .025) and reverse (χ^2 (1, N = 15) = 95.22, p < .001) types of error, and no change in the selection of the preposition error (χ^2 (1, N = 16) = 1.03, p = .31). Contrastively, the only type of response that was responsible for the significant working memory effect observed for the ASD group was the increase in selection of the reverse type of error (χ^2 (1, N = 15) = 40.62, p < .001).

Correlational Analysis

Correlational matrix for the group as a whole (n = 60), revealed significant correlations between intelligence measures and accuracy, as well as between vocabulary and accuracy. Significant positive correlations were evident between intelligence and accuracy of predicate attachment (r_s = .689, p < .001) and between intelligence and correct assignment of antecedent to reflexive on the short (r_s = .705, p < .001) and long working memory conditions (r_s = .304, p = .027). Significant positive correlation was also observed between vocabulary and accuracy of predicate attachment (r_s = .331, p = .028). However, once vocabulary was entered as a control, no significant correlations were observed between intelligence measures and accuracy.

When looking at the groups individually, different correlational patterns were noted. In the TLD, SLI, and ASD group, no significant correlations were observed. In the DS group, there was a significant correlation between intelligence measure and accuracy of assignment of antecedent to reflexive on the long working memory condition (r_s = .633, p = .011).

Discussion

The comparison of diverse groups that exhibit language disorders help determine what is common across conditions, clarify the symptoms of each condition, as well as understand the nature of language impairments and the ways in which language capacity is vulnerable in each disorder. Furthermore, information from comparative studies of language disorders help understand the processes that support language and the underlying mechanisms that impair linguistic abilities in different clinical populations (Ypsilanti & Grouios, 2008). The present study systematically investigated the syntactic structural assignment of predicates and reflexives in children with SLI, ASD and Down syndrome. We examined whether these children differed from typically developing children and from each other on the comprehension of syntactic structures in which knowledge of hierarchical syntactic assignment for a correct comprehension is required. In addition, we also examined the effects of different working memory demands in the comprehension of reflexive structures, comparing effects of syntactic and lexical causes of miscomprehension.

In our study, all three groups with language disorders exhibited lower accuracy than the group with typical language development on predicate attachment and on assignment of antecedent to reflexives. This finding indicates that an overall deficit in structuring hierarchical syntactic relations necessary for comprehension of these structures is present in SLI, ASD and Down syndrome. Studies on syntax in these populations, with the exception of SLI, have limited their scope so far to expressive language and receptive language focused on standardized language measures, which somehow restricts our comparison to previous findings.

The syntactic assignment of children with SLI have been studied mostly on reflexives and pronouns (e.g. van der Lely, 1996; van der Lely & Stollwerck, 1997) indicating a deficit in the assignment of these structures when syntactic knowledge is necessary. The previous study by Fortunato-Tavares and colleagues (in press) and the current study (which consists on a subsample of the SLI sample of the previous one) corroborate to the deficit in reflexive assignment in children with SLI and add that these children also have difficulties with predicate attachment.

The studies on ASD population and syntax are limited and no studies on syntactic assignment are found so far. In general, the studies on more complex syntax in ASD have revealed a deficit in investigated structures (e.g. response to wh-questions (Oi, 2008, 2010); sentence repetition (Riches et al., 2010); formulating sentences (Landa & Goldberg, 2007), suggesting that there is a syntactic deficit despite earlier assumptions that syntax was relatively unimpaired in this population. Our findings further support later claims that syntax is impaired in ASD as deficits on syntactic assignment measured by comprehension were observed in this population when compared to TLD age-matched controls. It should be highlighted that although the literature seems to point to a general syntactic deficit in ASD, the studies on complex syntax and ASD available have investigated only a limited number of syntactic structures, tested through different tasks - mostly those requiring verbal responses – in participants with different age ranges and matching procedures (although the majority of studies matched ASD to typical language developing controls for age, some included additional matching on IQ measures (Landa & Goldberg, 2007) or language measures (Riches et al., 2010; Oi, 2010). In sum, the study on syntax and autism is at its very early stages and further investigations are needed for a more complete picture. The current study provide further steps towards this knowledge as it makes clear that ASD children have problems in comprehending syntactic structures where hierarchy knowledge is necessary.

The few studies on syntactic assignment in children with Down syndrome (Perovic, 2004, 2006; Ring & Clahsen, 2005) have focused on reflexive and pronoun assignment. According to those studies, children with Down syndrome have deficits in assigning reflexives, but not pronouns, to their antecedents. The absence of difficulties with pronoun assignment of children with Down syndrome might be related to their vocabulary strength. Earlier studies suggest that lexical knowledge is sufficient for binding pronouns while the assignment of reflexives relies mostly on syntax (van der Lely & Stollwerck, 1997). Our findings corroborate the claim that children with Down syndrome have a deficit in assigning the correct antecedent to reflexives and add that this is also true for predicate attachment. Similar to the reflexive conditions in the previous studies (Perovic, 2004, 2006; Ring & Clahsen, 2005), in our study, lexical knowledge alone was insufficient for correctly attaching the predicate to its noun (e.g. *The circle on the star is blue*) and children had to rely on syntactic information. This necessary support on syntax made their performance significantly poorer than TLD age-matched group also on predicate attachment. Therefore, the difficulties of children with Down syndrome in syntactic assignment are not limited to reflexives.

Our findings support that the difficulties presented by individuals with Down syndrome in the syntactic assignment domain are somewhat different than SLI. Although not in a direct comparison, parallel of findings of separate studies on Down syndrome (Perovic, 2004, 2006; Ring & Clahsen, 2005) and SLI children (van der Lely; 1996; van der Lely & Stollwerck, 1997) reveals that, for syntactic binding, Down syndrome and SLI children might exhibit distinct patterns of impairment. In the studies by van der Lely and colleagues, children with SLI achieved lower accuracy than controls on conditions involving pronoun showing that, in contrast to children with Down syndrome, difficulties of SLI children in syntactic assignment of pronouns is not restricted to reflexives. Although the deficit in syntactic assignment of antecedent nouns to reflexives observed in the current study is consistent with findings from van der Lely (1998) and van der Lely & Stollwerck (1997) for SLI, and Perovic (2004, 2006) and Ring and Clahsen (2005) for Down syndrome, some differences between our study and these studies should be noted. Different tasks (forced choice judgment task and picture selection), different syntactic constructions (verbal phrase with reflexive, questions and subordinate structures), and different characteristics of controls and matching procedures were employed. Our study provided a novel direct comparison of SLI and Down syndrome groups, indicating for the first time that children with

Down syndrome have deficits that exceed those of SLI both on the assignment of reflexives and on the attachment of predicates.

The research on syntax and ASD is at its very early stages and to the best of our knowledge no specific syntactic structures have been directly compared between children with ASD and SLI. The most consistent comparison between these two groups with regards to syntax is application of the Recalling Sentences subtest of the CELF test (Clinical Evaluation of Language Fundamentals – Semel, Wiig, Secord, 1995) that so far has provided mixed findings on between-group comparisons. Some studies suggest that children and adolescents with SLI exhibit poorer performance on this subtest than those with ASD (Riches et al., 2010; Whitehouse, Barry and Bishop, 2008), whether others suggest that there is no significant difference (Botting & Conti-Ramsdem, 2003; Lloyd, Paintin & Botting, 2006). Another study with a similar task but different stimuli (Riches et al., 2010) also reported that children with SLI were significantly more affected by syntactic complexity, and were significantly more likely to make complete changes to syntactic structure. Interestingly, no study has reported poorer performance of ASD children on sentence repetition when compared to SLI children. This might possibly be related to the working memory demand involved in sentence repetition tasks as children have to store the verbal material in order to reproduce it, perhaps confounding the measures of linguistic and processing abilities. In our study, we see that children with ASD have more deficits than those with SLI when working memory demands are low and the two groups do not differ when there is an increased working memory demand. This suggests that effects of working memory have to be controlled for on the research comparing ASD and SLI and that working memory can indicate possible underlying differences between the two groups.

The comparison between ASD and SLI has also taken a path of age effects. Williams and colleagues (2008) suggest that children with SLI and ASD present similarities and differences in language according to age and that there are different profiles for preschool and school-age children. According to these authors, preschool children with ASD and SLI share common linguistic characteristics as both exhibit more general language impairment, involving receptive and expressive aspects of language. In contrast, school-age children exhibit different linguistic profiles; while children with SLI continue to exhibit a mixed language disorder, children with ASD present a prevalence of receptive impairment. We add that although both SLI and ASD school-age children exhibit deficits in receptive language, there might still be differences on this domain. In the current study we show that school-age children with SLI and ASD differ in comprehension of specific syntactic structures (predicate attachment and reflexive assignment) when there is a low demand of working memory somewhat corroborating to this claim.

Children with Down syndrome and ASD exhibited similar accuracy on comprehending sentences with predicate attachment and reflexive assignment. No studies comparing the two populations on syntactic assignment are found so far. Therefore the current study provides a novel finding: children with ASD and children with Down syndrome might exhibit some similarities in terms of syntactic comprehension, clear here for predicate attachment and reflexive assignment.

Deficits in the cognitive system may have consequences in the development of language in individuals with language disorders. Although these consequences may define the nature of impairment, the strengths and weakness of each clinical group, and the differences in their linguistic profiles this relationship does not appear to be as straightforward in our study. Even though it is tempting to use intelligence as an explanatory factor for the differences observed in performance given the significant correlations between intelligence and accuracy on the group as a whole, some facts suggest that this might not be the case. First, children with Down syndrome had lower intelligence than children with ASD ($p < .001$) and yet these two groups exhibited an overall similar performance. Second, children with TLD, SLI and ASD had similar intelligence scores and we see different patterns of performance across the conditions.

Hierarchical Ordering Deficit

The groups with SLI and TLD exhibited no significant preference for any type of error on predicate attachment, contradicting the HOD hypothesis (Cromer, 1978) for children with SLI as the selection of errors reflecting a flat structure was not the most frequent error choice for these children. However, the lack of hierarchy knowledge might possibly account for the deficits in comprehending sentences with predicate attachment for children with ASD and Down syndrome. In both groups (ASD and Down syndrome) the dominant error response on predicate attachment was the hierarchical - which represents a flat, instead of hierarchical syntactic structure - suggesting that HOD might explain some syntactic deficits in these children.

However, if the HOD is true, it should provide valid explanations for any structures involving a necessary hierarchy knowledge for a correct comprehension and this was not observed here. In our study, different patterns were observed for the assignment of reflexives. On syntactic structures involving reflexive assignment and short working memory demands, HOD holds true only for the ASD group. Furthermore, the HOD does not predict any effect of processing demands on comprehension and, therefore, there should not be differences in responses according to different working memory demands. Unlike the short working memory condition, all groups (including TLD) exhibited on the long working memory condition a heterogeneous error distribution that indicated a preference for errors involving incorrect structural assignment (hierarchical error) and a combination of syntactic and lexical error (reverse error). This is an indication of a direct influence of working memory on syntactic assignment not predicted by the HOD or other domain specific theories for language impairment.

Working memory Effect

When we examine more closely the working memory effects, we see three different patterns according to the groups of language disorder studied here. First, children with SLI (and TLD) exhibited decreased accuracy and increased selection of errors involving syntax and no difference in errors involving lexical (preposition) with the increase in working memory demand. Therefore, for these two groups, working memory played an effect on syntactic but not lexical causes of miscomprehension. Second, in ASD children, an increased working memory demand affected only selection of reverse pictures (which combine syntactic and lexical errors). Third, in children with Down syndrome, no working memory effect on the comprehension of syntactic structures involving assignment of reflexives was observed, revealing no interaction between working memory and syntactic assignment comprehension in these children.

One interesting finding regarding the Reflexive Assignment experiment is the decrease in accuracy of children with SLI with an increase in working memory demands. The increased working memory demands lead children with SLI to similar accuracy of children with ASD and Down syndrome. It is clear that the group of children with SLI is severely affected by working memory demands on syntactic comprehension, which rendered this group comparable to children with different disorders and lower intelligence. Furthermore, this effect also endorses the internal validity of the study as the conditions with short working memory demands revealed significant differences on accuracy between SLI children and those with ASD or Down syndrome.

There is not a consensus in the literature about working memory deficits in ASD and the findings of the current study do not provide straightforward evidence of a working memory effect on sentence comprehension in these children. Although a working memory effect is not found on accuracy (which presented a non-significant five percent decrease), a different error pattern in responses is observed. The fact that the most complex error available (reverse, as it combines both lexical and syntactic errors) increased with a more demanding working memory might reflect that children with ASD have more difficulties with increased working memory demands.

Children with ASD exhibited smaller working memory effects than those of SLI children, which might be some evidence that these two groups present different underlying causes of language impairment - working memory was not a clear cause for increased miscomprehension in ASD as it was for SLI. Whitehouse, Barry and Bishop (2008) comparing non word repetition of children with ASD and SLI evidenced that although the two groups made a similar number of repetition errors for nonwords of two- and three- syllables, the SLI participants group tended to produce more errors than the autism participants for the longer nonwords which also points to different underlying mechanisms of processing limitations in these two disorders. The findings of Whitehouse and colleagues together with ours suggest that these differences between ASD and SLI provide evidence against the proposal that there is a subtype among children with autism who have a language phenotype that is the same as that of children with SLI (Tager-Flusberg & Joseph, 2003).

There seems to be an agreement in the literature that individuals with Down syndrome show a verbal working memory deficit (e.g. Jarrold &

Baddeley, 1997; Lanfranchi et al., 2004; Miolo et al., 2005; Seung & Chapman, 2004). However, our findings contradict the studies that point to a direct association between working memory and language in these children (e.g. Chapman & Hesketh, 2001; Miolo et al., 2005; Laws, 2004; Laws & Gunn, 2004). When manipulating the direct demands of working memory on the linguistic stimuli we found no working memory effect on the comprehension of the investigated structure (reflexive assignment). The claim that there seems to be a relationship between overall language measures and memory deficits of individuals with Down syndrome might reflect only comorbidity of two deficits and not a direct association between them. If these two areas are areas of deficit in these children, it is not surprising to find correlations.

One possible explanation for the discrepancy in findings of the relationship between working memory and language is the debate on whether independent working memory measures (e.g., nonword and real word repetition, repetition of word lists, etc.) refer to the same working memory used on language. Waters and Caplan (1996) found that sentence list recall span was not a major determinant in the processing of garden path sentences. This finding led to a proposal of multiple working memory capacities that subserve language processing and to the suggestion that the sentence span task does not assess the working memory used for language comprehension in adults. We argue that the working memory tasks typically employed reflect the temporary storage of verbal material that plays only a secondary role in higher level language comprehension. Another possible explanation follows from the fact that individuals with Down syndrome tend to have generally impaired verbal abilities relative to their non-verbal skills (Chapman, 1995; Gunn & Crombie, 1996). Given this, it is possible that a particular problem in working memory performance is simply a reflection of a more general difficulty in verbal expression domains (Hulme & Roodenrys, 1995) usually required on independent working memory tasks. Therefore, when working memory is measured through comprehension, as in the current study, this effect might not be as clear.

In sum, the present study gives novel findings on the relationship between working memory and language in children with SLI, ASD, and Down syndrome. For SLI children it is clear that working memory has a direct effect on sentence comprehension. For children with ASD, although there was a change in error pattern this effect is not as straightforward as there was no effect in accuracy. Finally, working memory has no direct effect on sentence comprehension of children with Down syndrome, at least for the structure under investigation here. Taken together, these findings bring important theoretical and methodological points. There are clear differences between language profiles of children with SLI, ASD and Down syndrome and differences are also observed on underlying process (working memory). Although significant relationships between independent working memory measures and language have been reported for these disorders, when working memory is directly manipulated on the linguistic stimuli, we see different effects on language processing for children with SLI, ASD, and Down syndrome. This makes clear that the simple correlation between working memory measures and language measures and the direct manipulation of working memory demands on linguistic stimuli do not share the same underlying process.

Conclusions

Children with SLI, ASD and Down syndrome differ from children with TLD on the comprehension of predicate and reflexive structures where knowledge of syntactic structural assignment is required. Children with Down syndrome and ASD have greater difficulty with these structures than children with SLI but exhibit similar accuracy when compared to each other.

The present data contradicts the HOD hypothesis as a general explanation for syntactic deficits in children with language disorders. The lack of hierarchy knowledge was not the main cause of miscomprehension in children with SLI, but it possibly plays a significant role on children with Down syndrome and ASD depending on the structure under investigation.

Different working memory effects, as measured by direct manipulations of working memory on sentence stimuli, are found for children with SLI, ASD, and Down syndrome. The working memory effect on sentence comprehension is clear for children with SLI. The effect of working memory demands on sentence comprehension is smaller and not so clear for children with ASD. In turn, children with Down syndrome do not exhibit any effect of working memory demands on sentence comprehension.

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