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Proform-antecedent linking in listeners with language impairments and unimpaired listeners

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Language and Communicative Disorders

by

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The Dissertation of Samantha Michelle Engel is approved, and is acceptable in quality and form for publication on microfilm and electronically:

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EPIGRAPH

"There are ten parts of speech and they are all troublesome."

Mark Twain, *The Awful German Language*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT OF THE DISSERTATION

Proform-antecedent linking in listeners with language impairments and unimpaired listeners

by

Samantha Michelle Engel

Doctor of Philosophy in Language and Communicative Disorders

University of California, San Diego, 2016
San Diego State University, 2016

Professor Lewis Shapiro, Chair
Professor Tracy Love, Co-Chair

This dissertation explores how listeners extract meaning from personal and reflexive pronouns in spoken language. To be understood, words like *her* and *herself* must be linked to a prior element in the speech stream (or *antecedent*). This process draws on syntactic knowledge and verbal working memory processes. I present two original research studies investigating moment-to-moment sentence processing and final comprehension of sentences containing proforms in children and adults with and without language impairments.

Chapter 2 provides an overview of syntactic constraints and psycholinguistic evidence from unimpaired listeners in addition to an introduction to the language

impaired populations. Chapter 3 reviews psycholinguistic evidence of similarity-based interference in verbal working memory during unimpaired language processing before presenting a recent account – the Intervener Hypothesis – that points to similarity-based interference as a source of processing and comprehension difficulty in language impaired populations.

Chapter 4 presents a series of experiments in children with typical language development (TLD) and children with a developmental language impairment – specific language impairment (SLI). The processing patterns of the two participants groups reveal qualitative differences and children with SLI demonstrate increased comprehension difficulty relative to TLD children. Chapter 5 presents a series of experiments in adults with an acquired language impairment – agrammatic Broca's aphasia – and age-matched control participants. Results reveal increased processing and comprehension difficulty of sentences containing pronouns relative to reflexives for individuals with Broca's aphasia.

The processing patterns demonstrated by unimpaired child and adult participants reveal a number of striking similarities. In addition, the processing patterns of children with SLI mirror those of adults with Broca's aphasia. Although the etiology of language impairments differs in these groups, children with SLI and adults with Broca's aphasia share many of the same language processing difficulties. As such, I evaluate the potential of a single theoretical framework (the Intervener Hypothesis) to account for the patterns observed in each group. In addition, I evaluate how processing and comprehension patterns change across the lifespan in participants

with unimpaired language and the extent to which processing and comprehension patterns overlap.

CHAPTER 1:

Introduction

1.1 Introduction

Spoken language seems like magic: through the movement of pressure waves across time and space, we yield the practical necessity of communication and expression. As infants, we acquire the ability to coordinate the muscles of our mouth to form sounds and then to combine those sounds -- just so -- to form words. As young children, we are already adept at producing thousands of distinct sound sequences to convey meaning. As aptly as the single words of early childhood may serve us, language is rich with peculiarities and we quickly are able to use shortcuts, tricks and twists to get our meaning across more efficiently.

The focus of this dissertation is on one of the "shortcuts" of the English language: words like *her* and *herself*. These words are examples of third-person personal pronouns and we use them to refer to unique entities in the world. We do so because, more often than not, it is more expedient and pragmatic than to repeat the word (or sequence of words) that uniquely selects the entity we intend to communicate about. It would be awfully strange for example, in an ongoing conversation about the Queen of England to say, "*I've been reading a fascinating book about the Queen of England and I learned that the Queen of England has a fleet of nine corgis. The Queen of England calls the Queen of England's nine corgis the Queen of England's surest companions.*" It would be much more swift, and would express the very same meaning to say, "*I've been reading a fascinating book about the Queen of England and I learned that she has a fleet of nine corgis that she calls her surest companions*." To be sure, these shortcuts are not without their pitfalls. Consider the following frustrating interchange:

Figure 1-1. *"Says who?"*

The above comic illustrates that the use of words like *him* requires a speaker to cooperate with Grice's maxim of quality: "be informative, but not overly so" (Grice, 1975) and that as handy and frequently occurring as pronouns are, they remain "interpretationally dependent" (Newmeyer, 1988) on other pieces of linguistic information. This dissertation explores how listeners make meaning from bits of sound like *him, her, himself* and *herself* and the challenges they encounter along the way.

1.2 Overview of the Dissertation

This dissertation examines how listeners understand sentences containing pronouns (e.g., her, him) and reflexives (e.g., herself, himself). I investigate sentence processing in real time using a method with fine-grained temporal sensitivity – eyetracking-while-listening – in addition to investigating final comprehension using a sentence-picture matching task. I present a series of studies investigating processing and comprehension patterns in participants with unimpaired language and participants with language impairments. The following chapter reviews relevant linguistic considerations for sentences containing pronouns and reflexives and psycholinguistic evidence from children and adults with normal language function. Chapter 2 also provides an introduction to the language impaired populations studied within this

dissertation and underscores the motivation for investigating proform-antecedent linking in children with specific language impairment and adults with Broca's aphasia.

Chapter 3 focuses on the relationship between working memory and sentence processing and reviews research of similarity-based interference in unimpaired participants. Chapter 3 then presents the Intervener Hypothesis, which takes as its starting point the findings from similarity-based interference in unimpaired subjects and posits that similarity-based interference may also account for processing and comprehension deficits in language impaired populations.

Chapter 4 presents a study investigating how children with typical language development understand sentences containing proforms, how processing patterns change across development and contrasts performance with children with a developmental language disorder – specific language impairment. Chapter 5 presents a study investigating processing and comprehension patterns in a group of adults with an acquired language disorder – agrammatic Broca's aphasia – and presents data from age-matched-control participants as a comparison. In this way, the studies described herein provide a window into "normal" patterns across the lifespan and enables a comparison of populations with language impairments, both developmental and acquired.

REFERENCES

Grice, H.P. (1975). Logic and conversation. In P. Cole & J.L Morgan (Eds.), *Syntax and Semantics III: Speech Acts* (pp. 41-58). Academic Press, New York, NY.

Newmeyer, F.J. (Ed.). (1988). *Linguistic theory: foundations*. CUP Archive.

CHAPTER 2:

Sentence Processing

2.1 Sentence Processing

The purpose of this chapter is to lay bare the linguistic considerations relevant to sentences that contain pronouns and reflexives. I begin with a review of the structural constraints outlined by linguistic theory within the transformational grammar approach before presenting empirical evidence from psycholinguistic studies of listeners with unimpaired language. I then review evidence of sentence processing and comprehension in two populations with atypical language: adults with an acquired language disorder following neural injury -- agrammatic Broca's aphasia -- and children with a developmental language impairment – specific language impairment (SLI).

2.1.1 Structural Constraints

Binding theory refers to the grammatical subsystem within the Government and Binding (GB) framework (Chomsky, 1981) that constrains how pronouns and reflexives can be linked to other sentence elements. Principles A and B outline the conditions necessary for co-reference between a pronoun or reflexive and a preceding noun phrase (or *antecedent*). Binding relies on the co-indexation of a proform and antecedent and on the c-command relation between these two elements. For a proform and antecedent to be co-indexed, they must agree in features of gender and number. C-command refers to the structural relation between two sentence elements such that a node of a syntactic tree c-commands its sister node and all the descendants of its sister node (Reinhart, 1976); for a proform to be bound, it must be c-commanded by its antecedent.

Principle A states that a reflexive must be bound within its local domain (or *governing category*). Example (1) below shows how the antecedent of a reflexive is specified:

(1) Tina_a says that [Louise_b hurt $\text{herself}_{a*/b}$]

In keeping with Principle A, the reflexive *herself* in (1) must co-refer with the noun phrase within its local domain, thus the reflexive gets its reference from the NP *Louise; Louise* and *herself* cannot co-refer with the noun phrase outside of it, *Tina* (denoted by *).

Principle B states that a pronoun cannot be bound within its local domain and so must find its antecedent outside of the local domain. Example (2) below shows how the antecedent of a pronoun is specified:

(2) Tina_a says that [Louise_b hurt $\text{her}_{a/b*/c}$]

According to Principle B, the pronoun *her* and the noun phrase *Louise* in (2) cannot be co-indexed because the two share a local domain and the pronoun is c-commanded by the noun phrase. The pronoun *her* can be co-indexed with the noun phrase *Tina*, which is outside of the local domain. Principle B also permits the pronoun to be co-indexed with a third referent, external to the sentence (denoted by subscript 3). Note also that

the requirements for co-indexing (agreement in gender and number) and c-command are also met in (1) and (2) and illustrated below in Figure 2-1:

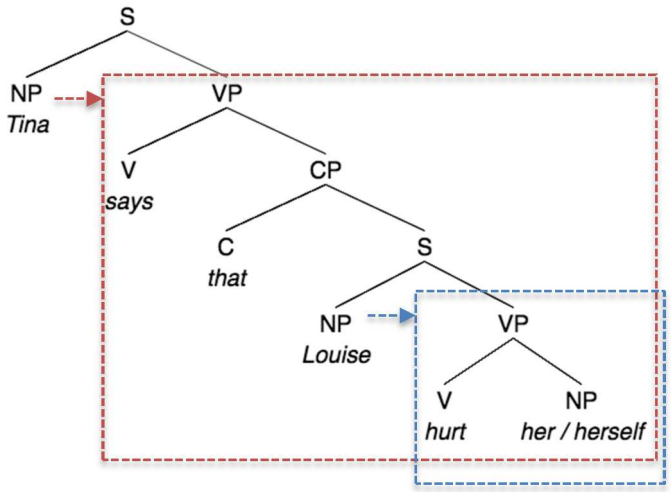

Figure 2-1. Syntactic tree illustrating c-command

Principles A and B are complementary in that Principle A determines a specific referent for a reflexive, while Principle B excludes a specific referent of a pronoun but leaves open more than one allowable possibility. In this way, the referent of a reflexive can be determined via syntactic information alone but this is not so for pronouns. A variety of accounts point to the role of non-structural information such as discourse prominence and pragmatics in determining the referent of pronouns (Levinson, 1987; Reuland, 2001; Gordon & Scearce, 2005). However, as the experiments presented within this dissertation are designed to test how structural information effects processing and comprehension of sentences containing pronouns and reflexives, we limit our review to the transformational view of binding constraints.

2.1.2 Psycholinguistic Evidence

Having established the constraints that govern proform-antecedent linking in terms of syntactic structure, we now examine empirical evidence that addresses how

listeners employ these constraints during language processing. Nicol (1988) and Nicol and Swinney (1989) investigated reactivation of structurally accessible and inaccessible antecedents using cross-modal lexical priming (CMLP). In cross-modal lexical priming, participants listen to auditory sentences as visual probe words appear on screen momentarily at critical points in the sentence (i.e., probe points). Participants are required to make a timed lexical decision. Response times are compared between trials where the lexical item was related to the sentence element of interest (i.e., antecedent) to baseline (unrelated) trials. The difference in response times between related and unrelated trials captures a priming effect, where increased activation of the sentence element of interest leads to faster response times. Nicol (1988) examined reactivation of structurally accessible and inaccessible antecedents in sentences such as:

(3) The boxer$_{a}$ told the skier$_{b}$ that the doctor$_{c}$ for the team would blame himself$_{a*/b*/c}$ for the recent injury.

(4) The boxer$_{a}$ told the skier$_{b}$ that the doctor$_{c}$ for the team would blame him$_{a/b/c*}$ for the recent injury.

Based on Principle A, *the doctor* in (3) is the only structurally accessible antecedent of the reflexive *himself* and *the boxer* and *the skier* are structurally inaccessible. In contrast, based on Principle B the pronoun *him* in (4) can refer to either *the boxer* or *the skier*, but *the doctor* is a structurally inaccessible antecedent of the pronoun. Findings reflected that only the structurally accessible antecedents were activated after

the pronoun and reflexive. That is, in (3) *the doctor* was activated after *himself* but *the boxer* and *the skier* were not. In the pronoun condition (4), both structurally accessible antecedents were activated (*the boxer, the skier*) but the inaccessible antecedent (*the doctor)* was not. These results are taken as support for the binding-as-initial-filter hypothesis, where binding principles are available and applied early in processing.

Psycholinguistic evidence from children with typical language development also provides support for the binding-as-initial-filter hypothesis. Using a variant of cross-modal priming called cross-modal picture priming (CMPP), McKee, Nicol and McDaniel (1993) and Love, Walenski and Swinney (2009) tested children's reactivation of correct (structurally accessible) and incorrect (structurally inaccessible) antecedents. In cross-modal picture priming, a picture that is related or unrelated to the sentence element of interest appears on screen during the auditory presentation of the sentence. Children are required to make a timed animacy judgment (i.e., *is it alive?*) and a priming effect is calculated. McKee, Nicol and McDaniel (1993) tested 4-6-year-old children using sentences such as:

(5) The alligator$_a$ knows that the leopard$_b$ with green eyes is patting himself$_{a*/b}$ on the head with a soft pillow.

(6) The alligator$_a$ knows that the leopard$_b$ with green eyes is patting him$_{a/b*}$ on the head with a soft pillow.

The authors investigated priming of the correct antecedent of the reflexive (*the leopard*) and found that children activated the correct antecedent in the reflexive

condition (5) but not in the pronoun condition (6). Love, Walenski and Swinney (2009) used the same materials to test children ages 5-13 for priming of the correct antecedent of the pronoun (*the alligator*) and found significant priming in the pronoun condition (6). These and other studies of real-time processing (Sekerina, Stromswold & Hestvik, 2004; Roberts, Marinis, Felser & Clahsen, 2007) reflect that, like adults, children as young as age 4 apply knowledge of binding principles during sentence processing. The results of the studies reviewed here serve as the basis for comparison in studies aimed at understanding how linguistic processes break down in the context of language impairments. In the following section we discuss two populations who demonstrate difficulty in the processing and comprehension of a variety of sentence types, including those that contain pronouns and reflexives.

2.2 Language Impaired Populations

The studies included in this dissertation present data from two populations with atypical language function: children with specific language impairment (SLI) and adults with Broca's aphasia.

2.2.1 Specific Language Impairment

SLI is a relatively common developmental language impairment estimated to affect about seven percent of kindergarten children in the U.S. (Tomblin et al., 1997). Children with SLI demonstrate significant impairments in language skills that cannot be accounted for by a frank neurological or sensory impairment, or by a more pervasive developmental delay. Children with SLI have difficulty understanding and producing syntactically complex sentences; these sentence types are often in non-canonical word order, containing displaced constituents and long-distance

dependencies. Specifically, children with SLI have difficulty resolving proform-antecedent dependencies (van der Lely & Stollwerck, 1997); greater difficulty with object-extracted questions and relative clauses than subject-extracted (Deevy & Leonard, 2004; Marinis & van der Lely, 2007; Novogrodsky & Friedmann, 2006; Hestvik, Schwartz & Tornyova, 2010); and greater difficulty understanding *which* than *who* questions (Friedmann and Novogrodsky, 2011). While the precise language deficits in SLI have been studied extensively, the etiology of these impairments is less well understood. Research to date suggests a genetic basis for the disorder (Lewis & Thompson, 1992, Bishop, North & Donlan; 1995, Bishop, 2002; 2006) in addition to atypical functional lateralization for language (Weismer, Plante, Jones & Tomblin, 2005, de Guibert et al., 2011, Badcock, Bishop, Hardiman, Barry & Watkins, 2012, Hugdahl et al., 2004; Whitehouse & Bishop; 2008).

Despite the absence of frank neurological damage, the language profiles of children with SLI have been compared to those of adults with Broca's aphasia (Friedmann, Biran & Dotan, 2013; Bastiaanse & Bol, 2001; Watkins, Dronkers & Vargha-Khadem, 2002). The similarity of the language difficulties in both groups is underscored by the use of the term *congenital aphasia* to describe SLI as early as the turn of 20th century and continuing into the 1960s (Town, 1911; Landau, Goldstein & Kleffner, 1960; Benton; 1964).

2.2.2 Broca's Aphasia

Unlike SLI, the cause of language difficulty in individuals with Broca's aphasia is better understood. Broca's aphasia most often results from damage to the inferior frontal cortex of the left hemisphere (i.e., Broca's area) because of a stroke or

neural trauma. Broca's aphasia is typically characterized by non-fluent, agrammatic speech production and comprehension difficulty in a variety of sentence types. Like children with SLI, individuals with Broca's aphasia have difficulty understanding sentences containing displaced constituents and long-distance dependencies such as proform-antecedent dependencies (Grodzinsky et al., 1993; Love, Nicol, Swinney, Hickock & Zurif, 1998; Avrutin, Lubarsky & Greene, 1999; Edwards & Varlokosta, 2007; Choy & Thompson, 2010), as well as *Wh-* questions and object-extracted relative clauses (e.g. Grodzinsky, 1990; Caramazza & Zurif, 1976; Swinney & Zurif, 1995; Drai & Grodzinsky, 2006; Sheppard, Walenski, Love & Shapiro, 2015).

2.2.3 Theoretical Accounts of SLI and Broca's Aphasia

In addition to the similarity of language comprehension difficulties in these groups, theoretical accounts of SLI and Broca's aphasia also demonstrate some overlap. Many of the sentence constructions known to be problematic in these groups are examples of syntactic "movement" (i.e., *Wh-* questions and object-extracted relative clauses) where a sentence constituent is displaced from its underlying position, leaving behind an unpronounced *trace* (or *gap* in psycholinguistic terminology). In such cases, a dependency relation is formed between an overt sentence element (i.e., spoken) and a phonologically empty gap position. In contrast, sentences containing pronouns and reflexives are not examples of syntactic movement and require a dependency relation to be formed between two overt sentence elements, the proform and antecedent.

Some theoretical accounts of SLI and Broca's aphasia have pointed to a deficit in the representation of linguistic knowledge. Within Broca's aphasia, the Trace

Deletion Hypothesis (TDH; Grodzinsky, 1995) posits that traces are not represented and as a result, constructions that contain syntactic movement result in impaired comprehension. As pronoun-antecedent dependencies do not contain traces, they are not predicted to be a source of comprehension difficulty according to the TDH. Within SLI, the Computational Grammatical Complexity hypothesis (CGC; van der Lely, 2005) and its predecessor the Representational Deficit for Dependent Relations (RDDR; van der Lely, 1998) posit that the ability to compute dependency relations in syntactically complex sentences in impaired. As such, the CGC predicts that the comprehension of pronoun-antecedent dependencies *and* syntactic movement constructions are impaired in SLI. Based on inconsistencies across studies of proform-antecedent dependencies in SLI (poor performance in van der Lely & Stollwerck, 1997, compared to good performance in Friedmann & Novogrodsky, 2011), Friedmann and Novogrodsky (2011) argue that the deficit in SLI is limited to syntactic movement constructions.

In the following chapter, we present the theoretical framework that serves as the focus of the dissertation – the Intervener Hypothesis – and discuss its implications for the processing and comprehension of syntactic movement constructions and proform-antecedent dependencies in the atypical populations discussed above.

REFERENCES

Avrutin, S., Lubarsky, S., & Greene, J. (1999). Comprehension of contrastive stress by Broca's aphasics. *Brain and Language*, *70*(2), 163-186.

Badcock, N. A., Bishop, D. V., Hardiman, M. J., Barry, J. G., & Watkins, K. E. (2012). Co-localisation of abnormal brain structure and function in specific language impairment. *Brain and language*, *120*(3), 310-320.

Bastiaanse, R., & Bol, G. (2001). Verb inflection and verb diversity in three populations: Agrammatic speakers, normally developing children, and children with specific language impairment (SLI). *Brain and language*, *77*(3), 274-282.

Benton, A. L. (1964). Developmental aphasia and brain damage. *Cortex*,*1*(1), 40-52.

Bishop, D. V. M. (2002). The role of genes in the etiology of specific language impairment. *Journal of communication disorders*, *35*(4), 311-328.

Bishop, D. V. (2006). What causes specific language impairment in children?. *Current directions in psychological science*, *15*(5), 217-221.

Bishop, D. V., North, T., & Donlan, C. (1995). Genetic basis of specific language impairment: Evidence from a twin study. *Developmental Medicine & Child Neurology*, *37*(1), 56-71.

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and language*, *3*(4), 572-582.

Chomsky, N. (1981). Lectures on binding and government. *Dordrecht: Foris*.

Choy, J. J., & Thompson, C. K. (2010). Binding in agrammatic aphasia: Processing to comprehension. *Aphasiology*, *24*(5), 551-579.

de Guibert, C., Maumet, C., Jannin, P., Ferré, J.-C., Tréguier, C., Barillot, C., … Biraben, A. (2011). Abnormal functional lateralization and activity of language brain areas in typical specific language impairment (developmental dysphasia). *Brain: A Journal of Neurology*, *134*(10), 3044–58.

Deevy, P., & Leonard, L. B. (2004). The comprehension of wh-questions in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *47*(4), 802-815.

Drai, D., & Grodzinsky, Y. (2006). A new empirical angle on the variability debate: Quantitative neurosyntactic analyses of a large data set from Broca's Aphasia.

Brain and Language, 96, 117–128.

Edwards, S., & Varlokosta, S. (2007). Pronominal and anaphoric reference in agrammatism. *Journal of Neurolinguistics*, *20*(6), 423-444.

Friedmann, N., & Novogrodsky, R. (2011). Which questions are most difficult to understand?: The comprehension of Wh questions in three subtypes of SLI. *Lingua*, *121*(3), 367-382.

Friedmann, N., Biran, M., & Dotan, D. (2013). Lexical retrieval and its breakdown in aphasia and developmental language impairment. *The Cambridge handbook of biolinguistics*, 350-374.

Gordon, P. C., & Scearce, K. A. (1995). Pronominalization and discourse coherence, discourse structure and pronoun interpretation. *Memory & Cognition*, *23*(3), 313-323.

Grodzinsky, Y. (1990). Theoretical perspectives on language deficits. Cambridge, MA: The MIT Press.

Grodzinsky, Y. (1995). Trace deletion, θ-roles, and cognitive strategies. *Brain and language*, *51*(3), 469-497.

Grodzinsky Y, Wexler K, Chien YC, Marakovitz S, Solomon J. (1993) The breakdown of binding relations. *Brain and Language*, *45*(3): 396–422.

Hestvik, A., Schwartz, R. G., & Tornyova, L. (2010). Relative clause gap-filling in children with specific language impairment. *Journal of psycholinguistic research*, *39*(5), 443-456.

Hugdahl, K., Gundersen, H., Brekke, C., Thomsen, T., Rimol, L. M., Ersland, L., & Niemi, J. (2004). fMRI brain activation in a Finnish family with specific language impairment compared with a normal control group. *Journal of Speech, Language, and Hearing Research*, *47*(1), 162-172.

Landau, W. M., Goldstein, R., & Kleffner, F. R. (1960). Congenital aphasia A clinicopathologic study. *Neurology*, *10*(10), 915-915.

Levinson, S. C. (1987). Pragmatics and the grammar of anaphora: A partial pragmatic reduction of binding and control phenomena. *Journal of linguistics*, *23*(02), 379-434.

Lewis, B. A., & Thompson, L. A. (1992). A study of developmental speech and language disorders in twins. *Journal of Speech, Language, and Hearing Research*, *35*(5), 1086-1094.

Love, T., Nicol, J., Swinney, D., Hickok, G. and Zurif, E. (1998) The Nature of Aberrant Understanding and Processing of Pro-forms by Brain-Damaged Populations. Proceedings from the Academy of Aphasia Conference, Brain and Language.

Love, T., Walenski, M., & Swinney, D. (2009). Slowed speech input has a differential impact on on-line and off-line processing in children's comprehension of pronouns. *Journal of psycholinguistic research*, *38*(3), 285-304.

Marinis, T., & van der Lely, H. K. (2007). On-line processing of wh-questions in children with G-SLI and typically developing children. *International Journal of Language & Communication Disorders*, *42*(5), 557-582.

McKee, C., Nicol, J., & McDaniel, D. (1993). Children's application of binding during sentence processing. *Language and Cognitive Processes*, *8*(3), 265-290.

Nicol, J. L. (1988). *Coreference processing during sentence comprehension.* PhD Thesis. Massachusetts Institute of Technology, Dept. of Brain and Cognitive Sciences.

Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of psycholinguistic research*, *18*(1), 5-19.

Novogrodsky, R., & Friedmann, N. (2006). The production of relative clauses in syntactic SLI: A window to the nature of the impairment. *Advances in Speech Language Pathology*, *8*(4), 364-375.

Reinhart, T. 1976. The syntactic domain of anaphora. Doctoral dissertation, Massachusetts Institute of Technology.

Reuland, E. (2001). Primitives of binding. *Linguistic inquiry*, *32*(3), 439-492.

Roberts, L., Marinis, T., Felser, C., & Clahsen, H. (2007). Antecedent priming at trace positions in children's sentence processing. *Journal of Psycholinguistic Research*, *36*(2), 175-188.

Sekerina, I. A., Stromswold, K., & Hestvik, A. (2004). How do adults and children process referentially ambiguous pronouns? *Journal of child language*, *31*(1), 123-152.

Sheppard, S. M., Walenski, M., Love, T., & Shapiro, L. P. (2015). The auditory comprehension of Wh-questions in aphasia: support for the intervener

hypothesis. *Journal of Speech, Language, and Hearing Research*, *58*(3), 781-797.

Swinney, D., & Zurif, E. (1995). Syntactic processing in aphasia. *Brain and Language*, *50*(2), 225-239.

Tomblin, J. B., Records, N. L., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research*, *40*(6), 1245-1260.

Town, C. H. (1911). Congenital aphasia. *The Psychological Clinic*, *5*(6).

Van der Lely, H. K. (1998). SLI in children: Movement, economy, and deficits in the computational-syntactic system. *Language acquisition*, *7*(2-4), 161-192.

Van der Lely, H. K. (2005). Domain-specific cognitive systems: insight from Grammatical-SLI. *Trends in cognitive sciences*, *9*(2), 53-59.

Van der Lely, H. K., & Stollwerck, L. (1997). Binding theory and grammatical specific language impairment in children. *Cognition*, *62*(3), 245-290.

Watkins, K. E., Dronkers, N. F., & Vargha-Khadem, F. (2002). Behavioural analysis of an inherited speech and language disorder: comparison with acquired aphasia. *Brain*, *125*(3), 452-464.

Weismer, S. E., Plante, E., Jones, M., & Tomblin, J. B. (2005). A functional magnetic resonance imaging investigation of verbal working memory in adolescents with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *48*(2), 405-425.

Whitehouse, A. J., & Bishop, D. V. (2008). Cerebral dominance for language function in adults with specific language impairment or autism. *Brain*, *131*(12), 3193-320

CHAPTER 3:

Interference in Verbal Working Memory

3.1 Introduction

The purpose of this chapter is to consider how demands on verbal working memory impact sentence processing. Because spoken language unfolds across time, sentence processing hinges on listeners' ability to hold components of the speech stream in working memory. For example, in sentences that contain long-distance dependencies, a listener must hold one sentence element in memory to link a subsequent element to it (i.e., proform-antecedent dependencies, filler-gap dependencies). Over the past 15 years, a variety of evidence has been amassed that points to interference within verbal working memory as a source of increased processing difficulty. This chapter details psycholinguistic evidence of similarity-based interference during sentence processing in unimpaired subject populations and presents a recent account – the Intervener Hypothesis – that proposes how similarity-based interference leads to increased processing difficulty and comprehension deficits in language impaired populations.

3.2 Similarity-Based Interference

Research within the area of similarity-based interference provides a framework for understanding why some sentences are more difficult than others. Bever (1974) noted that some doubly-center embedded sentences are nearly impossible to understand but others are a bit more intelligible. Consider:

(1) The reporter the politician the commentator met trusts said the president won't resign.

(2) The reporter everyone I met trusts said the president won't resign.

Bever's intuition was that (2) is easier to understand because the noun phrases (NPs) are of different lexical types compared to the NPs in (1). Following this observation, Gordon and colleagues (2001, 2002, 2004) conducted a series of studies to investigate how various types of noun phrases effect sentence processing and comprehension. For example, in an eyetracking-while-reading study, Gordon, Hendrick and Johnson (2001, 2004) compared reading times and comprehension accuracy of subject- (3) and object-extracted (4) relative clauses; subject-extracted retain canonical (subject-verb-object) word order while object-extracted have non-canonical order, such as:

(3) The banker that praised [the barber / a barber / Joe / you / everyone] climbed the mountain.

(4) The banker that [the barber / a barber / Joe / you / everyone] praised climbed the mountain.

Results reflected that the traditional processing advantage for subject-extracted over object-extracted relative clauses was significantly reduced or eliminated when the second NP in the object-extracted conditions was of a different type than the first. In an extension of this work, also using an eyetracking-while-reading method, Gordon Hendrick and Levine (2002) used a memory load paradigm where participants were required to remember a list of three NPs and measured reading times and comprehension accuracy of subject- and object-cleft sentences such as:

(5) *Memory load – match:* Joel-Greg-Andy

Sentence: It was Tony that [liked Joey / Joey liked] before the argument began.

(6) *Memory load – mismatch*: Joel-Greg-Andy

Sentence: It was the dancer that [liked the fireman / the fireman liked] before the argument began.

Results reflected lower comprehension accuracy and longer reading times for conditions where the type of NPs stored in memory were the same type as the sentence NPs (5) compared to mismatch conditions (6). The authors suggest that similarity-based interference occurs when NPs are of the same type (or *referential class*) and attribute improved performance to a reduction in similarity-based interference.

Related work in this area attempts to pinpoint the component of verbal working memory that is susceptible to similarity-based interference. Specifically, Van Dyke and colleagues (Van Dyke & Lewis, 2003; Van Dyke & McElree, 2006) suggest that similarity-based interference occurs during retrieval, rather than encoding phases. For example, Van Dyke and Lewis (2003) compared reading times during critical regions using an eyetracking-while-reading method in sentences such as:

(7) The worker was surprised that the resident who was living near the dangerous warehouse was complaining about the investigation.

(8) The worker was surprised that the resident who said that the warehouse was dangerous was complaining about the investigation.

In both sentences, a long-distance dependency is formed between the NP *the resident* when the verb phrase *was complaining* is encountered, and an NP of the same structural type, *the warehouse,* intervenes between the two. However, in (7) the intervening NP *the warehouse* is the grammatical object of the subject NP *the resident* but a grammatical subject in (8). In both sentences, the critical region for retrieval is the verb phrase *was complaining.* Results reflect increased reading times during the critical region for (8) compared to (7). The authors suggest that similarity-based interference occurs during retrieval, when an intervening NP matches the retrieval cues of the target element. The implications of this work are important for studies that use methods with fine-grained temporal resolution, such as eyetracking-while-listening and the potential for distinguishing between retrieval and encoding phases of verbal working memory. Taken together, the studies reviewed here reflect increased difficulty when sentences contain NPs of similar structure and that this difficulty appears to result from similarity-based interference that occurs during retrieval in verbal working memory. Additionally, these studies draw on data from unimpaired adult subjects and as such, do not speak to the potential role of similarity-based interference in the context of language impairments.

3.3 The Intervener Hypothesis

A recent theoretical account – the Intervener Hypothesis (IH) – posits that the sentence comprehension deficits that are a hallmark of individuals with Broca's

aphasia also result from similarity-based interference. As discussed in the previous chapter, the sentence comprehension deficits of individuals with Broca's aphasia and children with specific language impairment (SLI) demonstrate overlap. Prior studies examining the IH in language-impaired populations are described in detail in Chapters 4 (children with SLI) and 5 (individuals with Broca's aphasia) and are presented briefly below as an introduction to the issues.

Support for the IH in individuals with Broca's aphasia comes from Sheppard, Walenski, Love and Shapiro's (2015) study of *Wh*-questions. Using an eyetracking-while-listening method, Sheppard et al. (2015) found that individuals with Broca's aphasia demonstrated increased processing and comprehension difficulty in object-extracted *Which*- compared to *Who*- questions such as:

(9) Who did the fireman push ____ yesterday afternoon?

(10) Which mailman did the fireman push ____ yesterday afternoon?

The authors suggest that when an NP of similar structure intervenes between two elements of a dependency chain as in (10) but not (9), the intervening NP is considered as a possible element in the dependency chain and interferes with computing the dependency relation between the displaced *Wh*- phrase and its gap. A similar pattern of results comes from Friedmann and Novogrodsky (2011), where children with SLI performed similarly to individuals with Broca's aphasia in Sheppard et al. (2015) in a sentence-picture matching task.

Additional support for the IH in individuals with Broca's aphasia comes from Sullivan, Walenski, Love and Shapiro's (2016) study of unaccusative verbs. Using a sentence-picture matching task, Sullivan et al. (2016) found poor comprehension when sentences contained an intervening NP of similar structure between two elements of a dependency chain as in (11) compared to (12) below:

(11) The girl that observed **the boy** disappeared ____ into the trees.

(12) The girl observed that the boy disappeared ____ into the trees.

Note that in (12), no NP occurs between the single argument of the unaccusative verb, *the boy*, and its underlying position that occurs after the verb. However, in the subject-extracted relative clause (11), an NP of the same structural type as the displaced constituent (*the girl*) occurs between the two elements of the dependency chain yielding a similarity-based interference effect.

The studies included in this dissertation are the first to examine the IH in sentences containing pronouns and reflexives using a method that is sensitive to real-time sentence processing in children with specific language impairment and adults with Broca's aphasia. As discussed in the previous chapter, existing theoretical accounts of language impairments in these groups predict that constructions that are examples of syntactic movement are impaired, but that proform-antecedent linking, an example of long-distance dependencies that do not involve syntactic movement, are spared (for Broca's aphasia see: Grodzinksy, 1995; for SLI see: Friedmann & Novogrodsky, 2011). In contrast, the IH predicts that sentences containing pronouns

and reflexives that meet the criteria for similarity-based interference will result in increased processing and comprehension difficulty. The studies reported in Chapters 4 and 5 present sentences containing pronouns and reflexives, as in, for example:

(13) *The lion* saw that **the monkey** splashed *him*.

(14) The lion saw that *the monkey* splashed *himself*.

Sentences (13) and (14) use complement phrase constructions, where the pronoun *him* in (13) refers to the non-local NP *the lion* and the reflexive *himself* in (14) refers to the local NP *the monkey.* Critical to the predictions of the IH, in (13), a noun phrase of the same structural type (i.e., DET N; in boldface) intervenes between the pronoun and antecedent. Yet, by inserting pronouns and reflexives in subject relative constructions, we are able to reverse the relationship between the type of proform and the presence of an intervener, consider:

(15) The monkey that chased *the lion* splashed *him*.

(16) *The monkey* that chased **the lion** splashed *himself*.

In subject relative constructions, the pronoun *him* in (15) is near to its antecedent *the lion* and no NP linearly intervenes between the pronoun and antecedent. In contrast, the reflexive *himself* in (16) is far from its antecedent *the monkey* and a noun phrase of the same structural type intervenes between the reflexive and antecedent.

Note that the descriptions above characterize interveners in terms of linear

distance, where (13) and (16) contain an intervener and (14) and (15) do not. Yet when we characterize these sentence types in terms of syntactic structure a different characterization emerges. The syntactic structures of sentences (13-16) and their implications for the IH are discussed in detail in Chapters 4 and 5. However, to provide an introduction, in the reflexive conditions (14) and (16), the reflexive is structurally close to its antecedent. In contrast, in the complement phrase pronoun condition (13) the pronoun is deeply embedded in the overall structure of the sentence while in the subject relative pronoun condition (15) the antecedent *the lion* is deeply embedded. Critically then, both pronoun conditions contain an NP that structurally intervenes between the pronoun and antecedent. The difference in structural distance between sentence types is described in more detail in the introduction to Chapter 4.

The manipulation of sentence structure, proform type and presence of an intervening NP as in (13-16) provides a mechanism for evaluating the IH in terms of both linear and structural distance. If individuals with language impairments are subject to similarity-based interference in proform-antecedent constructions as outlined by the IH, the processing and comprehension patterns of sentences that contain interveners should demonstrate greater difficulty compared to non-intervener constructions. If similarity-based interference in these groups is best characterized in terms of linear distance, the IH predicts increased processing difficulty when a proform and antecedent are linearly far as in (13) and (16) and contain an intervening NP of similar structure. If on the other hand, similarity-based interference is better characterized in terms of structural distance, the IH predicts increased processing difficulty when a proform and antecedent are structurally far (as in 13 and 15) and

contain an intervening NP of similar structure.

GOALS OF THE DISSERTATION

This dissertation investigates how listeners extract meaning from personal and reflexive pronouns in spoken language. To be understood, words like *her* and *herself* must be linked to a prior element in the speech stream. This process draws on grammatical and syntactic knowledge in addition to verbal working memory. In service of this goal, I present original research investigating how unimpaired listeners process and understand proforms at different developmental stages. Chapter 4 presents data from children with typical language development and Chapter 5 from unimpaired adult participants.

In addition, this dissertation investigates how individuals with language impairments process and understand proforms. I present data from two populations with language impairments: children with a developmental language impairment (specific language impairment) and adults with an acquired language impairment (agrammatic Broca's aphasia). Although the etiology of language impairments differs in these groups, children with SLI and adults with Broca's aphasia share many of the same language difficulties. As such, I evaluate the potential of a single theoretical framework which points to similarity-based interference as the source of processing and comprehension difficulty, to account for the patterns observed in each group.

This dissertation also endeavors to understand the extent to which processing and comprehension patterns overlap. Sentence processing is investigated using an eyetracking-while-listening paradigm. This method provides a fine-grained temporal scale to evaluate how proform-antecedent dependencies are formed on a moment-to-

moment basis. Eyetracking-while-listening also has the advantage of being suitable for child populations and language-impaired populations as it requires participants only to listen to sentences and look at pictures without the need for a secondary task. This method also provides a rich data set, with 60 observations collected each second, and lends itself to a variety of statistical analysis methods. Throughout the dissertation I refer to methods that are sensitive to real-time processing as *online* or *processing* measures. Sentence comprehension is investigated using a sentence-picture matching task, a method that is also suitable for child and language impaired populations. In contrast to eyetracking-while-listening, sentence-picture matching provides an index of final interpretive comprehension, where participants can consciously reflect on the sentences heard and draw on a variety of linguistic knowledge including discourse and pragmatics. Throughout the dissertation I refer to methods that capture final interpretation as *offline* or *comprehension* measures.

REFERENCES

Bever, T. G. (1974). The ascent of the specious, or there's a lot we don't know about mirrors. In D. Cohen (Ed.), *Explaining linguistic phenomena* (pp. 173-200). Washington, DC: Hemisphere.

Gordon, P.C., Hendrick, R., Johnson, M. (2001). Memory interference during language processing. *Journal of Experimental Psychology: Learning, Memory and Cognition*; 27:1411–1423.

Gordon, P.C., Hendrick R., Johnson M. (2004) Effects of noun phrase type on sentence complexity. *Journal of Memory and Language*; 51: 97–114.

Gordon P.C., Hendrick R., Levine W.H. (2002). Memory-load interference in syntactic processing. *Psychological Science*;13: 425–430.

Sheppard, S. M., Walenski, M., Love, T., & Shapiro, L.P. (2015). The Auditory Comprehension of Wh-Questions in Aphasia: Support for the Intervener Hypothesis. *Journal of Speech, Language, and Hearing Research*, 1-17.

Sullivan, N., Walenski, M., Love, T., Shapiro, L.P. (2016): The comprehension of sentences with unaccusative verbs in aphasia: a test of the intervener hypothesis, *Aphasiology*, 1-15.

Friedmann, N., & Novogrodsky, R. (2011). Which questions are most difficult to understand?: The comprehension of Wh questions in three subtypes of SLI. *Lingua*, *121*(3), 367-382.

Van Dyke, J. A., & Lewis, R. L. (2003). Distinguishing effects of structure and decay on attachment and repair: A cue-based parsing account of recovery from misanalyzed ambiguities. *Journal of Memory and Language*, *49*(3), 285-316.

Van Dyke, J. A., & McElree, B. (2006). Retrieval interference in sentence comprehension. *Journal of Memory and Language*, *55*(2), 157-166.

CHAPTER 4:

Proform-Antecedent Linking in Children with Typical Language Development and Children with Specific Language Impairment

Proform-Antecedent Linking in Children with Typical Language Development and Children with Specific Language Impairment

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ABSTRACT

Purpose: To evaluate processing and comprehension of pronouns and reflexives (i.e., proforms) in children with specific language impairment and children with typical language development and the extent to which online processing overlaps with offline comprehension. We evaluate processing and comprehension patterns in terms of a specific hypothesis – the Intervener Hypothesis – that posits that similarity-based interference caused by the presence of an intervening NP between two elements of a dependency chain creates increased processing demands.

Methods: We used an eyetracking-while-listening paradigm to investigate real-time processing (Experiment 1) and a sentence-picture matching task to investigate final comprehension (Experiment 2) of sentences containing proforms in complement phrase and subject relative constructions.

Results: Children with typical language development demonstrate sensitivity to linear distance between proforms and antecedents, with younger children demonstrating greater difficulty in processing subject relative constructions and offline comprehension. Children with specific language impairment demonstrate increased processing difficulty in sentences containing pronouns relative to reflexives.

Conclusions: These results provide support for the Intervener Hypothesis, where children with specific language impairment show greater processing difficulty when sentences contain a noun phrase that structurally intervenes between a proform and antecedent. This study is the first to test the Intervener Hypothesis in children with a developmental language disorder, previous support for which comes from studies of adults with an acquired language disorder, agrammatic Broca's aphasia.

Keywords: *Specific Language Impairment; Sentence Processing; Binding; Similarity-Based Interference*

4.1 INTRODUCTION

The purpose of the current paper is to investigate the processing and comprehension of sentences containing pronouns and reflexives in children with typical language development (Study 1) and children with specific language impairment (SLI; Study 2). Within each study, we evaluate how proform type (e.g., pronouns and reflexives) and distance from antecedent influence moment-to-moment processing and comprehension using an eyetracking-while-listening paradigm (Studies 1 and 2, Experiment 1) and sentence-picture matching task (Studies 1 and 2, Experiment 2). The focus of the current paper is on a particular theoretical account, the Intervener Hypothesis (Sheppard, Walenski, Love & Shapiro, 2015; Sullivan, Walenski, Love & Shapiro, 2016), which posits that sentence processing is negatively impacted when a sentence element of similar structure intervenes between two elements of a dependency chain. This account, rooted in psycholinguistic evidence of similarity-based interference in unimpaired adult language processing (e.g., Gordon, Hendrick & Johnson, 2004; Gordon, Hendrick, Johnson & Lee, 2006), has yet to be tested in children with and without specific language impairment.

The goals of the current paper are: 1) to investigate the processing and comprehension of pronouns and reflexives at short and long distances from antecedents; 2) to evaluate the extent to which online (real time) and offline (final interpretation) behavior overlaps; 3) to compare patterns of children with typical language development and children with specific language impairment and 4) to evaluate how the predictions of the Intervener Hypothesis account for patterns observed in each group. We begin with a review of proform-antecedent linking in

typically developing children and children with specific language impairment. We then detail the Intervener Hypothesis and review related findings. Study 1 presents findings from a group of children with typical language development and Study 2 presents findings from children with specific language impairment.

4.1.1 Binding constraints

Within sentence processing and comprehension, pronouns and reflexives such as *him* and *himself* are examples of referential dependencies. Unlike referential expressions like *the mailman* or *John,* that uniquely identify an entity within a sentence (or larger discourse), proforms must be linked to a referential expression in order to be meaningfully understood. Within the Government and Binding framework (Chomsky, 1981), the manner in which pronouns and reflexives are bound to a referring expression (i.e., antecedent) is constrained by binding principles A and B; principle A states that a reflexive must be bound within its local domain and principle B states that a pronoun cannot be bound within its local domain:

(1) Janet_a says that [Susan_b drove $\text{herself}_{a*/b}$]

(2) Janet_a says that [Susan_b drove $\text{her}_{a/b*}$]

Based on Principle A, the reflexive *herself* in (1) must co-refer with the noun phrase within its local domain, *Susan,* and cannot co-refer to the noun-phrase outside of it, *Janet* (denoted by *). Based on Principle B the pronoun *her* in (2) cannot be co-indexed with *Susan* because the two share a local domain but can be co-indexed with the non-local noun phrase *Janet*.

4.1.2 Proform-antecedent linking in children with typical language development

Research in child language acquisition has demonstrated an asymmetry in children's understanding of pronouns and reflexives. Converging evidence across studies reflects that children's comprehension of reflexives mirrors adult performance by age 4 (Chien & Wexler, 1990; Grodzinsky & Reinhart, 1993; McKee, 1992). However, children continue to make errors in their interpretation of pronouns until around age 7 (Chien & Wexler, 1990; Grodzinsky & Reinhart, 1993; McKee, 1992; van der Lely and Stollwerck, 1997; Friedmann, Novogrodsky & Balaban, 2010). This developmental pattern is termed the Delay of Principle B Effect (DPBE) and reflects that by age 4, children have little difficulty correctly identifying *Susan* as the antecedent of the reflexive in (1) but have greater difficulty correctly identifying *Janet* in (2) and incorrectly interpret *Susan* as the antecedent of the pronoun, thereby permitting the reflexive reading of the pronoun.

In contrast to the comprehension difficulty evinced in comprehension studies, studies examining online processing provide evidence that children as young as age 4 are sensitive to the binding constraints that govern proform-antecedent linking (McKee, Nicol & McDaniel, 1993; Love, Walenski & Swinney, 2009). In a cross-modal picture priming task[1], McKee, Nicol and McDaniel (1993) tested 4-6 year old children using sentences such as:

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[1] In the cross-modal picture priming studies described here, participants listen to auditory sentences as pictures appear on screen at critical points in the sentence. Participants are required to make a timed animacy judgment (i.e. *is it alive?*) about a picture that is either related or unrelated to the sentence element of interest. The difference in response times between related and unrelated trials is used to index reactivation of the sentence element of interest. This approach is termed an *online* or *real time* task

(3) The alligator$_a$ knows that the leopard$_b$ with green eyes is patting himself$_{a*/b}$ on the head with a soft pillow.

(4) The alligator$_a$ knows that the leopard$_b$ with green eyes is patting him$_{a/b*}$ on the head with a soft pillow.

Children demonstrated a priming effect of the local antecedent (*the leopard*) in the reflexive condition (3) but not in the pronoun condition (4). Using the same materials, Love, Walenski and Swinney (2009) tested children ages 5-13 for priming of the non-local antecedent (*the alligator*) and found significant priming of the non-local antecedent in the pronoun condition (4). These and other online studies (Sekerina, Stromswold & Hestvik, 2004; Roberts, Marinis, Felser & Clahsen, 2007) reflect that children as young as age 4 show immediate linking of pronouns and reflexives to their grammatically appropriate antecedents, a profile that mirrors that of adults. Furthermore, these studies provide evidence that online processing captures competencies that are not reflected in offline comprehension measures.

4.1.3 Proform-antecedent linking in children with specific language impairment

Children with SLI have difficulty understanding and producing syntactically complex sentences. These sentence types often have non-canonical word order, and contain displaced constituents and long-distance dependencies. Specifically, children with SLI have difficulty resolving anaphoric relationships in sentences with pronouns and reflexives (van der Lely & Stollwerck, 1997); greater difficulty with object-extracted questions and relative clauses than subject-extracted (for questions see:

Deevy & Leonard, 2004; Friedmann & Novogrodsky, 2011; Marinis & van der Lely, 2007; for relative clauses see: Novogrodsky & Friedmann, 2006; Hestvik, Schwartz & Tornyova, 2010); and greater difficulty understanding *Which* than *Who* questions (Friedmann & Novogrodsky, 2011).

Friedmann and Novogrodsky (2011) tested comprehension of pronouns and reflexives in Hebrew speaking children with SLI ages 9-13 using a sentence-picture matching task. Participants were asked to choose between two pictures, one depicting the transitive action (*boy-wash-penguin*) and the other depicting the reflexive action (*boy-wash-boy*). Participants with SLI demonstrated good comprehension of both proforms and performance did not differ from control participants. These results conflict with the findings of an offline study conducted by van der Lely and Stollwerck (1997) that tested comprehension of pronouns and reflexives in children with SLI ages 9-12. In this study, participants were presented with a single picture and asked whether the picture matched the sentence. Children in the SLI group made significantly more errors than language-matched controls for both types of proforms when the sentences required them to only use syntactic knowledge without the help of lexical or semantic information (e.g., gender, quantifier, reflexivity). In an online cross-modal picture priming study, Hestvik et al. (2007) found that children with SLI were slower to reactivate the correct antecedent for pronouns than reflexives, and slower overall than the control group. A common thread from the studies described here is the suggestion that children with SLI have a deficit at the level of syntactic relationships, but may be able to resolve proform antecedent dependencies based on lexical-semantic knowledge.

4.1.4 The Intervener Hypothesis

The focus of the current paper is on a recent account of the sentence comprehension and processing deficits in adults with an acquired language disorder, agrammatic Broca's aphasia (Sheppard et al., 2015; Sullivan et al., 2016). Notably, many of the sentence constructions that are known to be problematic in individuals with Broca's aphasia are also problematic for children with SLI (e.g., *Wh*-questions, object-extracted relative clauses and pronoun-antecedent linking). The Intervener Hypothesis (IH) takes psycholinguistic evidence of similarity-based interference in unimpaired adult populations as its starting point. This work proposes an explanation for why some sentence types are harder to understand than others and points to interference within verbal working memory, rather than decay, as the source of processing difficulty (Gordon et al., 2004, 2006; Van Dyke, 2007; Van Dyke & McElree, 2006; Gibson, 2000; Lewis, 1996; Lewis & Vasishth, 2005). Specifically, complex sentences are more difficult to process when they contain multiple sentence elements (i.e., noun phrases) of the same structural type compared to multiple sentence elements that differ in structural type. Using an eyetracking-while-reading paradigm, Gordon et al. (2004, 2006) found increased reading times of sentences containing displaced constituents when two noun phrases had the same structure (i.e., DET N) relative to when the NP that intervened between elements of the dependency chain was a proper name or pronoun.

The IH proposes that the comprehension deficits that are a hallmark of Broca's aphasia can be explained via similarity-based interference during sentence processing. In an eyetracking-while-listening study, Sheppard et al. (2015) presented *who* and

which questions in subject- and object- extracted constructions:

Two mailmen and a fireman got into a fight yesterday afternoon.

(5) Who pushed the fireman yesterday afternoon?

(6) Who did the fireman push ____ yesterday afternoon?

(7) Which mailman pushed the fireman yesterday afternoon?

(8) Which mailman did the fireman push ____ yesterday afternoon?

In (8) the direct-object noun phrase (NP), *which mailman*, has been displaced from its underlying position occurring after the verb *push* to the beginning of the sentence, leaving behind a 'gap' (in psycholinguistic terminology). Note that the displaced NP, *which mailman*, crosses over an intervening argument position occupied by the subject NP, *the fireman*. The intuition here is that the intervening NP is considered as a possible element in the dependency chain and interferes with computing the dependency relation between the displaced *Wh*-phrase and its gap. Critically, according to the IH, only in cases where the NPs in the sentence are similarly structured (i.e., DET N) will interference among the NPs occur. Thus, only (8) contains such a structure, since in (5) and (6), the displaced *Wh*-phrase (*who*) is a bare operator and thus has a distinct structure from the intervening NP (*the fireman*), and (7) is a subject-extracted *Wh*-question and thus does not meet the structural description for an intervener. In line with the predictions made by the IH, the performance of individuals with Broca's aphasia in Sheppard et al. (2015) revealed chance accuracy and significantly more gazes to the incorrect referent compared to the correct referent for object-extracted *Which*-questions only (8). Additional support for the IH in individuals with Broca's aphasia comes from a study of unaccusative verbs (Sullivan

et al., 2016).

Few studies have directly investigated similarity-based interference in children with SLI. However, the findings from a handful of studies suggest that children with SLI are susceptible to interference effects. Marton and Schwartz (2003) compared children with SLI to age matched peers using tasks that combined non-word repetition and sentence comprehension tasks. While it was not the focus of the study, the authors note that performance of the SLI group in a listening span task was characterized by interference errors: children repeated words that were in the sentence but were not the sentence-final word or repeated sentence-final words from previous items. This work suggests that children with SLI may have greater difficulty inhibiting irrelevant information and are more susceptible to proactive interference in verbal working memory tasks than typically developing peers (Marton, Kelmenson & Pinkhasova, 2007; Marton, Campanelli, Eichorn, Scheur & Yoon, 2014).

Friedmann and Novogrodsky (2011) tested the IH in a study of children with SLI ages 9-13. The authors tested offline comprehension of *Wh*-questions in subject- and object- extracted constructions like those in (5-8) above. Results revealed a similar pattern as Sheppard et al. (2015): children performed well, that is comparable to a control group, on *Who*-subject, *Who*-object and *Which*-subject extracted questions but had significantly poorer comprehension of *Which*-object extracted questions. These results suggest that interference effects may play a role in the comprehension deficits in SLI.

As stated earlier in our goals, we aim to test the IH in children with specific language impairment using sentences containing pronouns and reflexives. On the

surface, sentences containing pronouns and reflexives appear dissimilar to the *Wh*-questions described above. In *Wh*-questions, dependency chains are formed between a displaced *Wh*-phrase and a covert sentence element (the unpronounced trace position), and as such *Wh*-questions are an example of syntactic displacement or movement. The same cannot be said for sentences containing proforms, where dependency chains are formed between two overt sentence elements and no underlying movement occurs. However, both are examples of sentences with dependency chains and can be manipulated via sentence structure to contain interveners as delineated by the IH. Consider:

(9) *The lion* saw that **the monkey** splashed *him*.

(10) The lion saw that *the monkey* splashed *himself*.

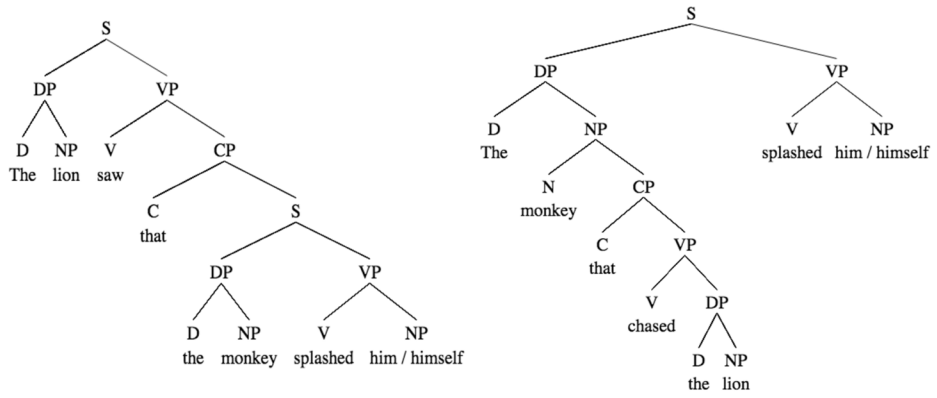
(11) The monkey that chased *the lion* splashed *him*.

(12) *The monkey* that chased **the lion** splashed *himself*.

Sentences (9) and (10) use complement phrase constructions, where the pronoun *him* in (9) refers to the non-local NP *the lion* and the reflexive *himself* in (10) refers to the local NP *the monkey.* Critical to the predictions of the IH, in (9), a noun phrase of the same structural type (i.e., DET N; in boldface) intervenes between the pronoun and antecedent. Sentences (11) and (12) use subject relative constructions where the pronoun *him* in (11) is near to its antecedent *the lion* with no linearly intervening noun phrase. The reflexive *himself* in (12) is far from its antecedent *the monkey* and a noun phrase of the same structural type intervenes between the two elements of the

dependency chain. Sentences (9) and (12) contain an NP that linearly intervenes between the proform and antecedent while sentences (10) and (11) do not.

However, when we examine the syntactic structure of sentences 9-12, a different characterization emerges. Figure 4-1 (below) displays the syntactic structure (simplified) of the complement phrases (9, 10; Figure 4-1A) and subject relatives (11, 12; Figure 4-1B) presented above.



A. Complement Phrase B. Subject Relative

Figure 4-1. Syntactic structure of complement phrase and subject relative sentences

The complement phrase constructions (Figure 4-1A) demonstrate a direct correspondence between linear and structural distance. By this we mean that the reflexive finds its antecedent within the local sentential clause (*the monkey splashed himself)* and the reflexive is linearly close to the antecedent. In contrast, the pronoun *him* is deeply embedded in the overall structure of the sentence and finds its antecedent *the lion* in the specifier position of the overall sentence (i.e., the subject of the first determiner phrase). In subject relative constructions (Figure 4-1B), the

reflexive is positioned within the verb phrase (*splashed himself)* and its antecedent *the monkey* is in the specifier position of the adjacent determiner phrase. In comparison, the antecedent of the pronoun, *the lion,* is deeply embedded in the overall structure of the sentence. When we compare pronoun conditions between sentence structures, we see that in one case (4-1A) the pronoun is deeply embedded and in the other (4-1B), the antecedent is deeply embedded. In contrast, there is no distinction between level of embeddedness of the reflexive or its antecedent across structures. In both constructions, the reflexive is positioned within the verb phrase *splashed himself*, and finds its antecedent *the monkey* in the adjacent determiner phrase. Critically then, both pronoun conditions contain an NP that structurally intervenes between the pronoun and antecedent.

These sentences are examples of dependency chains between overt sentence elements while previous work has investigated filler-gap dependencies in constructions that contain syntactic movement (*Wh*-questions, Sheppard et al., 2015; unaccusative verbs, Sullivan et al., 2016). Friedmann, Novogrodsky and Balaban (2010) tested the IH in a group of typically developing children ages 2-6 using complement phrase and subject relative sentences containing pronouns and reflexives like those in (9-12). The authors used a sentence-picture matching task to measure final comprehension and found that children made more errors in pronoun conditions when the sentence contained an intervener (9) compared to conditions without an intervener (11) but that performance did not differ for reflexive conditions with and without an intervener. The results are consistent with previous studies that report children younger than age 7 incorrectly interpret pronouns in complement phrase

constructions (consistent with DPBE). Additionally, comprehension of reflexives does not differ when a noun phrase linearly intervenes between the proform and antecedent. The IH has yet to be investigated in typically developing children older than age 6 (who are developmentally past the predicted age for errors consistent with DPBE) using methods that are sensitive to online processing and offline comprehension. Furthermore, the IH has yet to be tested in proform-antecedent constructions in children with specific language impairment. As such, the current paper presents an opportunity to 1) refine the Intervener Hypothesis by distinguishing between linear and structural distance in proform-antecedent dependencies and 2) extend the theoretical framework to a developmental language disorder.

Returning to the goals of the current paper, we aim to evaluate the online processing and offline comprehension of sentences containing pronouns and reflexives. We do so in two populations, children with typical language development and children with specific language impairment. We present findings from children with typical language development first (Study 1) to serve as a basis for comparison to children with specific language impairment (Study 2). We frame our study with respect to the Intervener Hypothesis, which predicts that the presence of an intervening NP results in increased processing difficulty and investigate the extent to which the hypothesized processing difficulty effects final comprehension.

4.2 Study 1: Proform-antecedent linking in children with typical language development

Study 1 presents data from children with typical language development. Experiment 1 uses an eyetracking-while-listening paradigm to investigate how

proform-antecedent dependencies are processed in real time. Experiment 2 uses a sentence-picture matching task to assess final comprehension.

4.2.1 Experiment 1: Online processing of proform-antecedent dependencies

4.2.1.1 Method

Participants

Nineteen children ranging in age from 6;8 to 13;7 (M=10;4; 8 boys, 11 girls) participated in the study. All participants were monolingual native English speakers with normal hearing and normal (or corrected-to-normal) vision and had no reported neurological impairment or social/emotional disorders (e.g., autism, attention deficit disorder). Participants received a battery of standardized measures in order to evaluate their language abilities and nonverbal intelligence. Language was assessed using the Clinical Evaluation of Language Fundamentals-IV (CELF-IV; Semel, Wiig & Secord, 2003), Test for Reception of Grammar (TROG-2; Bishop, 2003), and Children's Communication Checklist-2 (CCC-2; Bishop, 2003). Nonverbal intelligence was assessed using the Test of Nonverbal Intelligence (TONI-3; Brown, Sherbenou & Johnsen, 1997). All participants were within the normal range on the CELF-IV (core language index of 85 or above), the TROG-2 (standard score of 85 or above), the CCC-2 (General Communication Composite score of 80 or above) and the TONI-3 (standard score of 85 or above). Demographic information and assessment scores for TLD participants are presented below in Table 4-1.

Table 4-1. TLD Participants: Demographic information and assessment scores

N	19
Age	10;4 (2;7)
Age Range	6;8 – 13;7
Sex	8 M / 11 F
TONI-3	110.47 (16.67)
CELF-IV	110.63 (11.72)
TROG	107.26 (7.1)

Participants were recruited from schools in the San Diego Unified School District. Parents brought the children to our laboratory for 3-4 visits each lasting one hour or less. At each visit, language assessments were administered and children participated in the experimental tasks. After each visit, parents were compensated $5 for traveling expenses, and child participants were compensated $5 per visit and allowed to choose a prize.

Materials and Design

In this eyetracking-while-listening task, participants listened to auditory sentences arranged in two-sentence discourse sets while looking at a four-picture display. The first sentence established a felicitous context by introducing the characters and setting (e.g. "*A lion and a monkey were chasing each other with a bucket")* and the second sentence contained a proform in one of four experimental conditions (e.g. "*The lion saw that the monkey splashed himself with the cold water"*). As shown in Table 4-2, proforms (reflexives, personal pronouns) were inserted into two distinct sentence types, complement phrases and subject relatives. A 5-8 syllable

prepositional or adverbial phrase was added after the proform in order to collect eye-gaze data from the onset of the proform to the end of the sentence. All sentences were recorded by a female native speaker of English at an average rate of 4.69 syllables per second. An example discourse sentence and the four experimental sentence conditions (yielding a 2 X 2 design) are shown in Table 4-2.

Table 4-2. Example experimental sentence set

1.	*Discourse Sentence*		A lion and a monkey were chasing each other with a bucket	
	Clause Type	**Distance**	**Proform**	
1a.	Complement Phrase	Short	Reflexive	The lion saw that <u>the monkey</u> splashed <u>himself</u> with the cold water.
1b.	Complement Phrase	Long	Pronoun	<u>The lion</u> saw that **the monkey** splashed <u>him</u> with the cold water.
2.	*Discourse Sentence*		A monkey and a lion were chasing each other with a bucket.	
2a.	Subject Relative	Long	Reflexive	<u>The monkey</u> that chased **the lion** splashed <u>himself</u> with the cold water.
2b.	Subject Relative	Short	Pronoun	The monkey that chased <u>the lion</u> splashed <u>him</u> with the cold water.

Sentences (1a) and (1b) contain complement phrases headed by the complementizer *that*. Sentence (1a) contains a short distance reflexive, where *himself* refers to the local NP *the monkey*. Sentence (1b) contains a long distance pronoun where *him* refers to the non-local NP *the lion* and contains an intervening NP *the monkey* between the pronoun and its antecedent. Sentences (2a) and (2b) are subject relatives: (2a) contains a long distance reflexive where *himself* refers to the first NP *the monkey* and the second NP *the lion* intervenes between the reflexive and antecedent. Sentence (2b) contains a short distance pronoun where *him* refers to the second NP *the lion*.

The order of mention of the two NPs was counterbalanced across sentence types with the discourse sentence matching the order of mention in the experimental sentence. This manipulation resulted in 160 unique discourse sets, and 40 additional discourse sets were created as filler items to add variety and distract from the experimental manipulation. 30% of all trials (60 trials total) were followed by a simple yes/no question that probed comprehension of the discourse sentence and did not probe the proform-antecedent relation of the target sentence in order to maintain attention throughout the experiment (e.g., "*Was the monkey climbing a tree?"*). Half of the comprehension probes required a *yes* response and the other half required a *no.* For each discourse set, a four picture display was constructed that contained the two characters mentioned in the sentence and possible referents of the proform (e.g., *the lion, the monkey*), the inanimate NP mentioned at the end of the discourse sentence (*a bucket)*, and an unrelated inanimate NP (see Figure 4-2, below). Pictures were placed in the corner quadrants of the screen and were counterbalanced across positions. Discourse sets were counterbalanced across two presentation lists and were completed at two separate visits at least one week apart.

Procedure

Participants sat facing a Tobii X120 eyetracker and were positioned with their eyes at a distance of 60cm from the eyetracker. The eyetracker was calibrated at the beginning of each experimental session. Stimuli were presented with E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). As shown in Figure 4-2, each trial began with a 500ms fixation cross, followed by a 250ms blank screen. The four-picture display was presented for 1000ms before the discourse sentence began,

followed by a 250ms pause and the experimental sentence. The picture display remained onscreen for 500ms after the experimental sentence ended. For trials that contained a comprehension probe (30%), a question mark appeared onscreen for 500ms and then the comprehension probe played, followed by a 1750ms response period (see Figure 1). If a response was made before 1750ms the trial ended and the next trial began. Each session was divided into two fifteen-minute blocks with a break provided in between.

Participants completed a practice session of 10 trials to become familiar with the task and ask any questions. It also allowed the experimenter to ensure the child understood the task and provided an opportunity to reinstruct if needed. For all trials, gaze location was sampled at 60hz in each of the four quadrants and thus eye gaze location was recorded every 17ms throughout each trial. Participants responded to the comprehension probes using a response box with buttons labeled *YES* and *NO*. An example picture display, sentence set and timing parameters for a single trial are shown in Figure 4-2.

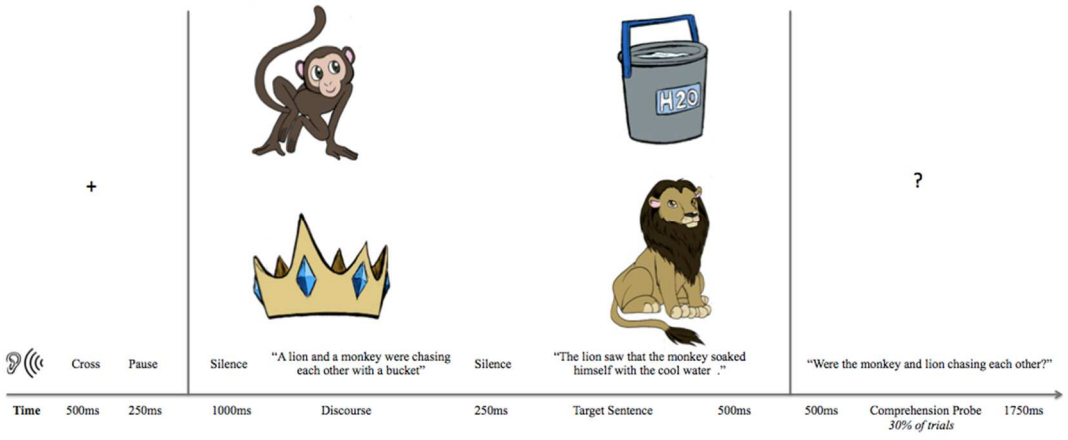


Figure 4-2. Example picture display and timing parameters for a single trial

4.2.1.2 Analysis and Results

We divide our analysis in three sections. We begin by reporting accuracy on the yes/no comprehension probe. We then report the proportion of gazes to the correct referent and the results of analyses of variance investigating the effect of distance and proform type. We follow this with an examination of the moment-to-moment time-course of gaze behavior by 1) examining gazes to both the correct and incorrect referent over time and 2) statistically evaluating gazes to the correct referent over time using growth curve analyses. Given the age range of our TLD participants, we evaluate the effect of age throughout our analyses by dividing the group into younger (ages 6-8; n=6) and older children (ages 9-13; n=12) to determine if performance differs across development.

Comprehension probe accuracy

30% of all trials included a yes/no comprehension question at the end of the trial. These questions did not probe the proform-antecedent relation and were included to ensure that participants were attending to the task. Mean comprehension accuracy for all probes was 80% (SD=0.13) for session 1 and 83% (SD=0.13) for session 2. Because no response was recorded if a child did not respond before 1750ms, we also calculated comprehension accuracy only for trials to which a response was made. Mean comprehension accuracy for trials where a response was made was 93% (SD=0.08) for session 1 and 95% (SD=0.05) for session 2.

Proportion of gazes to correct referent

To analyze gaze behavior, we defined four rectangular areas of interest (AOIs) of the same size around each of the pictures in the display. When data were available

from both eyes, gaze location was computed as their average. When gaze location was available from only one eye, gaze location was computed on that eye alone. When gaze location was not available from either eye, the sample was excluded from further analyses. Gaze samples that were outside any of the four AOIs were excluded from further analyses. A gaze was conservatively defined as six consecutive samples within the same AOI (a total of 102ms; see Manor & Gordon, 2003). Gazes that did not meet this criterion were excluded from further analyses. The resulting data set included looks to the four AOIs that lasted at least 102ms. Data from one participant was removed after initial screening of the data revealed that gazes to the discourse inanimate NP (e.g., *bucket* in (1) and (2) above) constituted nearly half of all gazes across conditions (49%). This pattern was not the case for any of the remaining 18 participants, for whom the majority of gazes corresponded to the two potential referents of the proform.

To determine overall accuracy of gaze data, we calculated for each subject and each item the proportion of gazes to the correct referent (time looking at the correct referent divided by time looking at the incorrect referent and two distractor pictures). The analysis window began at the onset of the proform and continued for 1000ms. The analysis window was shifted 200ms forward to account for delay in eye movements (Allopena, Magnuson & Tanenhaus, 1998). To avoid problems with analyzing raw proportions in linear models, proportions were transformed using the empirical logit transformation (see Jaeger, 2008). Raw proportions are reported within the text for ease of interpretation. Analyses were conducted using R version 3.3.1 (R Core Team,

2016), the *lme4* package (Bates, Maechler, Bolker & Walker, 2015), and the *eyetrackingR* package (Dink & Ferguson, 2016).

Proportion of gazes to the correct referent are presented in Table 4-3.

Table 4-3. Proportion of gazes to correct referent

	Pronouns	Reflexives	***Distance Mean***
Long Distance	0.353 (0.109)	0.406 (0.099)	**0.379 (0.106)**
Short Distance	0.327 (0.09)	0.462 (0.09)	**0.395 (0.112)**
Proform Mean	**0.341 (0.099)**	**0.434 (0.098)**	

To determine whether the proportion of gazes to the correct referent differed between conditions we conducted an analysis of variance with proportion of gazes to the correct referent as the dependent measure and distance (long, short), proform (pronoun, reflexive) and age group (6-8 years, 9-13 years) as within subjects factors. This yielded a main effect of **proform** ($F_{(1,2631)} = 42.67$, $p < 0.001$) and **age group** ($F_{(1,2631)} = 5.23$, $p = 0.02$) as well as an interaction between distance and proform ($F_{(1,2631)} = 6.85$, $p = 0.009$). The effect of **proform** reflects that gazes to the correct referent were higher in reflexive conditions compared to pronouns. The effect of **age group** reflects that younger children showed significantly fewer gazes to the correct referent (M = 0.369, SD = 0.08) than older children (M = 0.396, SD = 0.12). The interaction between distance and proform reflects the effect of sentence structure, where gazes to the correct referent were higher in complement phrase conditions

(short reflexive, long pronoun) compared to their subject relative counterparts (long reflexive, short pronouns).

Time-course of gazes to correct and incorrect referents

To investigate the continuous time-course of gazes, we calculated the proportion of gazes to each of the four AOIs within 100ms bins across the 1000ms analysis window. The majority of gazes were devoted to the correct and incorrect referents of the proform, with gazes to the inanimate discourse NP and inanimate distractor NP constituting a minority of gazes (mean gazes to discourse NP = 0.19, mean gazes to distractor NP = 0.09); for this reason gazes to the two inanimate NPs are not plotted in Figure 4-3.

Figure 4-3 (below) displays the time-course of gazes to correct and incorrect referent AOIs beginning at the onset of the proform (which occurred immediately after NP2 in the auditory stream) and continuing for 1000ms across both age groups (n=18). In short distance conditions (Figures 4-3A and 4-3B), the correct referent was the most recent NP in the auditory stream (NP2). In the short reflexive condition (4-3A) children showed a higher proportion of gazes to the correct referent over the entire window. In the short pronoun condition (4-3B), children showed a higher proportion of gazes to the correct referent at the onset of the pronoun, followed by a slight decrease in conjunction with a slight increase in gazes to the incorrect referent. By 300ms post-pronoun onset, gazes to the correct and incorrect referent appear roughly equal.

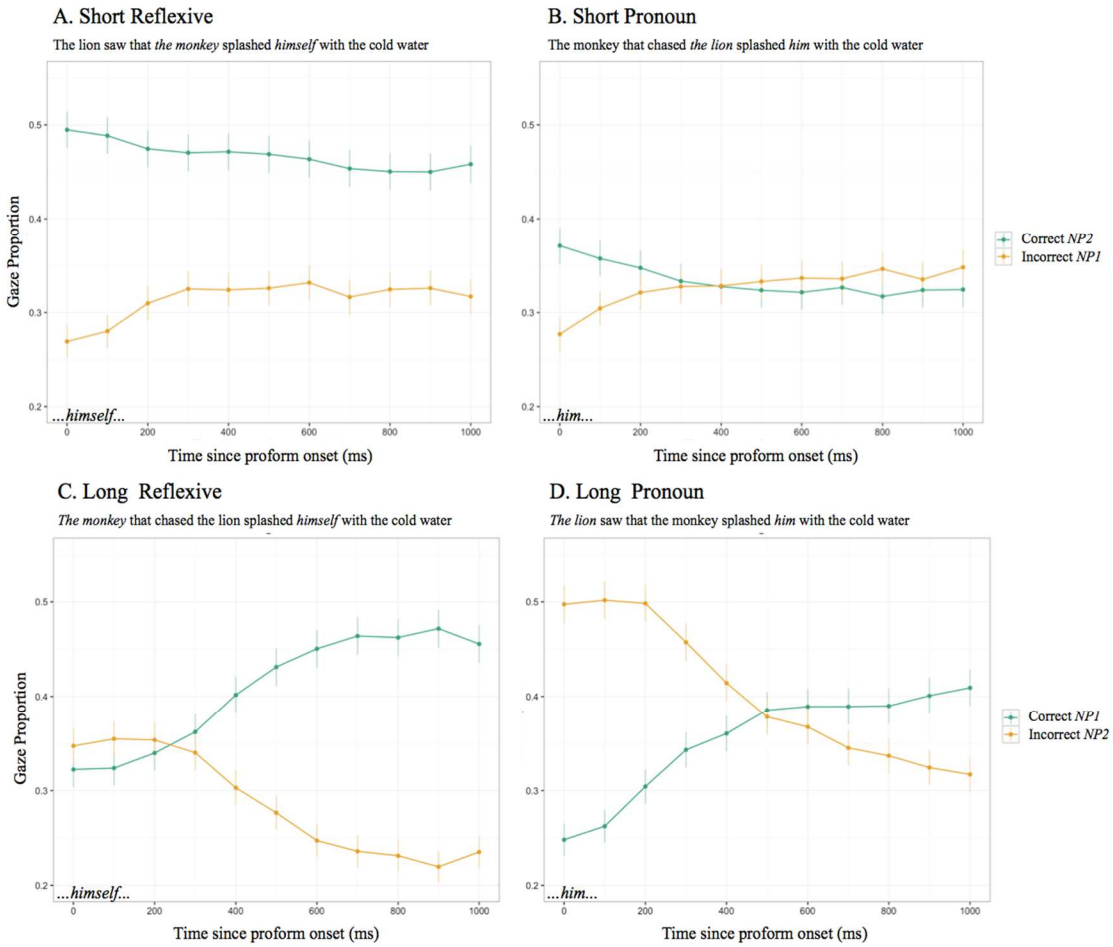


Figure 4-3. Time-course of gazes to correct and incorrect referent AOIs

In long distance conditions (Figures 4-3C and 4-3D), the *incorrect* referent was the most recent NP (NP2). In the long reflexive condition (4-3C) gazes to the incorrect referent were slightly higher at the onset of the reflexive. Gazes to the correct referent then increased steadily (as gazes to the incorrect referent decreased) and exceeded gazes to the incorrect referent between 200-300ms post reflexive onset. A similar pattern is shown in the long pronoun condition (4-3D), where children also demonstrated a higher proportion of gazes to the incorrect referent at the onset of the

pronoun, followed shortly thereafter by an increase in gazes to the correct referent in conjunction with a decrease in gazes to the incorrect referent. Gazes to the correct referent of the pronoun exceeded those of the incorrect referent between 500-600ms post pronoun-onset.

Figure 4-4 displays the time-course of gazes to correct (green line) and incorrect (yellow line) referent AOIs separately for younger (ages 6-8, dashed line) and older (9-13, solid line) participant groups.

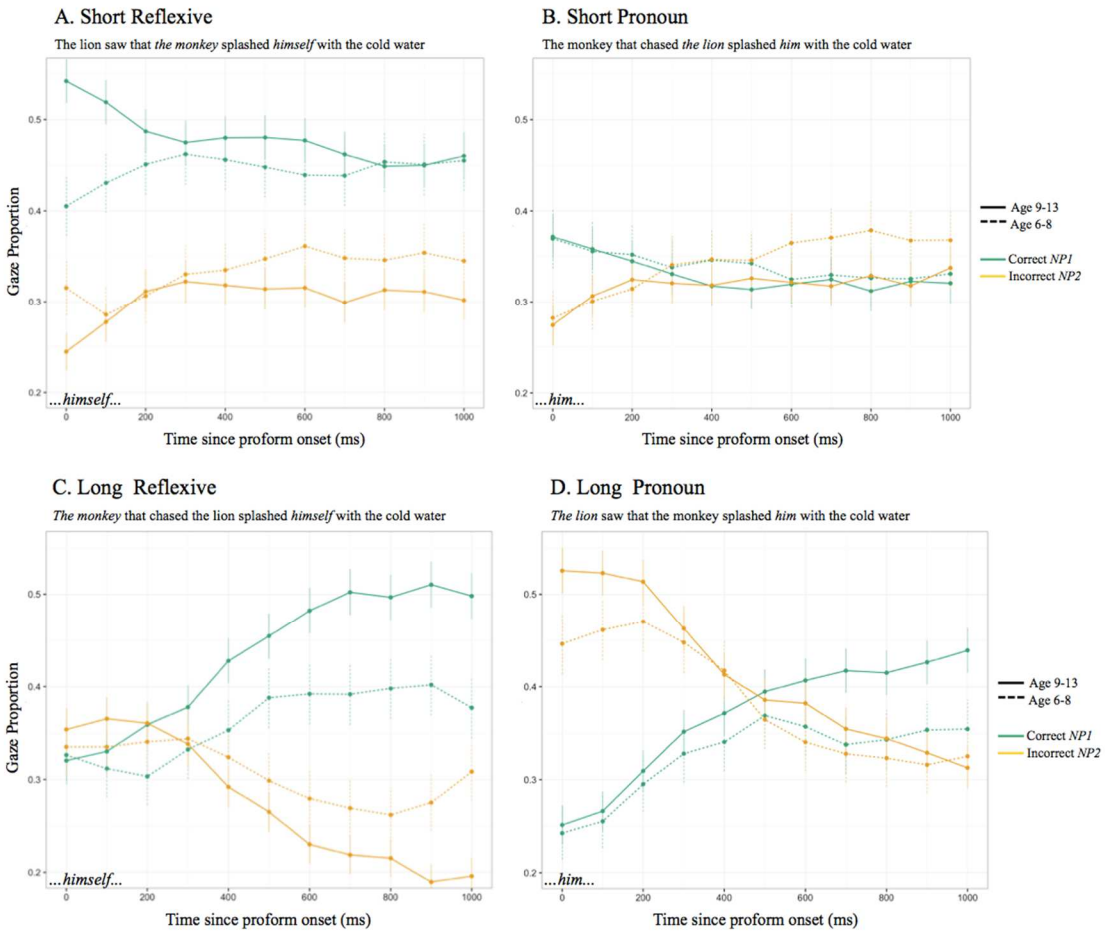


Figure 4-4. Time-course of gazes to correct and incorrect referent AOIs for younger (ages 6-8) and older (9-13) participant groups

Consistent with the results of the ANOVA reported above, younger children showed a lower proportion of gazes to the correct referent. In the complement phrase conditions (4-4A, 4-4D), gaze patterns of younger and older children appear similar. For short reflexives (4-4A), gazes to the correct NP are higher from the onset of the proform to the end of the analysis window for both groups. For long pronouns (4-4D), both groups initially look at the most recently heard NP2 but then shift their gazes to the correct referent (in excess of the incorrect referent) at 500ms for both groups. However, several differences can be observed in the subject relative conditions (4-4B, 4-4C). In the short pronoun condition (4-4B), older children displayed roughly equivalent proportions of gazes to the correct and incorrect referent between 300-1000ms post-pronoun onset, while younger children showed a greater proportion of gazes to the incorrect referent (NP1) between 500-1000ms post-pronoun onset. In the long reflexive condition (Figure 4-4C), older children's gazes to the correct referent exceeded those to the incorrect referent between 200-300ms post-reflexive onset but younger children did not show this pattern until 200ms later (400ms post-reflexive onset).

Growth Curve Analysis

To statistically evaluate gaze patterns over time, we conducted a growth curve analysis using mixed effect models (GCA; Mirman, Dixon & Magnuson, 2008) with the continuous time-course of gazes to the correct referent as the dependent variable. To implement the GCA model, we calculated the proportion of gazes to the correct referent within 100ms bins across the entire 1000ms window. The model included fixed effects of proform (pronoun, reflexive), distance (long, short) and age group (6-8

years, 9-13 years) and random effects of subjects and items. To determine the best-fitting model, first and second order orthogonal polynomials (corresponding to linear and quadratic growth curves, respectively) were added individually and improvements in model fit were determined using model comparisons. The addition of both time terms significantly improved model fit as assessed by -2 times the change in log-likelihood, distributed as chi-squared with degrees of freedom equal to the number of parameters added. The resulting model included fixed effects of proform, distance, and age group and random effects of subjects and items on all time terms. Fixed effect factors were contrast coded using sum-coding with long distance as the reference level for distance comparisons, pronouns as the reference level for proform comparisons, and younger children as the reference level for age group comparisons.

Table 4-4 presents fixed effects from the resulting model. Since proportions were transformed using the empirical logit transformation, it is not possible interpret the estimates intuitively. For this reason, we report proportions within the text to aid interpretation.

Table 4-4. Fixed effects from best fitting model

	Estimate	Std. Error	T value	p
(Intercept)	-0.596	0.081	-7.360	< 1e-04*
Linear	0.313	0.122	2.565	0.010*
Quadratic	-0.071	0.073	-0.977	0.328
Distance	-0.151	0.046	-3.285	0.001*
Proform	-0.221	0.046	-4.786	< 1e-04*
Age Group	0.069	0.063	1.105	0.269
Distance x Proform	0.078	0.046	1.697	0.090
Distance x Age Group	0.053	0.014	3.657	0.000*
Proform x Age Group	-0.041	0.014	-2.861	0.004*
Distance x Proform x Age Group	0.016	0.014	1.108	0.268

*, $p < 0.05$

Figure 4-5 presents the continuous time-course of gazes to the correct referent for distance and proform comparisons, with the best fitting model plotted against the observed data. Figure (4-5A) displays long versus short distance comparisons for the entire group, while figure (4-5B) displays the data separately for younger and older age groups. Figure (4-5C) displays reflexive versus pronoun conditions and figure (4-5D) displays the data split into age groups.

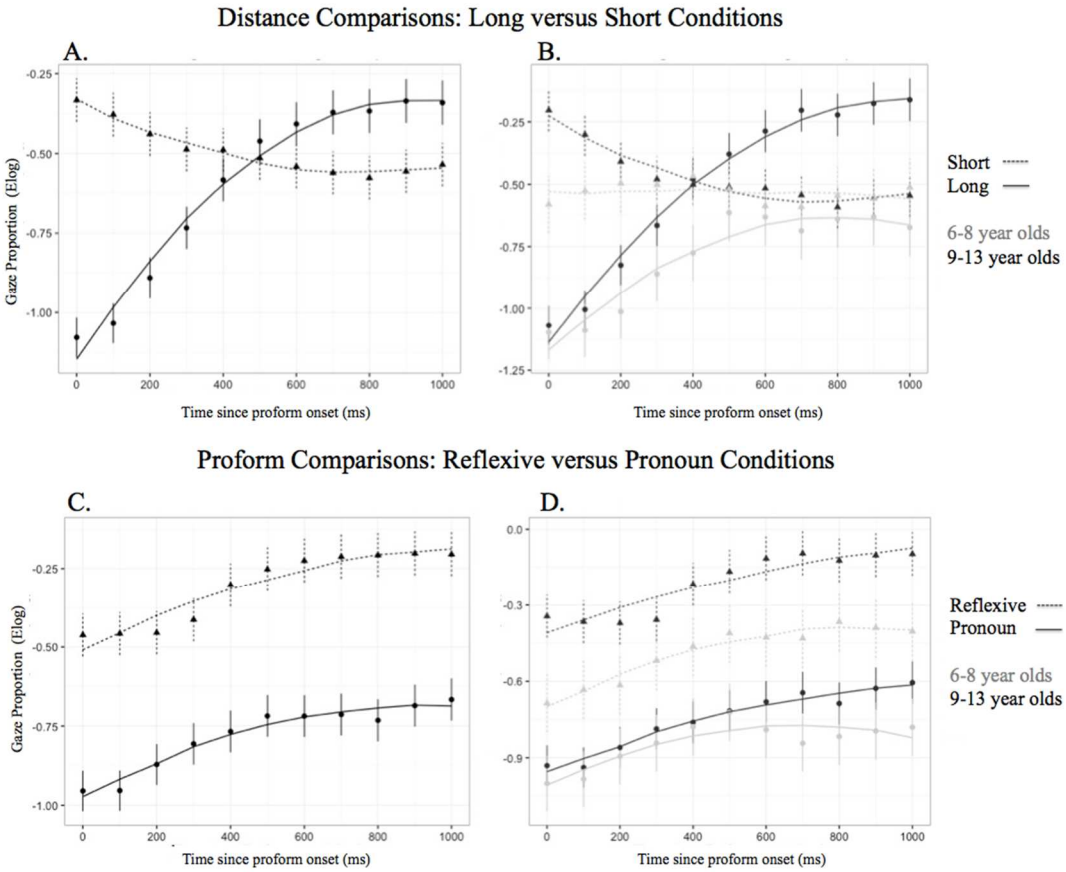


Figure 4-5. Model fit for distance and proform factors

The main effect of proform reflects that participants' gazes to the correct referent were higher for reflexives (M = 0.434) than pronouns (M=0.341). The main effect of distance reflects that gazes to the correct referent were higher for short distance (M=0.395) relative to long distance (M=0.379) conditions. The model also captured an interaction between distance and age group, with younger children demonstrating fewer gazes to the correct referent (M=0.348) than older children (M=0.396) in long distance conditions. Additionally, the model captured an interaction between proform and age group, with younger children demonstrating

fewer gazes to the correct referent ($M_{reflexive}$= 0.404, $M_{pronoun}$= 0.335) than older children ($M_{reflexive}$ = 0.449, $M_{pronoun}$ = 0.344).

As the data clearly show differences in the shape of gazes to the correct referent over time, we re-ran the model to include the interaction of the linear and quadratic terms with proform, distance and age group, thus allowing us to evaluate differences in the slope and curvature of gazes to the correct referent. In addition to the main effects and interactions captured in the previous model, this model yielded a significant interaction between the linear term and distance (Estimate = 0.681, SE = 0.885, t = 7.69, $p < 0.001$), reflecting that long distance conditions demonstrated a steeper positive slope compared to short distance conditions. This model also captured a significant interaction between the quadratic term and distance (Estimate = -0.231, SE = 0.058, t = -3.98, $p < 0.001$), reflecting the positive curvature of the long distance conditions and negative curvature of the short distance conditions. Additionally, the model captured a significant three-way interaction between the linear term, distance and age group (Estimate = - 0.415, SE = 0.096, t = -4.34, $p < 0.001$), reflecting the steeper slope of increases in gazes to the correct referent for older children compared to younger children.

Summary of results from Experiment 1

The complement phrase sentence conditions provided examples of pronouns and reflexives in their typical binding relations: reflexives are at a short distance from their antecedent and pronouns at a long distance, with a noun phrase linearly intervening between the pronoun and antecedent. Performance in complement phrase conditions was better in the short reflexive relative to long pronoun condition. This

difference comes from the fact that gazes to the correct referent in the short reflexive condition begin at a higher proportion than to the incorrect referent, and remain stable over the 1000ms analysis window, while in the long pronoun condition, gazes to the correct referent begin at a lower proportion than to the correct referent followed by an increase where gazes to the correct referent exceed those of the incorrect referent by 500ms post-proform onset.

The subject relative sentence structure provided complementary conditions: pronouns were at a short distance from their antecedent and reflexives at a long distance. Compared to complement phrase conditions, the subject relatives proved more difficult. Within the subject relative conditions, we found an advantage for long reflexives relative to the short pronouns. We then conducted growth curve analyses to determine how distance and proform type influenced gaze behavior over time. This analysis reflects an advantage for short relative to long distance conditions and an advantage for reflexives over pronouns. In short distance conditions, the correct antecedent was also the most recent NP in the auditory stream but the opposite is true for the long distance conditions. As such, growth curve analyses reflect that long distance conditions demonstrate a linear increase in gazes to the correct referent.

We also found evidence for age related differences. Overall, children in the younger age group (6-8 years) demonstrated a lower proportion of gazes to the correct referent than older children (9-13 years). In complement phrase conditions, younger and older children demonstrated the same overall pattern. However, in subject relative conditions, older children demonstrated a higher proportion of gazes to the correct referent roughly 200ms before younger children in the long reflexive condition along

with fewer gazes to the incorrect referent in the short pronoun conditions. Age effects also emerged from our growth curve analysis: younger children showed a lower proportion of gazes to the correct referent in long distance conditions and pronoun conditions compared to older children. Additionally, the positive slope corresponding to increased gazes to the correct referent was steeper for older children in long distance conditions than that of younger children.

4.2.2 Experiment 2: Offline comprehension of pronouns and reflexives in children with typical language development

Our second experiment investigates final comprehension of sentences containing pronouns and reflexives with and without intervening noun phrases between the proform and antecedent. We use a sentence-picture matching task to measure final interpretation of the sentence types used in Experiment 1.

4.2.2.1 Method

Participants

All participants from Experiment 1 participated in Experiment 2 (n=19).

Materials and Design

Ten target sentences from each of the four conditions in Experiment 1 were used (complement phrases: short reflexive, long pronoun; subject relatives: long reflexive, short pronoun; 40 sentences total). For each sentence, a pair of colored line drawing was created with each picture depicting the two characters in the sentence. One picture depicted the transitive action described in the pronoun condition and the other depicted the reflexive action. Picture pairs were randomized such that the same condition did not repeat within 3 items and the position of the target picture was

counterbalanced such that the target picture was on top for half of all items. An example picture pair and sentences are provided in Figure 4-6.

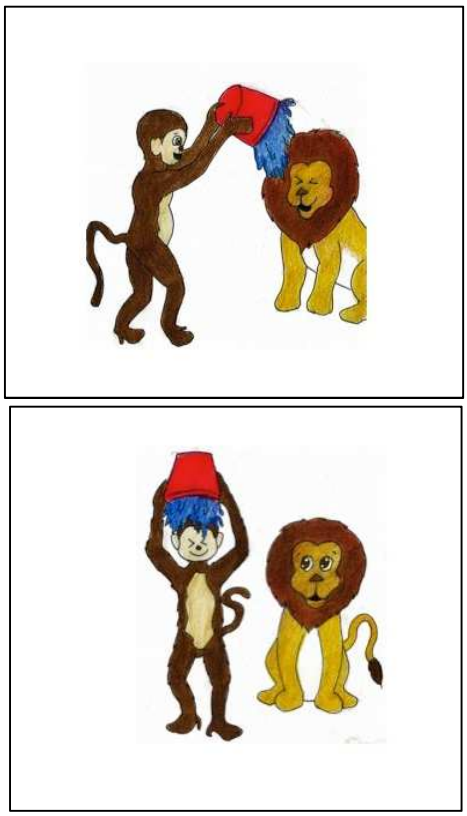


Figure 4-6. Example picture pair from sentence picture matching task

Complement Phrase	**Long Pronoun**	**The lion** saw that *the monkey* splashed **him**/*himself* with the cold water.
	Short Reflexive	
Subject Relative	*Long Reflexive*	*The monkey* that chased **the lion** splashed **him**/*himself* with the cold water.
	Short Pronoun	

Procedure

Participants were instructed to listen carefully to the sentences and point to the picture that best matched the sentence they just heard. The task began with four practice trials (one from each condition) to familiarize the participant with the task. Feedback was provided for all practice items. The experimenter spoke each sentence aloud and repetitions were allowed upon the participant's request.

4.2.2.2 Analysis and results

As shown in Table 4-5 below, mean comprehension accuracy was calculated for each participant in each condition. First, unequal variance t-tests were used to compare comprehension accuracy to chance performance (50%). Paired t-tests were then performed to determine if there was a statistical difference in comprehension accuracy between conditions. Paired t-tests were also performed to determine if younger and older children differed in comprehension accuracy within each condition. Finally, we conducted an analysis of variance with fixed effects of proform, distance and age group.

Results

Mean comprehension accuracy and standard deviations are presented in Table 4-5.

Table 4-5. Mean accuracy (and standard deviations) for sentence picture matching task

All Participants			
	Pronouns	Reflexives	***Distance Mean***
Long	89.47 (15.80)*	91.05 (10.49)*	**90.263 (13.25)**
Short	91.58 (8.34)*	90 (14.91)*	**90.789 (11.94)**
Proform Mean	**90.53 (12.51)**	**90.53(12.72)**	
Older Children (9-13 years)			
	Pronouns	Reflexives	***Distance Mean***
Long	93.85 (11.21)*	94.62 (7.76)*	**94.23 (9.45)**
Short	92.31 (9.27)*	94.62 (6.60)*	**93.46 (7.97)**
Proform Mean	**93.08 (10.11)**	**94.62 (7.06)**	
Younger Children (6-8 years)			
	Pronouns	Reflexives	***Distance Mean***
Long	80 (20.98)*	83.33 (12.11)*	**81.67 (16.42)**
Short	90 (6.32)*	80 (22.80)*	**85 (16.79)**
Proform Mean	**85 (15.67)**	**81.67 (17.49)**	

*, $p < 0.05$

Results of all t-tests reflect good comprehension of all sentence types. Comprehension accuracy was well above chance in all conditions ($p < 0.001$ for all comparisons) and did not significantly differ between conditions ($p > 0.5$ in all comparisons). The effects of distance and proform type were non-significant in the analysis of variance, reflecting overall high comprehension scores in all conditions. The analysis of variance did yield a significant main effect of age group ($F_{(1,68)} = 12.97$, $p < 0.001$), reflecting that younger children made more errors overall ($M = 83.33$, $SD = 16.33$) compared to older children ($M = 93.85$, $SD = 8.66$).

We reserve discussion of Study 1 for the overall discussion following Study 2.

4.3 Study 2: Proform-antecedent linking in children with specific language impairment

Study 2 presents data from children with specific language impairment using the same methods and materials as Study 1. Experiment 1 uses an eyetracking-while-listening paradigm to investigate the online processing of proform-antecedent. Experiment 2 assesses final comprehension using a sentence-picture matching task.

4.3.1 Experiment 1: Online processing of pronouns and reflexives in children with specific language impairment

4.3.1.1 Method

Participants

Six children ranging in age from 7;1 to 14;11 (M = 10; 4 boys, 2 girls) participated in the study. All participants were monolingual native English speakers with normal hearing and normal (or corrected-to-normal) vision and had no reported neurological impairment or social/emotional disorders (e.g., autism, attention deficit disorder). Participants received a battery of standardized measures in order to evaluate their language abilities and nonverbal intelligence. Language was assessed using the Clinical Evaluation of Language Fundamentals-IV (CELF-IV; Semel, Wiig & Secord, 2003), Test for Reception of Grammar (TROG-2; Bishop, 2003), and Children's Communication Checklist-2 (CCC-2; Bishop, 2003). Nonverbal intelligence was assessed using the Test of Nonverbal Intelligence (TONI-3; Brown, Sherbenou & Johnsen, 1997).

All participants met the following criteria for language impairment: a score from the CELF-IV of at least 1.5 SD below the mean on core language scores and at least 1.2 SD below the mean on two of three expressive and two of three receptive subtests (see Shafer, Morr, Datta, Kurtzberg & Schwartz, 2005; Marton & Schwartz,

2003); at least 1 SD below the mean on the TROG-2; a CCC-2 GCC (General Communication Composite) score of less than 80; a standard score within the normal limits (85 or above) on the TONI-3. The CCC-2 was also used to identify pragmatic impairment, defined as a SIDI (Social Interaction Difference Index) score of less than -15. Negative SIDI scores indicate greater pragmatic than grammatical impairment, accounting for a child's overall language competence. None of the SLI participants met the criteria for a pragmatic impairment. Demographic information and assessment scores for SLI participants are presented in Table 4-6.

Table 4-6. SLI Participants: Demographic information and assessment scores

N	6
Age	10 (2;9)
Age Range	7;1 – 14;11
Sex	4 M / 2 F
TONI-3	99 (8.83)
CELF-IV	71.5 (8.73)
TROG	78.67 (8.59)
SIDI (CCC-2)	10.33 (11.54)

Participants were recruited from schools in the San Diego Unified School District. Parents brought the children to our laboratory for 3-4 visits each lasting one hour or less. At each visit, language assessments were administered and children

participated in the experimental tasks. After each visit, parents were compensated $5 for traveling expenses, and child participants were compensated $5 and allowed to choose a prize.

Materials and Design

The same materials and design as Study 1, Experiment 1 were used. To briefly recap, the eyetracking-while-listening task presented auditory sentences arranged in two sentence discourse sets. In the target sentences, proforms were inserted into complement phrase and subject relative sentence structures. 160 total target sentences were presented in four conditions (short reflexive, long pronoun, long reflexive, short pronoun) and 40 additional filler items were added. 30% of all trials were followed by yes/no comprehension question that did not probe the proform-antecedent relation in order to maintain attention.

Procedure

The same procedure as Study 1, Experiment 1 was used.

4.3.1.2 Analysis and results

Comprehension probe accuracy

As in Study 1, Experiment 1, 30% of all trials included a yes/no comprehension question at the end of the trial that did not probe the proform-antecedent relation. These questions were included to ensure that participants were attending to the task. Mean comprehension accuracy for all probes was 59% (SD = 0.18) for session 1 and 68% (SD = 0.14) for session 2. Because no response was recorded if a child did not respond before 1750ms, we also calculated comprehension accuracy only for trials to which a response was made. Mean comprehension accuracy

for trials where a response was made was 76% (SD = 0.11) for session 1 and 75% (SD = 0.13) for session 2.

Proportion of gazes to correct referent

Proportion of gazes to the correct referent was calculated following the same procedure as Study 1, Experiment 1. The resulting data set included gazes that were within one of the four AOIs and lasted at least 102ms in duration. The analysis window began at the onset of the proform (shifted 200ms forward to account for gaze delay) and continued for 1000ms. Mean proportions of gazes to the correct referent are presented in Table 4-7.

Table 4-7. SLI Participants: Proportion of gazes to correct referent

	Pronouns	Reflexives	***Distance Mean***
Long Distance	0.361 (0.051)	0.357 (0.084)	**0.359 (0.066)**
Short Distance	0.289 (0.064)	0.433 (0.078)	**0.361 (0.102)**
Proform Mean	**0.325 (0.067)**	**0.395 (0.086)**	

To determine whether the proportion of gazes to the correct referent differed between conditions we conducted an analysis of variance with proportion of gazes to the correct referent as the dependent measure with distance (long, short) and proform (pronoun, reflexive) as within subjects factors. Gazes to the correct referent were significantly higher for reflexives compared to pronouns (main effect of proform; $F_{(1,902)} = 9.51$, $p = 0.002$). The interaction between proform and distance was also significant ($F_{(1,902)} = 12.17$, $p < 0.001$), where gazes to the correct referent were higher

for short- compared to long reflexives, but higher for long- compared to short pronouns. This interaction captures the effect of sentence structure, where complement phrase conditions display an advantage over their subject relative counterparts.

Time-course of gazes to correct and incorrect referent

While the ANOVAs reported above are useful for understanding the overall amount that participants devoted gazes to the correct referent, they do little to inform about changes in gaze behavior over time. As in Study 1, Experiment 1, we calculated the proportion of gazes to each of the four AOIs within 100ms bins across the 1000ms analysis window. The majority of gazes were devoted to the correct and incorrect referents of the proform, with gazes to the inanimate NP and distractor NP constituting a minority of gazes (mean gazes to discourse NP = 0.148, mean gazes to distractor NP = 0.131); for this reason gazes to the two inanimate NPs are not plotted in Figure 4-7.

Figure 4-7 displays the time-course of gazes to correct and incorrect referent AOIs beginning at the onset of the proform and continuing for 1000ms.

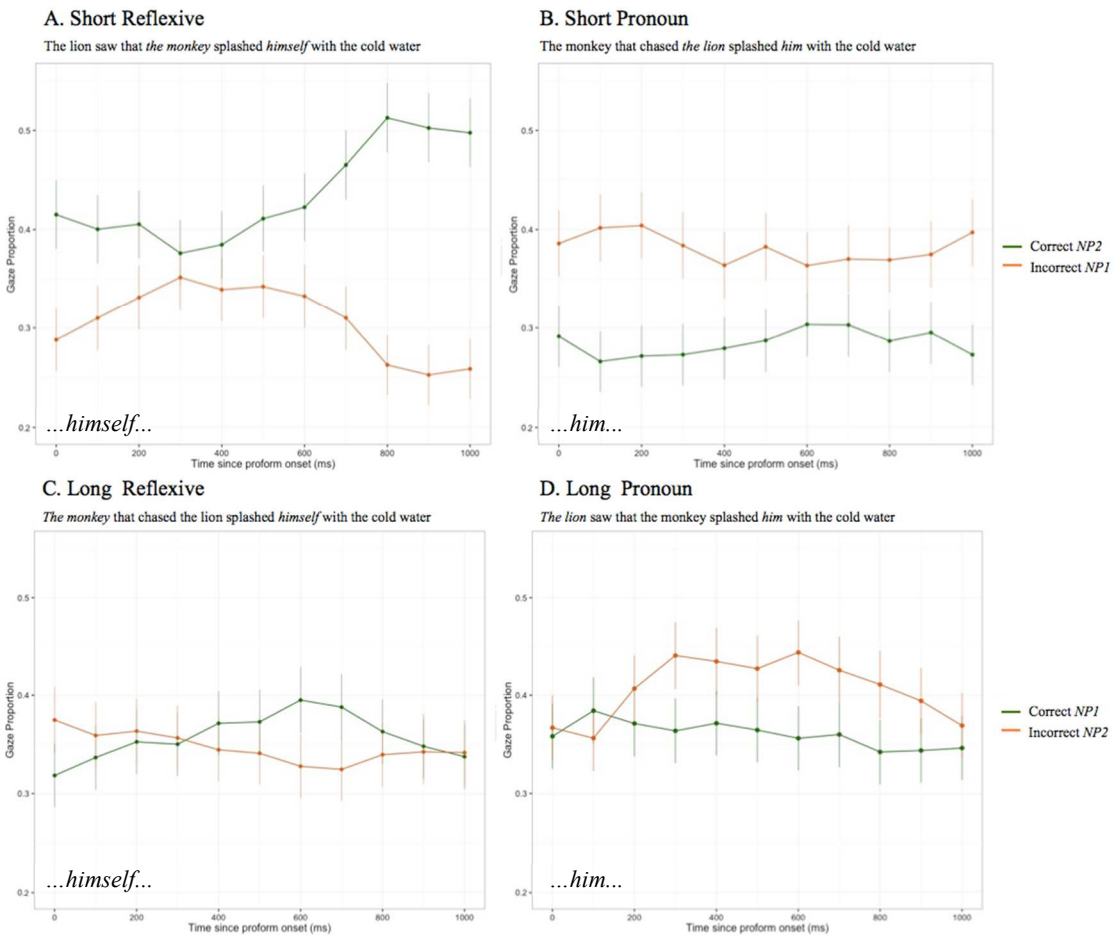


Figure 4-7. SLI participants: Time-course of gazes to correct and incorrect referent AOIs

In short distance conditions (Figures 4-7A, 4-7B), the second NP was both the correct referent of the proform and the most recent NP, however the gazes of participants with SLI differed between conditions. In the short reflexive condition (4-7A), gazes to the correct referent were higher than to the incorrect referent at the onset of the reflexive. Gazes to the correct referent began to increase 300ms later and peaked 800ms post reflexive onset. In contrast, the short pronoun condition reflects that gazes to the incorrect referent were greater than the correct referent immediately following the pronoun and remained stable over the entire window.

In long distance conditions (Figures 4-7C, 4-7D) the incorrect referent (NP2) occurred immediately before the proform. In the long reflexive condition, gazes to the most recent (incorrect) referent were greater than the correct referent between 0-300ms post reflexive onset and gazes to the correct referent exceeded the incorrect referent between 400-800ms. In the long pronoun condition, gazes to the incorrect (most recent) referent exceeded the correct referent (NP1) as early as 200ms and remained stable over the remaining window.

Growth curve analysis

To statistically evaluate differences in gaze patterns over time, we conducted a growth curve analysis using mixed effect models (GCA; Mirman, Dixon & Magnuson, 2008) in the same fashion as Study 1, Experiment 1. The continuous time course of gazes to the correct referent serve as the dependent variable and gaze proportion was calculated within 100ms bins across the 1000ms window. The model included fixed effects of proform (pronoun, reflexive) and distance (long, short) and random effects of subjects and items. To determine the best-fitting model, first and second order orthogonal polynomials (corresponding to linear and quadratic growth curves, respectively) were added individually and improvements in model fit were determined using model comparisons. The addition of the linear term significantly improved model fit over the base model. The addition of the quadratic term did not significantly improve model fit. The resulting model included fixed effects of proform and distance and random effects of subjects and items on the linear term. Fixed effect factors were contrast coded using sum-coding.

Table 4-8 presents fixed effects from the resulting model. Recall that the estimates in Table 4-8 correspond to proportions following the empirical logit transformation. To aid interpretation, we report proportions within the text.

Table 4-8. Fixed effects from best fitting model

	Estimate	Std. Error	T value	p
(Intercept)	-0.689	0.117	-5.889	< 1e-04*
Linear	0.195	0.129	1.503	0.133
Distance	-0.012	0.062	-0.205	0.838
Proform	-0.169	0.062	-2.728	0.006*
Distance x Proform	0.172	0.062	2.779	0.005*

*, $p < 0.05$

Figure 4-8 displays the time-course of gazes to the correct referent for distance and proform comparisons, with the best fitting model plotted against the data.

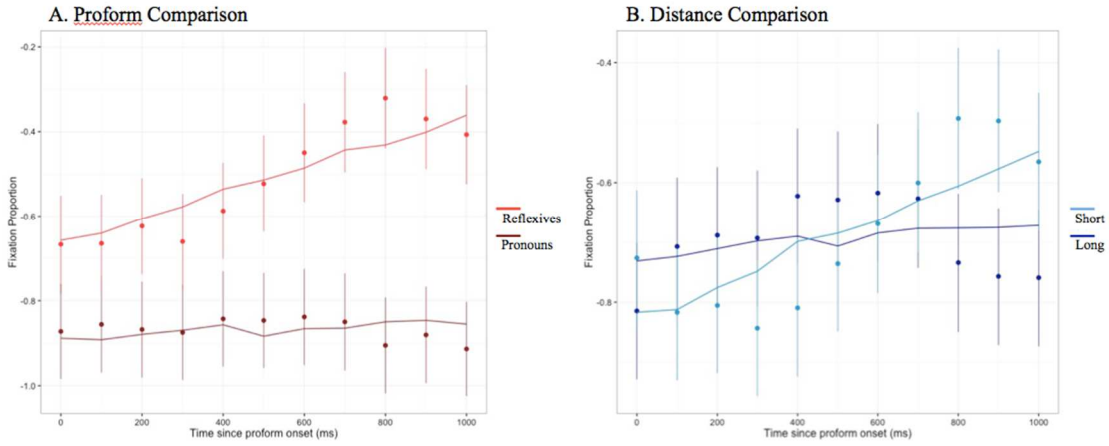


Figure 4-8. SLI Participants: Model fit for distance and proform factors

The model yielded a main effect of proform, reflecting a higher proportion of gazes to the correct referent in reflexive compared to pronoun conditions (Figure 4-8A). In

addition, the interaction between distance and proform was significant. In line with the results of the ANOVAs reported earlier and the patterns depicted in Figure 4-6, the interaction captures that gazes to the correct referent were higher for short- compared to long- reflexives, but higher for long- compared to short pronouns. The effect of distance was non-significant, suggesting that gazes to the correct referent did not differ across time for the short compared to long distance conditions (Figure 4-8B). Although reflexive conditions show a slight increase in gazes to the correct referent over time, the effect of the linear term was non-significant.

We reserve our discussion of these findings for the general discussion and turn now to Experiment 2.

4.3.2 Experiment 2: Offline comprehension of pronouns and reflexives in children with specific language impairment

Our fourth experiment investigates the comprehension accuracy of children with specific language impairment in a sentence-picture matching task, using the same sentence types as Experiment 1.

4.3.2.1 Method

Participants

All participants from Experiment 1 participated in Experiment 2 (n=6).

Materials and Design

The same materials and design as Study 1, Experiment 2 were used. To recap, ten target sentences from each of the four conditions in Experiment 1 were used (40 sentences total). A pair of colored line drawing was created for each sentence, one

picture depicted the transitive action described in the pronoun conditions and the other depicted the reflexive action. Presentation order of conditions was randomized and the position of the target picture was counterbalanced across items.

Procedure

The same procedure as Study 1, Experiment 2 was used. Participants were instructed to listen carefully to the sentences and point to the picture that best matched the sentence. Participants began with four practice trials for which feedback was provided and repetitions were allowed upon request.

4.3.2.2 Analysis and results

Analyses were conducted in the same fashion as Study 1, Experiment 2. Comprehension accuracy in each condition was compared to chance performance (50%) using unequal variance t-tests followed by paired t-tests to determine if there was a statistical difference between conditions. Finally, we conducted an analysis of variance with fixed effects of proform and distance.

Results

Mean comprehension accuracy (and standard deviations) of participants with specific language impairment are presented in Table 4-9.

Table 4-9. SLI Participants: Mean accuracy (and standard deviations) for sentence-picture matching task

	Pronouns	Reflexives	***Distance Mean***
Long Distance	73.33 (8.16)*	66.67 (25.81)$^{n.s.}$	**70 (18.59)**
Short Distance	81.67 (11.69)*	70 (16.73)*	**75.83 (15.05)**
Proform Mean	**77.5 (10.55)**	**68.33 (20.82)**	

*, $p < 0.05$

Comprehension of sentences in long pronoun, short reflexive, and short pronoun conditions were significantly greater than chance ($p < 0.033$ for all comparisons). Comprehension of long reflexive sentences did not significantly differ from chance ($t(5) = 1.58$, $p = 0.17$). Comprehension accuracy did not significantly differ between conditions ($p > 0.22$ for all comparisons). Analysis of variance results reflect that the effects of distance ($F(1,20) = 0.71$, $p = 0.41$) and proform ($F(1,20) = 1.75$, $p = 0.20$) were non-significant. The interaction of proform and distance ($F(1,20) = 0.13$, $p = 0.73$) was also non-significant.

We largely hold off on comparing TLD and SLI participants for the general discussion, however, as comprehension accuracy of the SLI group is lower than the TLD group, we compared overall comprehension accuracy of both groups. SLI participants' overall comprehension accuracy ($M = 72.92$, $SD = 16.81$) was significantly lower than the TLD group ($M = 90.53$, $SD = 12.53$; $t(98) = -5.51$, $p < 0.001$) and significantly lower than younger TLD participants ($M = 83.33$, $SD = 16.33$; $t(46) = -2.18$, $p = 0.035$) and older TLD participants ($M = 93.85$, $SD = 8.67$; $t(74) = -7.18$, $p < 0.001$).

4.4 Discussion

We sought to investigate the processing and comprehension of pronouns and reflexives in children with TLD and SLI. To this end, we presented data from two experiments in each participant group and used an eyetracking-while-listening paradigm to chart proform-antecedent linking in real time and a sentence-picture

matching task to measure final interpretation. We begin our discussion with the results from the offline experiments (Experiment 2 from Studies 1 (TLD) and 2 (SLI)). These results show that children with TLD have little difficulty understanding sentences containing pronouns and reflexives, even when such sentences contain a noun phrase that intervenes between the proform and antecedent. Our analysis of younger versus older TLD participants reflects that younger children make more errors in interpreting these sentences, but that comprehension accuracy does not differ between conditions. Overall, our findings regarding the comprehension of pronouns and reflexives in TLD participants are consistent with previous literature, where children understand both proforms by age 7 and no longer demonstrate errors consistent with the delay of Principle B effect (Chien & Wexler, 1990; Grodzinsky & Reinhart, 1993; McKee, 1992; van der Lely & Stollwerck, 1997). The good comprehension of TLD participants contrasts with participants with SLI, who demonstrated greater difficulty overall as reflected by lower comprehension accuracy compared to TLD participants. This comprehension difficulty is consistent with previous work reporting that children with SLI continue to make errors in their comprehension of proforms between ages 9-12 (van der Lely & Stollwerck, 1997).

We now turn to the online study with an initial focus on the TLD participants. The processing patterns revealed by the eyetracking-while-listening experiment reflect that TLD participants are sensitive to linear distance between a proform and antecedent. The performance of TLD participants was also modulated by the sentence construction in which the proforms were embedded: gazes to the correct referent were higher for complement phrase structures (where each clause contains a single subject

NP) compared to subject relatives (where the main clause contains two NPs, and the second modifies the first). Within the complement phrase structures, the gaze patterns of younger and older TLD participants were qualitatively similar. Within subject relatives, younger children demonstrated increased processing difficulty as reflected by a slightly later increase in gazes to the correct referent for long reflexives and a higher proportion of gazes to the incorrect referent for short pronouns. Overall, TLD participants processing patterns reflect an advantage for short distance conditions, where the correct referent of the proform is the most recent NP in the auditory stream in addition to an advantage for reflexives over pronouns. In long distance conditions, where the most recent NP in the auditory stream was the incorrect referent of the proform, TLD participants initially gazed more at the incorrect referent before shifting their gaze to the correct referent. The relative processing difficulty of long distance and pronoun conditions compared to short distance and reflexive conditions is in contrast to offline comprehension in the sentence picture matching task, where TLD participants demonstrate good comprehension overall.

The results from participants with SLI present a qualitatively different picture. Unlike TLD participants, who were temporarily distracted by the most recent (incorrect) NP in the long pronoun condition, participants with SLI demonstrated a higher proportion of gazes to the incorrect NP for the majority of the analysis window. In addition, gazes to the incorrect NP were also higher for the majority of the analysis window in the short pronoun condition, where the correct NP was the most recent in the auditory stream. As described in our introduction, pronoun conditions differ from reflexives in terms of structural distance between the proform and antecedent. In both

pronoun conditions, the correct antecedent is structurally distant from the proform and an NP of similar structure intervenes. In reflexive conditions, the reflexive and antecedent are structurally close and contain no intervening NP. In the short reflexive condition, participants with SLI demonstrated a higher proportion of gazes to the correct (linearly and structurally close) referent over the entire analysis window. In the long reflexive condition, gazes to the correct referent were initially lower than gazes to the incorrect (linearly close) referent, before gazes to the correct referent increase and exceed those of the incorrect referent by 400ms post-reflexive onset. Unlike TLD participants, the gaze patterns of participants with SLI did not demonstrate an advantage for short distance conditions, where the correct referent was linearly close to the proform. Rather, gazes to the correct referent were higher in reflexive conditions where the proform and antecedent are structurally close with no intervening NP. The processing difficulty evinced by participants with SLI is also evident in their comprehension offline, where accuracy was significantly lower than TLD participants.

Both TLD and SLI participants demonstrated an advantage during online processing of reflexives compared to pronouns. In the short reflexive condition, TLD participants' gazes to the correct referent were higher than to the incorrect referent over the entire analysis window. This is also true for SLI participants; however, gazes were delayed relative to the TLD participants: gazes to the correct referent began to increase 300ms post reflexive onset and did not reach a proportion similar to TLD participants until 800ms. In comparison, gaze patterns in the long reflexive condition appear quite similar for younger TLD and SLI participants: both groups demonstrated a lower proportion of gazes to the correct NP than older TLD participants and gazes to

the correct referent exceeded those of the incorrect referent by 400ms post reflexive onset.

Finally, we focused our paper around a recent theoretical account, the Intervener Hypothesis. To date, support for the IH comes from studies of adults with an acquired language disorder, agrammatic Broca's aphasia. At first blush, children with developmental language impairments and adults who have suffered a frank neural injury appear dissimilar. However, the two groups demonstrate overlap in the sentence structures that are linked to comprehension deficits, for example, object-extracted relative clauses, *Wh*-questions, and sentences containing proforms (for comprehensive review of SLI see: Leonard; 2014; for agrammatic Broca's aphasia see: Caramazza & Zurif, 1976; Drai & Grodzinsky, 2006; Grodzinsky, 1990; Friedmann & Gvion, 2012; Dickey & Thompson, 2009; Love & Oster, 2002). There is also common ground between existing theoretical accounts of SLI and Broca's aphasia, with theories of each pointing to a deficit in the representation of dependency relations (for SLI see: Computational Grammatical Complexity – van der Lely; 2005; for Broca's aphasia see: Trace Deletion Hypothesis – Grodzinsky; 2000).

The innovation of the current study is to extend the IH to children with SLI precisely because of the overlap of comprehension deficits with individuals with agrammatic Broca's aphasia. Furthermore, the IH can be tested in sentence constructions that are examples of underlying syntactic movement and in long distance dependencies that do not involve movement, as presented in the current paper. In so doing, the IH has the potential to provide a single account of comprehension and processing deficits across a range of sentence constructions and clinical populations.

The results of the current study support the predictions of the IH, where children with SLI demonstrate greater difficulty in sentences containing proforms where the proform and antecedent are structurally distant and an NP of similar structure intervenes. Children with TLD demonstrate sensitivity to linear distance between a proform and antecedent in that they temporarily gaze more at the most recent NP in the auditory stream, before shifting to the correct NP. Furthermore, children with SLI demonstrate qualitative differences in the moment-to-moment processing of proform-antecedent dependencies and poorer comprehension relative to TLD participants.

The findings of the current study are limited by the small sample size of our SLI participant group. While the mean age of participants in our SLI and TLD groups were nearly identical (SLI = 10; TLD = 10-4), the sample sizes of each group differed. Additionally, we were unable to match our SLI and TLD participants based on language performance, as the scores of even our younger TLD participants exceeded those with SLI. Future work that tests processing and comprehension of these, and other sentence types, and uses both age- and language matched controls is needed to validate the findings reported here.

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DC000494, and T32 DC007361.

REFERENCES

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. Journal of Memory and Language, 38, 419–439.

Bates, D., Maechler, M., Bolker, B., Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48.

Bishop, D.V. (2003). *Test for Reception of Grammar: TROG-2*. San Antonio, TX: Pearson.

Bishop, D. V. (2003). *The Children's Communication Checklist: CCC-2*. London: Harcourt Assessment.

Brown, L., Sherbenou, R. J., & Johnsen, S. K. (1997). *Test of nonverbal intelligence. A language free measure of cognitive ability, 3rd Edition*. Austin, TX: PRO-ED.

Chomsky, N. (1981). *Lectures in Government and Binding*: Dordrecht: Foris.

Chien, Y. C., & Wexler, K. (1990). Children's knowledge of locality conditions in binding as evidence for the modularity of syntax and pragmatics. *Language acquisition*, *1*(3), 225-295.

Dink, J. & Ferguson, B. (2016). eyetrackingR. R package version 0.1.6, URL: http://www.eyetracking-R.com.

Deevy, P., & Leonard, L. B. (2004). The comprehension of *Wh*-questions in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *47*(4), 802-815.

Friedmann, N., & Novogrodsky, R. (2011). Which questions are most difficult to understand?: The comprehension of *Wh*-questions in three subtypes of SLI. *Lingua*, *121*(3), 367-382.

Friedmann, N., Novogrodsky, R., & Balaban, N. (2010). The Effect of Crossing Dependencies on the Acquisition of Pronoun Comprehension. In F. P. A. Castro, J. Costa & M. Lobo (Ed.), *Language Acquisition and Development: Generative Approaches to Language Acquisition* (pp. 146–156). Newcastle, UK: Cambridge Scholars Press.

Gibson, E. (2000). The dependency locality theory: A distance-based theory of linguistic complexity. *Image, language, brain*, 95-126.

Gordon, P.C., Hendrick, R., & Johnson, M. (2004). Effects of noun phrase type on sentence complexity. *Journal of Memory and Language*, *51*, 97–114.

Gordon, P.C., Hendrick, R., Johnson, M., & Lee, Y. (2006). Similarity-based interference during language comprehension: Evidence from eye tracking during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1304–1321.

Grodzinsky, Y., & Reinhart, T. (1993). The innateness of binding and coreference. *Linguistic inquiry*, 69-101.

Hestvik, A., Schwartz, R. G., & Tornyova, L. (2010). Relative clause gap-filling in children with specific language impairment. *Journal of psycholinguistic research*, *39*(5), 443-456.

Hestvik, A., Schwartz, R., Tornyova, L., Almodovar, D., Love, T., & Swinney, D. (2007). Binding theory and syntactic movement are dissociated in SLI. In *20th Annual CUNY Sentence Processing Conference, University of California at San Diego, USA*.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of memory and language*, *59*(4), 434-446.

Lewis, R.L. (1996). Interference in short-term memory: the magical number two (or three) in sentence processing. *Journal of Psycholinguistic Research*, *2*(1), 93–115.

Lewis, R.L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science, 2*(3), 375–419.

Love, T., Walenski, M., & Swinney, D. (2009). Slowed speech input has a differential impact on on-line and off-line processing in children's comprehension of pronouns. *Journal of psycholinguistic research*, *38*(3), 285-304.

Marinis, T., & van der Lely, H.K. (2007). On-line processing of wh-questions in children with G-SLI and typically developing children. *International Journal of Language & Communication Disorders*, *42*(5), 557-582.Marton and Schwartz (2003)

Marton, K., Campanelli, L., Eichorn, N., Scheuer, J., & Yoon, J. (2014). Information processing and proactive interference in children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research*, *57*(1), 106-119.

Marton, K., Kelmenson, L., & Pinkhasova, M. (2007). Inhibition control and working memory capacity in children with SLI. *Psikhologyah: ketav'et mada'i Yisre'eli le-'iyun ule-mehkar*, *50*(2), 110.

Marton, K., & Schwartz, R.G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, *46*(5), 1138.

McKee, C. (1992). A comparison of pronouns and anaphors in Italian and English acquisition. *Language Acquisition: A Journal of Developmental Linguistics*, 2, 21–54.

McKee, C., Nicol, J., & McDaniel, D. (1993). Children's application of binding during sentence processing. *Language and Cognitive Processes*, *8*(3), 265-290.

Mirman, D., Dixon, J. A., & Magnuson, J. S. (2008). Statistical and computational models of the visual world paradigm: Growth curves and individual differences. *Journal of Memory and Language*, 59(4), 475–494.

Novogrodsky, R., & Friedmann, N. (2006). The production of relative clauses in syntactic SLI: A window to the nature of the impairment. *Advances in Speech Language Pathology*, *8*(4), 364-375.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Roberts, L., Marinis, T., Felser, C., & Clahsen, H. (2007). Antecedent priming at trace positions in children's sentence processing. *Journal of Psycholinguistic Research*, *36*(2), 175-188.

Sekerina, I. A., Stromswold, K., & Hestvik, A. (2004). How do adults and children process referentially ambiguous pronouns?. *Journal of child language*, *31*(1), 123-152.

Semel, E., Wiig, E.H., & Secord, W.A. (2003). Clinical evaluation of language fundamentals, fourth edition (CELF-4). Toronto, Canada: The Psychological Corporation/A Harcourt Assessment Company.

Shafer, V. L., Morr, M. L., Datta, H., Kurtzberg, D., & Schwartz, R. G. (2005). Neurophysiological indexes of speech processing deficits in children with specific language impairment. *Journal of Cognitive Neuroscience*, *17*(7), 1168-1180.

Sheppard, S. M., Walenski, M., Love, T. & Shapiro, L.P. (2015). The Auditory Comprehension of Wh-Questions in Aphasia: Support for the Intervener Hypothesis. *Journal of Speech, Language, and Hearing Research*, 1-17.

Sullivan, N., Walenski, M., Love, T. & Shapiro, L.P. (2016): The comprehension of sentences with unaccusative verbs in aphasia: a test of the intervener hypothesis, *Aphasiology*, 1-15.

Van der Lely, H. K., & Stollwerck, L. (1997). Binding theory and grammatical specific language impairment in children. *Cognition*, *62*(3), 245-290.

Van Dyke, J. A. (2007). Interference effects from grammatically unavailable constituents during sentence processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 407–430.

Van Dyke, J. A., & McElree, B. (2011). Cue-dependent interference in comprehension. *Journal of Memory and Language*, *65*, 247–263.

CHAPTER 5:

Proform-Antecedent Linking in Individuals with Broca's Aphasia

Proform-Antecedent Linking in Individuals with Broca's Aphasia

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ABSTRACT

Purpose: To evaluate processing and comprehension of pronouns and reflexives in individuals with agrammatic Broca's aphasia and age-matched control participants. Specifically, we evaluate processing and comprehension patterns in terms of a specific hypothesis -- the Intervener Hypothesis – that posits that the difficulty of individuals with agrammatic Broca's aphasia results from similarity-based interference caused by the presence of an intervening NP between two elements of a dependency chain.

Methods: We used an eyetracking-while-listening paradigm to investigate real-time processing (Experiment 1) and a sentence-picture matching task to investigate final interpretive comprehension (Experiment 2) of sentences containing proforms in complement phrase and subject relative constructions.

Results: Individuals with Broca's aphasia demonstrated a greater proportion of gazes to the correct referent of reflexives relative to pronouns and significantly greater comprehension accuracy of reflexives relative to pronouns.

Conclusions: These results provide support for the Intervener Hypothesis, previous support for which comes from studies of *Wh-* questions and unaccusative verbs, and we argue that this account provides an explanation for the deficits of individuals in Broca's aphasia across a growing set of sentence constructions. The current study extends this hypothesis beyond filler-gap dependencies to referential dependencies and allows us to refine the hypothesis in terms of the structural constraints that meet the description of the Intervener Hypothesis.

Keywords: *Aphasia; Sentence Processing; Binding; Similarity-Based Interference*

5.1 INTRODUCTION

Individuals with agrammatic Broca's aphasia typically have difficulty comprehending sentences containing syntactic dependencies. Previous investigations have explored these deficits in constructions that contain filler-gap dependencies (e.g. object relatives, *Wh*- questions) and referential dependencies between proforms (e.g. him/himself) and antecedents. The current study investigates real-time processing (Experiment 1) and final comprehension (Experiment 2) of sentences containing proforms in two participant groups: individuals with Broca's aphasia resulting from left-hemisphere brain damage (LHD participants) and neurologically unimpaired age-matched control (AMC) participants.

Our purpose is to investigate how distance between a proform and antecedent effects processing and comprehension patterns. To do so we present pronouns and reflexives in complement phrase and subject relative sentence constructions. Consider:

(1) **The grandma** said that *the baker* cleaned *herself*/**her** with a clean washcloth.

(2) *The baker* that helped **the grandma** cleaned *herself*/**her** with a clean washcloth.

In complement phrase constructions (1), reflexives are linearly[2] close to their antecedent (*the baker*) but pronouns are far (*the grandma*) while the opposite is true for subject relative constructions, as in (2), where reflexives are linearly far and pronouns close to their antecedent. Importantly, different considerations apply when

[2] As the current study examines auditory sentence processing, linear and temporal distance are equivalent.

we characterize distance in terms of syntactic structure: reflexives are structurally close to their antecedents in both sentence constructions and pronouns are structurally far. By manipulating sentence structure in this way, we are able to examine the effects of linear and structural distance on real-time dependency linking and comprehension patterns in individuals with Broca's aphasia.

We reserve detailed discussion of structural distance between proforms and antecedents for the final discussion and label our sentence types in terms of linear distance throughout our methods and results. To briefly forecast our findings, the results of the current study suggest that structural distance critically modulates dependency linking in individuals with Broca's aphasia; when either the proform or its antecedent is 'deeply embedded' in the sentence structure, performance deteriorates. We begin here with a discussion of classical binding constraints and a review of previous studies. We then describe in more detail the theoretical framework underlying the current study, the Intervener Hypothesis, and describe its application to the sentence types used here.

5.1.1 Dependency relations: Binding constraints

Proforms like *him* and *himself* are examples of referential dependencies: in order to be understood, they must be linked to another sentence element (or *antecedent*). Pronouns and reflexives differ in terms of the Binding Principles that constrain how referential dependencies are formed. Consider:

(3) The grandma$_a$ said that the baker$_b$ cleaned herself$_{a*/b}$.

(4) The grandma$_a$ said that the baker$_b$ cleaned her$_{a/b*}$.

Within the Government and Binding framework (Chomsky, 1981) the interpretation of the reflexive *herself* in (3) is constrained by binding principle A, which states that a reflexive must have a local antecedent *the baker*, where 'local' refers to the same clause in which the reflexive and its antecedent are positioned. The interpretation of the pronoun *her* in (4) is constrained by binding principle B, which states that a pronoun cannot take an antecedent within its local clause.

Sentences containing pronouns and reflexives also differ in other important ways. First, the dependency relation between a reflexive and antecedent can be determined using only syntactic information within the sentence. For sentences with pronouns (e.g., *The baker cleaner her*), syntactic information alone is insufficient to unambiguously determine the dependency relation between a pronoun and antecedent. Unlike reflexives, pronouns require access to discourse information in addition to syntactic information. For this reason, pronouns are said to be discourse-linked (D-linked; e.g., Avrutin, 2000, 2006) and thus add an additional level of complexity to be successfully processed. Second, and more to the purpose of the current investigation, the pronoun *her* in (4) is far from its antecedent *the grandma* and a sentence element of the same structure (*the baker;* DET N) intervenes between the two elements of the dependency chain. This is not the case for sentences such as (3), where the reflexive *herself* is close to its antecedent *the baker* and a sentence element of the same structure does not intervene between the two elements of the dependency chain. The possibility we consider here is that the presence of an intervening element between a proform and antecedent creates a greater challenge for establishing the dependency chain in

sentences containing pronouns relative to reflexives. In line with the Intervener Hypothesis detailed below, we posit that this difficulty arises as a result of similarity-based interference between the intervening element and the target element of the dependency chain (see Gordon, Hendrick, & Johnson, 2004; Gordon, Hendrick, Johnson, & Lee, 2006 for unimpaired subjects; see Sheppard, Walenski, Love & Shapiro, 2015; Sullivan, Walenski, Love & Shapiro, 2016 for individuals with Broca's aphasia).

Several studies of individuals with Broca's aphasia have found poor comprehension of binding constructions (Grodzinsky, Wexler, Chien, Marakovitz & Solomon, 1993; Love, Nicol, Swinney, Hickok & Zurif, 1998; Avrutin, Lubarsky & Greene, 1999; Edwards & Varlokosta, 2007; Choy & Thompson, 2010). Using a sentence-picture matching task[3], Grodzinsky et al. (1993) reported chance performance in sentences containing pronouns but good comprehension when they contain reflexives. However numerous other studies have found a different pattern, that is, chance or low performance for sentences containing either pronouns or reflexives (Edwards & Varlokosta, 2007; Love et al., 1998; Choy & Thompson, 2010).

Fewer studies have examined the online processing of sentences containing pronouns and reflexives in individuals with Broca's aphasia. Using a cross-modal priming method, Love et al. (1998) presented sentences of the type:

(5) The boxer said that **the skier** in the hospital would blame him/**himself** for the injury.

[3] In a sentence-picture matching task, participants listen to a sentence and then choose the picture (out of two or three) that best matches the sentence. This method is typically untimed and allows for the use of metalinguistic, conscious, reflection in generating a response.

The authors investigated the time course of re-activation of the noun phrase, *the skier* (the correct antecedent for the reflexive condition) and found that participants with Broca's aphasia incorrectly re-activated *the skier* after hearing the pronoun (*him*) but showed no re-activation for the correct antecedent for the reflexive.

In another online study, but with an eye tracking-while-listening method, Choy and Thompson (2010) investigated the proportion of gazes to the correct referent using sentences of the type:

(6) **The soldier** told *the farmer* with glasses to shave **him**/*himself* in the bathroom.

In the reflexive condition, unimpaired participants and participants with Broca's aphasia looked more to the correct referent than the incorrect referent during the reflexive and in the time window following the reflexive (the multi-word prepositional phrase). In the pronoun condition, looks to the correct and incorrect referent were not different during the pronoun but were significantly greater to the correct referent in the subsequent time window for both participant groups. The authors interpret their findings as evidence that participants with Broca's aphasia demonstrate a similar time course of pronoun-antecedent linking to unimpaired participants. Importantly, looks to referents were summed in the time windows analyzed and reflexives and pronouns differ in duration, leading to a larger analysis window for reflexives relative to pronouns. In addition, the time window corresponding to the prepositional phrase was considerably longer than the proform time window. Although the patterns of both

groups appear similar when gazes are summed over a multi-word prepositional phrase following the proform, the study did not analyze gaze behavior using a fine-grained temporal scale.

Thus, though there are inconsistencies in the results of the studies reviewed here, there is reasonable evidence to suggest that individuals with Broca's aphasia have difficulty processing and understanding sentences containing pronouns. Given the paucity of studies that measure online processing in aphasia, further work is needed to understand whether difficulty is encountered during online sentence processing of proform-antecedent dependencies.

5.1.2 Dependency relations: Displacement

In addition to difficulty understanding the dependency relations in binding constructions, individuals with Broca's aphasia have difficulty understanding dependency relations in sentences that have non-canonical word order and contain displaced constituents, such as *Wh*-questions, passives and object-extracted relative clauses (e.g., Grodzinsky, 1990; Caramazza & Zurif, 1976; Swinney & Zurif, 1995; Drai & Grodzinsky, 2006). Unlike binding constructions, on some accounts the dependency relations in these sentence types are the result of syntactic movement or displacement.

The focus of the current paper is on a recent account, the Intervener Hypothesis (IH), that aims to explain the comprehension deficits that are a hallmark of Broca's aphasia (Sheppard, Walenski, Love, & Shapiro, 2015; Sullivan, Walenski, Love & Shapiro, 2016). In an eye tracking-while-listening study, Sheppard et al. (2015) presented *Who* and *Which* questions in subject- and object-extracted

constructions:

Two mailmen and a fireman got into a fight yesterday afternoon.

(7) Who pushed the fireman yesterday afternoon?

(8) Who did the fireman push ____ yesterday afternoon?

(9) Which mailman pushed the fireman yesterday afternoon?

(10) Which mailman did the fireman push ____ yesterday afternoon?

In (10) the direct-object NP, *which mailman*, has been displaced from its underlying position occurring after the verb *push* to the beginning of the sentence, leaving behind a 'gap' (in psycholinguistic terminology). Note that the displaced NP, *which mailman*, crosses over an intervening argument position occupied by the subject NP, *the fireman*. The intuition here is that the intervening NP is considered as a possible element in the dependency chain and interferes with computing the dependency relation between the displaced *Wh*-phrase and its gap. Critically, according to the IH, only in cases where the NPs in the sentence are similarly structured (e.g., contain a Det-N structure) will interference among the NPs occur. Thus, only (10) contains such a structure, since in (7) and (8), the displaced *Wh*-phrase (*who*) is a bare operator and thus has a distinct structure from the intervening NP (*the fireman*), and (9) is a subject-extracted *Wh*-question and thus does not meet the structural description for an intervener. In line with the predictions made by the IH, the performance of individuals with Broca's aphasia in Sheppard et al. (2015) revealed chance accuracy and significantly more gazes to the incorrect referent compared to the correct referent for

object-extracted *Which*-questions only (10).

Additional support for the IH comes from a study of unaccusative verbs in individuals with Broca's aphasia. In a sentence-picture matching task, Sullivan et al. (2016) presented non-alternating unaccusative verbs in complement phrase constructions and subject-extracted relative clauses:

(11) The girl observed that <u>the boy</u> disappeared ____ into the trees.

(12) <u>The girl</u> that observed **the boy** disappeared ____ into the trees.

In the complement phrase construction (11), no NP occurs between the single argument of the unaccusative verb, *the boy*, and its underlying position that occurs after the verb. In the subject-extracted relative clause (12), an NP (***the boy)*** of the same structural type as the displaced constituent (*the girl*) occurs between the two elements of the dependency chain. Consistent with the predictions of the IH, participants with Broca's aphasia showed poor comprehension of intervener constructions (12) but good comprehension of non-intervener constructions (11).

5.1.3 Current study

The goal of the present study is to test the Intervener Hypothesis in individuals with agrammatic Broca's aphasia using proforms. Sentences that contain pronouns as in (4, above) are subject to intervener effects as outlined by the IH, while sentences that contain reflexives (3, above) are not. This confound between distance and binding, where pronouns are at a long distance from their antecedent and contain an intervener, is not however, a necessary one. To this end the current study manipulates

sentence structure in order to tease apart the relative contributions of proform type and the presence of an intervener. We use eyetracking-while-listening (Experiment 1) to investigate sentence processing and a sentence-picture matching task (Experiment 2) to probe final comprehension patterns in individuals with Broca's aphasia and a group of neurologically healthy age-matched control participants. If it is the case that individuals with Broca's aphasia are subject to intervener effects in binding constructions, we predict that the presence of an intervening argument between a proform and its antecedent should result in poorer performance relative to sentences that do not.

5.2 Experiment 1: Online Processing of Pronouns and Reflexives

We begin with an eyetracking-while-listening experiment in a group of individuals with Broca's aphasia and a group of neurologically healthy age-matched control participants. The use of eyetracking allows us to investigate the moment-to-moment processing of sentences containing pronouns and reflexives in sentence structures with and without interveners.

5.2.1 Method

Participants

Group 1: Participants with Broca's aphasia (LHD). Six individuals with Broca's aphasia participated in the study (mean age at time of testing: 55 years; range: 39-64 years). All participants with Broca's aphasia experienced a single, unilateral left-hemisphere stroke, were native English speakers with normal or corrected-to-normal visual and auditory acuity, and were right-handed before their stroke. All

participants were neurologically and physically stable (i.e., at least six months post-onset), with no reported history of alcohol or drug abuse, active psychiatric illness, intellectual disability, or other significant brain disorder or dysfunction. Diagnosis of Broca's aphasia was based on the administration of standardized language assessments to determine the extent and severity of language impairment. Assessments included the Boston Diagnostic Aphasia Examination – Third Edition (BDAE-3; Goodglass, Kaplan & Barresi, 2000), S.O.A.P. (Subject-relative, Object-relative, Active and Passive) Test of Auditory Sentence Comprehension (Love & Oster, 2002) and Western Aphasia Battery (WAB; Kertesz, 2006). All participants demonstrated an auditory comprehension deficit that was defined as at- or below-chance performance on comprehension of non-canonically ordered sentences (object-relatives and passives) from the SOAP Test (Love & Oster, 2002). All of the participants were tested at the Language and Neuroscience Group Laboratory at San Diego State University and were paid $15 per session. Demographic information and assessment scores for these participants are presented below in Table 5-1.

Table 5-1. Demographic information for participants with Broca's aphasia

Participant	Gender	BDAE† Severity Level	Years Post Stroke	Age at Testing	Education	SOAP‡ Canonical	SOAP§ Non-canonical
LHD101	M	2	7	64	Ph.D.	95%	35%
LHD130	M	4	5	61	4 years of college	95%	65%
LHD132	M	4	9	51	4 years of college	85%	55%
LHD140	F	2	13	39	4 years of college	80%	30%
LHD159	F	3	3	61	2 years of college	100%	70%
LHD169	M	1	3	57	High School	80%	40%

† BDAE = Boston Diagnostic Aphasia Examination (0 = no usable speech or auditory comprehension, 5 = minimal discernable speech handicap).
‡ SOAP Canonical = Average percent correct of active and subject relative items on Subject-relative, Object-relative, Active, and Passive Test of Auditory Sentence Comprehension (SOAP) Test of Auditory Sentence Comprehension.
§ SOAP Non-Canonical = Average percent correct of passive and object relative items on SOAP Test of Auditory Sentence Comprehension.

Group 2: Age-matched control (AMC) participants. Ten AMC participants were included in this study (mean age at time of testing: 62 years; range 56-70 years). All AMC participants were native English speakers with normal or corrected-to-normal visual and auditory acuity, with no reported history of alcohol or drug abuse, active psychiatric illness, intellectual disability, or other significant brain disorder or dysfunction.

Materials and Design

Participants were presented with auditory sentences arranged in two-sentence discourse sets while looking at a four-picture display (see Figure 5-1). All sentences were recorded by a female native speaker of English at a normal average rate of

speech of 4.69 syllables per second. As demonstrated below in Table 5-2, proforms (reflexives, pronouns) were inserted into two distinct sentence types, complement phrase and subject relatives, allowing us to manipulate distance across the two proform types. A 5-8 syllable prepositional or adverbial phrase was added to the end of each sentence in order to collect eye-gaze data from onset of the proform to the end of the sentence. Examples of a discourse sentence and the four experimental sentence conditions (yielding a 2 X 2 design) are shown in Table 5-2.

Table 5-2. Example experimental sentences by condition

1	*Discourse Sentence*			A grandma and a baker made a big mess while baking a cake.
		Distance	**Proform**	
1a	Complement Phrase	Short	Reflexive	The grandma said that the baker cleaned herself with a clean washcloth.
1b		Long	Pronoun	The grandma said that **the baker** cleaned her with a clean washcloth.
1c	Subject Relative	Long	Reflexive	The baker that helped **the grandma** cleaned herself with a clean washcloth.
1d		Short	Pronoun	The baker that helped the grandma cleaned her with a clean washcloth.

As discussed briefly in our Introduction, sentences (1a) and (1b) contain complement phrases headed by the complementizer *that*. Sentence (1a) contains a short distance reflexive where *herself* refers to the local NP *the baker*. Sentence (1b) contains a long distance pronoun where her refers to the non-local NP *the grandma* and contains an intervening NP *the baker* between the pronoun and its antecedent. Sentences (1c) and (1d) are subject relatives: (1c) contains a long distance reflexive where *herself* refers to the first NP *the baker* and the second NP *the grandma* intervenes between the

reflexive and antecedent. Sentence (1d) contains a short distance pronoun, where *her* refers to the second NP *the grandma*. This manipulation resulted in 160 unique discourse sets, with 40 additional discourse sets created as filler items to add variety. The order of mention of the two NPs was counterbalanced across sentence types with the order of mention in the discourse sentence matching that of the target sentence. For each discourse set, a four picture display was constructed that contained the two characters mentioned in the sentence and possible referents for the proform, the inanimate NP mentioned at the end of the discourse sentence, and an unrelated inanimate NP. Pictures were placed in the corner quadrants of the screen and were counterbalanced across positions. The discourse sets were counterbalanced across two presentation lists and were completed at separate visits at least one week apart.

Procedure

Participants sat facing a Tobii X120 eyetracker and were positioned with their eyes at a distance of 60cm from the eyetracker. The eyetracker was calibrated at the beginning of each experimental session. Stimuli were presented with E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Each trial began with a 500ms fixation cross, followed by a 250ms blank screen. The four-picture display was presented for 1000ms before the discourse sentence began, followed by a 250ms pause and the experimental sentence. The picture display remained onscreen 500ms after the experimental sentence (see Figure 5-1).

Participants were given a 10 item practice session to familiarize themselves with the task and ask any questions. It also served as an opportunity for the experimenter to ensure participant compliance and allowed for instruction if needed.

For all trials, gaze location was sampled at 60hz in each of the four quadrants and thus eye gaze location was recorded every 17ms throughout each trial. 25% of target trials were followed by a simple yes/no question that probed only comprehension of the discourse sentence and did not probe the proform-antecedent relation of the target sentence. These yes/no questions were used to maintain attention and participants responded using a button response box. An example picture display, sentence set and timing parameters for a single trial are shown in Figure 5-1.

Figure 5-1. Example picture display and timing parameters for Experiment 1

5.2.2 Analysis and Results

We defined four rectangular areas of interest (AOIs) of the same size around each of the pictures in the display. When data were available from both eyes, gaze location was computed as their average. When gaze location was available from only

one eye, gaze location was computed on that eye alone. When gaze location was not available from either eye, the sample was excluded from further analyses. Gaze samples that were outside any of the four AOIs were excluded from further analyses. A gaze was conservatively defined as six consecutive samples within the same AOI (a total of 102ms; see Manor and Gordon, 2003). Gazes that did not meet this criterion were not included for analysis. The resulting data set included gazes to the four AOIs that lasted at least 102ms.

To determine overall accuracy of gaze data, we calculated for each subject and each item the proportion of gazes to the correct referent (time looking at the correct referent divided by time looking at the incorrect referent and two distractor pictures). The analysis window began at the onset of the proform and continued for 1000ms. The analysis window was shifted 200ms forward to account for delay in eye movements (Allopena, Magnuson & Tanenhaus, 1998). To avoid problems with analyzing raw proportions in linear models, proportions were transformed using the empirical logit transformation (see Jaeger, 2008). Raw proportions are reported within the text for ease of interpretation. Analyses were conducted using R version 3.3.1 (R Core Team, 2016), the *lme4* package (Bates, Maechler, Bolker & Walker, 2015), and the *eyetrackingR* package (Dink & Ferguson, 2016).

5.2.2.1 Age-matched control (AMC) participants

Proportion of gazes to correct referent

To evaluate if performance differed between sentence structures we compared mean proportion of gazes to the correct referent over the 1000ms window in complement phrase and subject relative constructions in an analysis of variance. We

found no significant effect of sentence structure ($F_{(1,1415)} = 0.781$, $p = 0.377$). Mean gazes to the correct referent for the conditions of interest are presented in Table 5-3.

Table 5-3. AMC Participants: Mean gazes (and standard deviation) to correct referent

	Pronouns	Reflexives	***Distance Mean***
Long Distance	0.315 (0.105)	0.382 (0.130)	**0.349 (0.120)**
Short Distance	0.367 (0.094)	0.470 (0.084)	**0.418 (0.102)**
Proform Mean	**0.341 (0.101)**	**0.426 (0.116)**	

To begin, we submitted mean proportion of gazes to the correct referent across the 1000ms time period as the dependent measure in an analysis of variance with distance (2: long, short) and proform (2: pronoun, reflexive) as within-subjects factors. There were main effects of distance ($F_{(1,1413)} = 21.80$, $p < .001$), where the proportion of gazes to the correct referent was higher for short compared to long distance conditions, and proform ($F_{(1,1413)} = 13.71$, $p < .001$), where gazes to the correct referent were higher for reflexive compared to pronoun conditions. There was no significant interaction between distance and proform ($F_{(1,1413)} = 0.792$, $p = 0.374$).

Next, we conducted a series of follow-up comparisons (one-way ANOVAs) to investigate the impact of distance within each proform level (long pronoun vs. short pronoun; long reflexive vs. short reflexive) and the impact of proform within each distance level (long pronoun vs. long reflexive; short pronoun vs. short reflexive).

Analysis of distance: As shown in Table 5-3, the long pronoun condition (M=0.315, SD=0.105) yielded significantly fewer gazes to the correct referent relative to the short pronoun (M=0.367, SD=0.094) condition ($F_{(1,703)}=7.258$, $p < 0.01$) and the

long reflexive condition (M=0.382, SD=0.130) yielded significantly fewer gazes to the correct referent than the short reflexive (M=0.470, SD=0.084) condition ($F_{(1,710)}$=14.789, $p < 0.001$).

Analysis of proform: The short pronoun condition (M=0.367, SD=0.094) yielded significantly fewer gazes to the correct referent relative to the short reflexive (M=0.470, SD=0.084) condition ($F_{(1,703)}$=9.863, $p < 0.010$), see Table 5-3. The long pronoun condition (M=0.315, SD=0.105) also yielded fewer gazes to the correct referent relative to the long reflexive (M=0.382, SD=0.130) condition; however, after correcting the significance value for multiple comparisons (0.05/4=0.0125), the effect of proform was no longer significant ($F_{(1,710)}$=4.269, $p = 0.039$).

Time-course analyses

Gazes to correct and incorrect referent: To investigate the continuous time-course of gazes, we calculated the proportion of gazes to each of the four AOIs within 100ms bins across the entire 1000ms window. Figure 5-2 displays the proportion of gazes to the correct NP (NP1 for long distance conditions, NP2 for short) and to the incorrect NP. The proportion of gazes to the inanimate NP mentioned at the end of the discourse sentence and the distractor inanimate NP constituted a minority of overall gazes (mean gazes to discourse NP < 0.22, mean gazes to distractor NP < 0.10 in all conditions), suggesting that participants primarily devoted their gazes to the correct and incorrect referents of the proform. For this reason, gazes to the two inanimate NPs are not plotted in Figure 5-2.

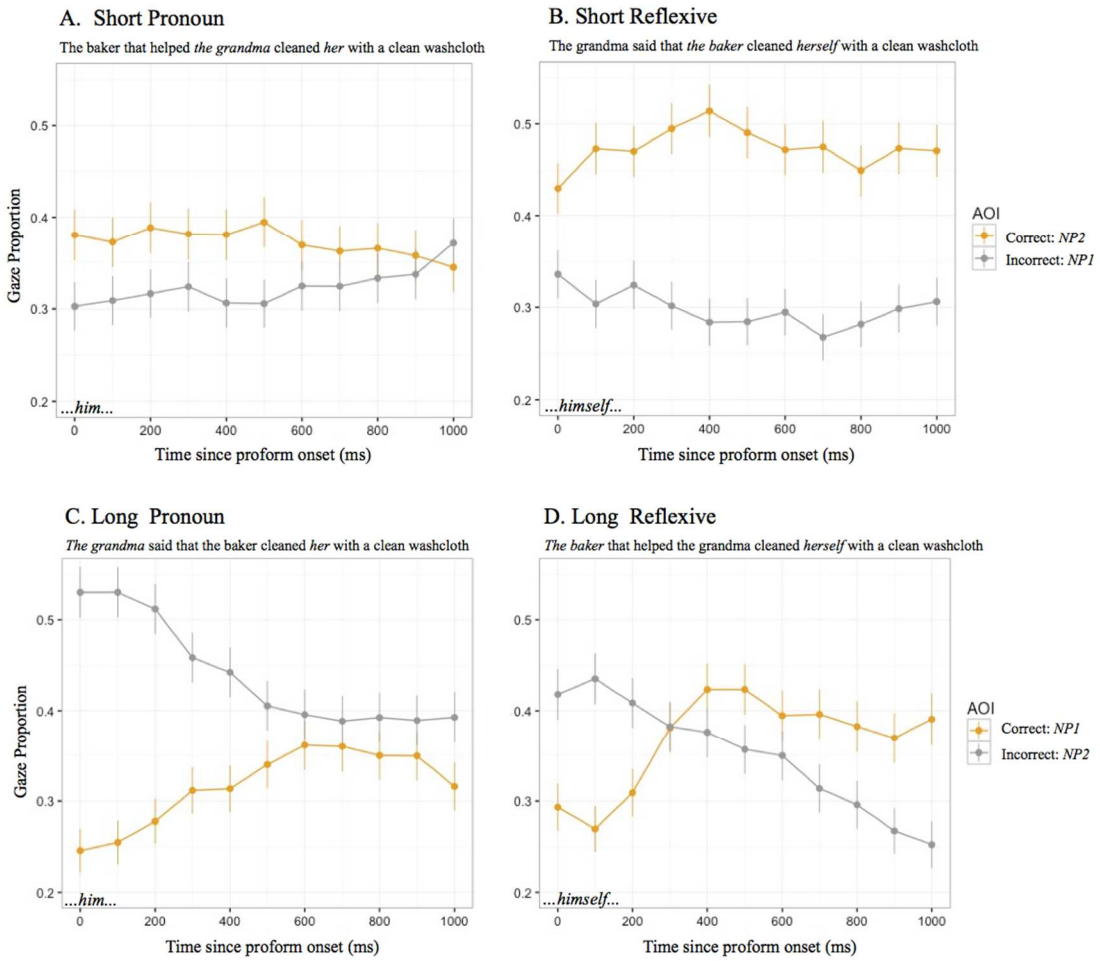


Figure 5-2. AMC participants: Gazes to correct and incorrect referent AOIs. Proportions were calculated in 100ms bins beginning at the onset of the proform (shifted 200ms to account for gaze delay) and continuing for 1000ms. Error bars represent standard error of the mean.

Visual examination of these results reveal that, in the short distance conditions (Figures 5-2A and 5-2B), participants showed a higher proportion of gazes to the correct NP over the entire window. Recall that in the short distance conditions, NP2 is both the correct referent of the proform and the most recent NP in the auditory stream. Notably, the difference in the proportion of gazes to the correct and incorrect referents is smaller in the short pronoun condition (5-2A) relative to the short reflexive

condition (5-2B). Nonetheless, similar gaze patterns can be seen for both short distance conditions, where gazes to the correct referent (NP2) exceed those to the incorrect referent from the onset of the proform and continue over the analysis period.

In the long distance conditions (Figures 5-2C and 5-2D), participants showed a higher proportion of gazes to the incorrect NP (i.e., NP2) at the beginning of the time window, followed by an increase in gazes to the correct NP (i.e., NP1) and a decrease in gazes to the incorrect NP. In the long reflexive condition (5-2D), gazes to the correct NP began increasing immediately following the onset of the proform and exceeded the proportion of gazes to the incorrect NP between 300 and 400ms post proform onset. In the long pronoun condition (5-2C), gazes to the correct NP also began increasing immediately following the onset of the proform, reaching a peak between 500-600ms post proform onset. Although the proportion of gazes to the correct NP did not exceed those to the incorrect NP, the pattern of gazes reflects a steady increase in gazes to the correct NP accompanied by a steady decrease in gazes to the incorrect NP.

This descriptive analysis suggests that participants tended to look at the NP they most recently encountered in the auditory stream (NP2) at the onset of the proform. In the short distance conditions, where NP2 was also the correct referent of the proform, participants continued to direct their gazes at NP2. In the long distance conditions, where NP1 was the correct referent, participants shifted their gazes to the correct NP immediately following the onset of the proform.

Growth curve analysis: In order to statistically evaluate differences between conditions over time, we conducted a growth curve analysis using mixed effect models

(GCA; Mirman, Dixon & Magnuson, 2008) with the continuous time course of gazes to the correct referent as the dependent variable. To implement the GCA model, we calculated the proportion of gazes to the correct referent within 100ms bins across the 1000ms window. The model included fixed effects of proform (pronoun, reflexive) and distance (long, short) and random effects of subjects and items. To determine the best fitting model, first, second and third order orthogonal polynomials (corresponding to linear, quadratic and cubic growth curves, respectively) were added individually and improvements in model fit were assessed using model comparisons. The resulting model included fixed effects of proform (pronoun, reflexive) and distance (long, short), the interaction of each time term and factor (proform, distance) and random effects of subjects and items on all time terms. The proform and distance factors were contrast coded using sum-coding with the proportion of gazes to correct referent in pronoun conditions contrasted with reflexive conditions and proportion of gazes to the correct referent in long-distance conditions contrasted with short-distance conditions. Figure 5-3 presents the continuous time course of gazes to the correct referent for each condition.

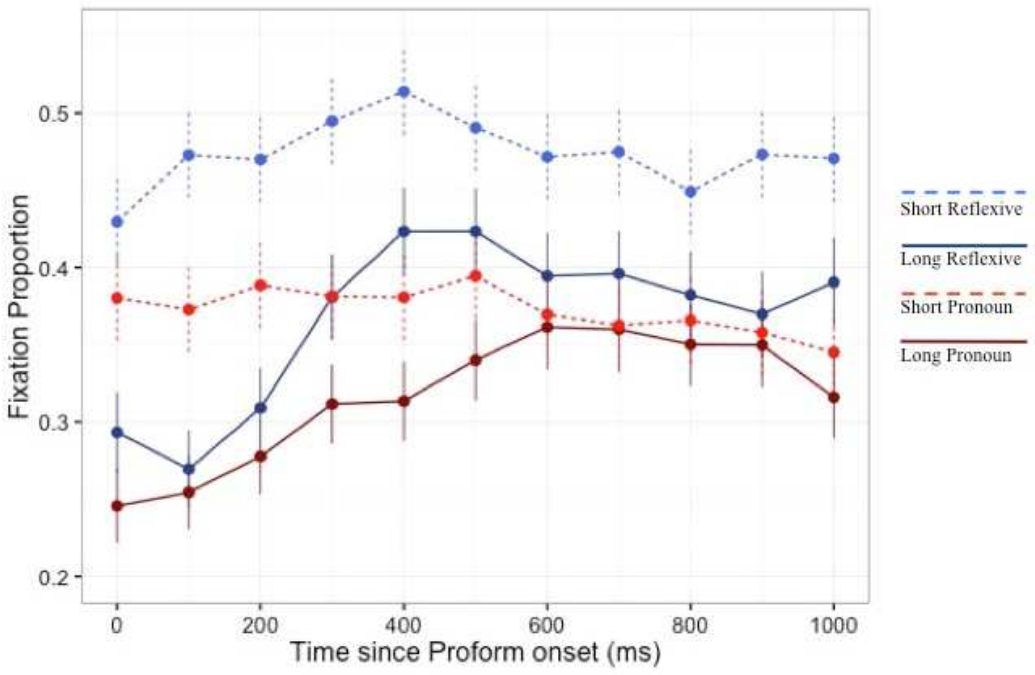


Figure 5-3. AMC Participants: Time-course of gazes to correct referent AOI. Proportions were calculated in 100ms bins beginning at the onset of the proform (shifted 200ms to account for gaze delay) and continuing for 1000ms. Error bars represent standard error of the mean.

The growth curve analysis revealed a significant main effect of distance (Estimate = -0.210, SE = 0.051, t = -4.143, $p < 0.0001$) and proform (Estimate = -0.189, SE = 0.051, t = -3.726, $p < 0.001$), indicating a higher proportion of gazes to the correct referent in the short versus long conditions and in the reflexive versus pronoun conditions. The analysis also revealed a significant interaction between distance and the linear time term (first-order orthogonal polynomial; Estimate = 0.297, SE = 0.112, t = 2.662, p = 0.008) indicating a steeper rise in the time-course of gazes to the correct referent in long distance versus short distance conditions.

5.2.2.2 Individuals with Broca's Aphasia (LHD participants)

Proportion of gazes to correct referent

As with the age-matched control group, we first evaluate whether performance differed between sentence structures by comparing mean proportion of gazes to the correct referent over the 1000ms window in complement phrase and subject relative constructions in an analysis of variance and found no significant effect of sentence structure ($F_{(1,912)} = 0.379$, $p = 0.541$). We continue our analysis of individuals with Broca's aphasia by submitting the overall mean proportion of gazes to the correct referent as the dependent measure in an analysis of variance with distance (long, short) and proform (pronoun, reflexive) as within-subjects factors. Mean proportion of gazes to the correct referent for LHD participants are presented in Table 5-4.

Table 5-4. LHD Participants: Mean gazes (and standard deviation) to correct referent

	Pronouns	Reflexives	***Distance Mean***
Long Distance	0.271 (0.126)	0.340 (0.146)	**0.305 (0.135)**
Short Distance	0.295 (0.117)	0.395 (0.155)	**0.345 (0.141)**
Proform Mean	**0.283 (0.117)**	**0.367 (0.146)**	

This analysis yielded a main effect of proform only ($F_{(1,910)} = 8.959$, $p = .003$), where the proportion of gazes to the correct referent was higher for reflexive compared to pronoun conditions. There was no significant main effect of distance ($F_{(1,910)} = 2.211$, $p = 0.137$) and no interaction between distance and proform ($F_{(1,910)} = 0.386$, $p = 0.535$).

As we did earlier, we conducted a series of follow-up comparisons (one-way ANOVAs) to investigate the impact of distance within the two proform levels (long

pronoun vs. short pronoun; long reflexive vs. short reflexive) and the impact of proform within the two distance levels (long pronoun vs. long reflexive; short pronoun vs. short reflexive).

Analysis of distance: The long pronoun condition yielded fewer gazes to the correct referent (M = 0.271, SD = 0.126) relative to the short pronoun condition (M = 0.295, SD = 0.117) and the long reflexive condition yielded fewer gazes to the correct referent (M = 0.340, SD = 0.146) than the short reflexive condition (M = 0.395, SD = 0.155); however, after correcting the significance value for multiple comparisons, the effect of distance was non-significant ($p > 0.155$ for both comparisons).

Analysis of proform: The long pronoun condition yielded fewer gazes to the correct referent (M = 0.271, SD = 0.126) relative to the long reflexive condition (M = 0.340, SD = 0.146) but again, was non-significant at the adjusted significance value ($p > 0.08$). The effect of proform was significant in the short distance comparison, where the short pronoun condition yielded fewer gazes to the correct referent (M = 0.295, SD = 0.117) relative to the short reflexive condition (M = 0.395, SD = 0.155; $F_{(1,452)} = 6.406$, $p = 0.012$).

Time course analyses

Gazes to correct and incorrect referent: Following the same procedure as the AMC group, we calculated the proportion of gazes to each of the four AOIs within 100ms bins across the 1000ms window. Figure 5-4 displays the proportion of gazes to the correct referent (NP1 for long distance conditions, NP2 for short) and incorrect referent AOIs for LHD participants. As with the AMC group, the proportion

of gazes to the inanimate NP mentioned at the end of the discourse sentence and the distractor inanimate NP constituted a minority of overall gazes (mean gazes to discourse NP < 0.22, mean gazes to distractor NP < 0.18 in all conditions), providing evidence that LHD participants primarily devoted their gazes to the correct and incorrect referents of the proform. For this reason, gazes to the two inanimate NPs are not plotted in Figure 5-4.

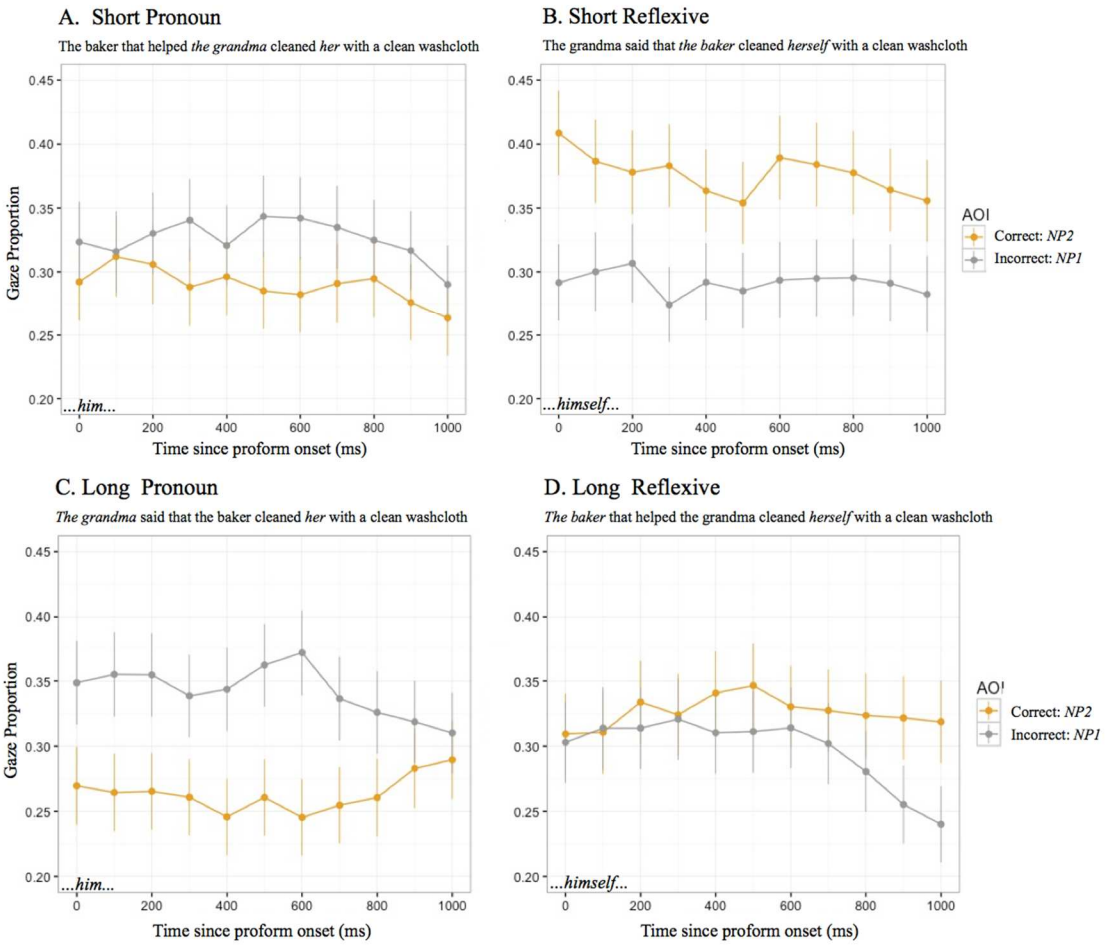


Figure 5-4. LHD participants: Gazes to correct and incorrect referent AOIs. Proportions were calculated in 100ms bins beginning at the onset of the proform (shifted 200ms to account for gaze delay) and continuing for 1000ms. Error bars represent standard error of the mean.

In the short distance conditions (Figures 5-4A and 5-4B), the difference in the proportion of gazes remained relatively stable across the 1000ms window. However, the long distance conditions reveal a different pattern: in the long reflexive condition, gazes to the incorrect referent began to decrease at 600ms and in the long pronoun condition, gazes to the correct referent began to increase at 600ms as gazes to the incorrect referent began to decrease. In the reflexive conditions (Figures 5-4B and 5-4D), LHD participants showed a higher proportion of gazes to the correct referent (NP2 for short reflexive, NP1 for long reflexive). A complementary pattern can be seen for the pronoun conditions, where participants showed a higher proportion of gazes to the incorrect referent (NP1 for short pronoun, NP2 for long pronoun).

In contrast to the AMC group, LHD participants did not demonstrate a clear preference for the NP that was most recently encountered in the auditory stream (NP2). Rather, LHD participants tended to look at the most recent NP in the short reflexive condition (the correct referent) and long pronoun conditions (the incorrect referent). The opposite pattern can be seen in the short pronoun and long reflexive conditions, with participants preferring the first NP that occurred in the auditory stream, resulting in greater gazes to the incorrect referent for the short pronoun condition but greater gazes to the correct referent for the long reflexive condition. Furthermore, unlike the performance of the AMC participants in the long distance conditions, who began shifting their gaze to the correct referent (NP1) immediately after the onset of the proform, LHD participants did not begin to look away from the incorrect NP until between 600-700ms post proform onset in the long distance conditions.

Growth curve analysis: We then conducted growth curve analysis in the same manner as the AMC group by calculating the proportion of gazes to the correct referent within 100ms bins across the entire 1000ms window. The model included fixed effects of proform (pronoun, reflexive) and distance (long, short) and random effects of subjects and items. First, second and third order orthogonal polynomials were added individually and improvements in model fit were assessed using model comparisons. The addition of the second and third order time terms did not improve model fit over the model that included the linear time term alone. The best fitting model included fixed effects of proform (pronoun, reflexive) and distance (long, short), the interaction of the linear time term on each factor (proform, distance) and random effects of subjects and items on the linear time term. Proform and distance factors were contrast coded using sum-coding. Figure 5-5 presents the continuous time course of gazes to the correct referent for each condition for LHD participants.

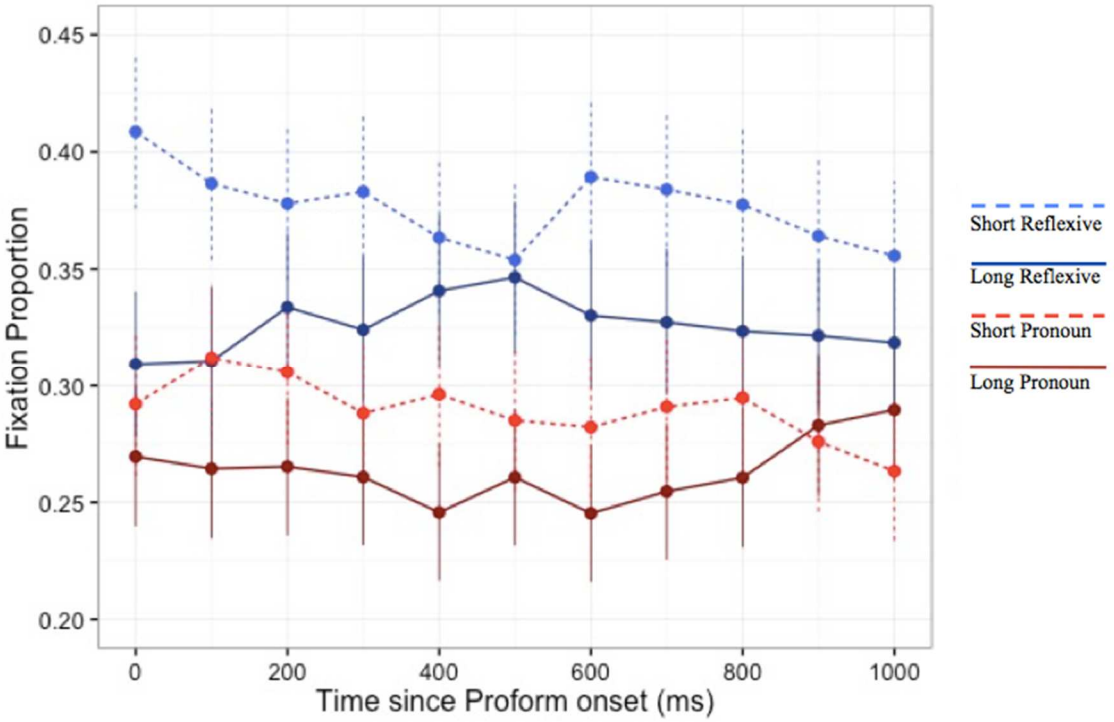


Figure 5-5. LHD Participants: Time-course of gazes to correct referent AOI. Proportions were calculated in 100ms bins beginning at the onset of the proform (shifted 200ms to account for gaze delay) and continuing for 1000ms. Error bars represent standard error of the mean

The analysis revealed a significant main effect of proform (Estimate = -0.183, SE = 0.058, t = -3.131, p = 0.0017) but no main effect of distance or interaction between the linear term and either distance or proform. These results indicate a significantly higher proportion of gazes to the correct referent for the reflexive versus pronoun conditions.

5.2.3 Summary of results from Experiment 1

In our investigation of the real-time processing of sentences containing pronouns and reflexives with and without interveners, we employed a variety of analysis techniques. We began by comparing the overall proportion of gazes to correct

referent in two participant groups, individuals with Broca's aphasia (LHD participants) and age-matched control (AMC) participants. These analyses revealed that AMC participants showed an advantage in gazes to the correct referent in sentences that did not contain an intervener (short distance conditions) relative to those that did (long distance conditions). The AMC participants also demonstrated an advantage for sentences containing reflexives relative to pronouns. The effect of distance between a proform and antecedent was further confirmed via one-way ANOVAs, which demonstrated an advantage for short distance pronouns relative to long distance pronouns, and short distance reflexives relative to long distance pronouns. The effect of proform type was evident in our comparison of short reflexives versus short pronouns and long reflexives versus long pronouns, although the difference in gazes was statistically significant only for the short pronoun versus short reflexive comparison.

While this analysis method provides an informative picture of overall patterns, it is limited in terms of temporal resolution. In order to examine the time-course of gaze patterns at a more fine-grained level, we examined the time-course of gazes to the correct and incorrect referent in each of the four conditions. This descriptive analysis revealed that AMC participants tended to look at the most recent NP (NP2) in the auditory stream when they encountered the proform. In the short distance conditions, where NP2 was also the correct referent of the proform, participants continued to direct their gazes to NP2 over the course of the analysis window. The relative advantage of reflexives compared to pronouns is also evident in the short distance conditions, where the difference between gazes to the correct versus incorrect

referent, and the overall proportion of gazes to the correct NP are greater in the short reflexive condition. In contrast, the long distance conditions required participants to shift their gaze from the most recent NP in the auditory stream (NP2) to the first NP of the sentence after the proform was encountered. The time-course graphs of gazes to the correct and incorrect referent for AMC participants (Figure 5-2) in long distance conditions reflect an immediate and steady increase in gazes to the correct referent (NP1). Evidence for the relative advantage of the reflexive compared to the pronoun is observed in the form of a higher proportion of gazes to the correct referent in the long reflexive relative to the long pronoun conditions. Further evidence for the advantage of reflexives comes from the observation that gazes to the correct referent reached a peak roughly 200ms earlier in the long reflexive relative to the long pronoun condition for AMC participants.

To statistically evaluate the time-course of gazes to the correct referent across conditions, we employed growth curve analyses using mixed effect models. These analyses confirmed the outcomes of both the more coarse grained ANOVAs and the descriptive analyses, by revealing an advantage for short versus long distance conditions and reflexive versus pronoun conditions. Additionally, the significant interaction between distance and the linear time term confirms our observation that the long distance conditions demonstrated a steep rise in gazes to the correct referent relative to the short-distance conditions.

We repeated the same suite of analyses for individuals with Broca's aphasia and discovered striking differences between the LHD and AMC participant groups. In terms of the overall proportion of gazes to the correct referent, LHD participants

demonstrated an advantage for reflexive relative to pronoun conditions. This advantage was also statistically significant in the short reflexive relative to short pronoun comparison. While LHD participants did indeed demonstrate a numerically larger proportion of gazes to the correct referent in the long reflexive versus long pronoun condition, the advantage for the reflexive condition was not statistically significant. Similarly, the overall proportion of gazes to the correct referent was greater for long distance relative to short distance conditions, but these differences did not reach statistical significance.

In the short distance conditions, gazes to the preferred referent (correct-NP2 for short reflexives; incorrect-NP1 for short pronouns) remained relatively stable over the analysis window. However, the long distance conditions revealed a decrease in gazes to the incorrect referent around 600ms post proform onset. This is in contrast to AMC participants, who tended to re-orient their gazes to the correct referent immediately following proform onset in long distance conditions. While AMC participants demonstrated a clear preference for the most recently encountered NP (NP2) at the beginning of the analysis window, LHD participants tended to direct their gazes at the most recent NP (NP2) in the short reflexive and long pronoun conditions but demonstrated the opposite pattern (preferring NP1) in the long reflexive and short pronoun conditions.

Turning now to our statistical evaluation of the time-course of gazes to the correct referent, we discovered that the best fitting model included linear change over time, but did not improve with the addition of non-linear time terms (i.e., quadratic or cubic growth curves). Consistent with our descriptive analysis and visual inspection of

the time course, LHD participants demonstrated more stable gazes to the selected referent relative to AMC participants, who showed clear change over time. This final analysis further confirmed the advantage for reflexive conditions relative to pronoun conditions, despite the fact that the correct referent was the most recently encountered NP (NP2) for the short reflexive condition, and the first NP in the long reflexive condition. We reserve our discussion of the theoretical significance of these findings for the general discussion and turn now to Experiment 2.

5.3 Experiment 2: Offline Comprehension of Pronouns and Reflexives

Our second experiment investigated the effects of interveners and proform type using a sentence-picture matching task so that we could measure final comprehension of our sentences. Here we use the same sentence types and participants as Experiment 1.

5.3.1 Method

Participants

All participants from Experiment 1 (six participants with Broca's aphasia and ten AMC participants) participated in Experiment 2.

Materials and Design

Ten target sentences from each of the four conditions used in Experiment 1 were included (short reflexive, long pronoun, short pronoun, long reflexive; 40 sentences total). For each sentence, a pair of color line drawings was created. The same two characters were depicted in each drawing. In one picture, the transitive action described in the pronoun conditions was depicted and in the other, the reflexive

action described in the reflexive conditions was depicted. The 40 picture pairs were randomized such that the same condition did not repeat within 3 items. The position of the target (correct) picture was counterbalanced such that 50% of the time the correct picture was on the top and vice versa. An example picture pair is provided in Figure 5-6.

Figure 5-6. Example picture pair for Experiment 2: sentence-picture matching task
Long Pronoun/*Short Reflexive*: **The grandma** said that *the baker* cleaned **her**/*herself* with a clean washcloth.
Long Reflexive/**Short Pronoun**: *The baker* that helped **the grandma** cleaned **her**/*herself* with a clean washcloth

Procedure

Participants were instructed to listen carefully to the sentences and point to the picture that best matched the sentence they just heard. Participants were familiarized with the task with four practice items (one from each condition) and feedback was provided for practice items. The experimenter spoke each sentence aloud and repetitions were allowed upon the participant's request.

5.3.2 Analysis and Results

To determine comprehension accuracy, participant responses for the four sentence conditions were subjected to unequal variance t-tests comparing response accuracy to chance performance (50%) for each group. For each group (AMC, LHD), a paired t-test was performed to determine if there was a statistical difference in comprehension accuracy among the four conditions. Paired t-tests were also performed to determine if there was a statistical difference between long versus short distance conditions and pronoun versus reflexive conditions.

Results

Comprehension accuracy for both subject groups is shown in Table 5-5.

Table 5-5. Mean comprehension accuracy (and standard deviation) for AMC and LHD participants.

AMC Participants			
	Pronouns	Reflexives	***Distance Mean***
Long Distance	99.09 (3.02)	96.36 (6.74)	**97.73 (5.28)**
Short Distance	100 (0)	100 (0)	**100 (0)**
Proform Mean	**99.95 (2.13)**	**98.18 (5.01)**	
LHD Participants			
	Pronouns	Reflexives	***Distance Mean***
Long Distance	63.33 (20.66)	83.33 (12.11)	**73.33 (19.23)**
Short Distance	70 (26.83)	90 (8.94)	**80 (21.74)**
Proform Mean	**66.67 (23.09)**	**86.67 (10.73)**	

AMC participants' results revealed ceiling effects, with 100% accuracy for short-distance conditions and 97.73% accuracy for long-distance conditions. Accuracy for

pronoun and reflexive conditions was 99.95% and 98.18, respectively. Comprehension accuracy for each condition was significantly above chance ($p < 0.001$ for all comparisons). Paired t-tests revealed no significant difference between conditions ($p > 0.05$ for all comparisons).

For participants with Broca's aphasia, comprehension accuracy was significantly greater than chance in the short-reflexive ($t(5)=10.95$, $p < 0.001$) and long-reflexive ($t(5)=6.74$, $p < 0.001$) conditions. The opposite was true for the Pronoun conditions: neither the short-pronoun ($t(5)=1.83$, $p = 0.128$) nor long-pronoun condition ($t(5)=1.58$, $p=0.175$) was significantly different than chance. Paired t-tests revealed no significant difference between conditions ($p > 0.06$ for all comparisons). However, comprehension accuracy in reflexive conditions was significantly greater than in Pronoun conditions ($t(11)=2.87$, $p=0.015$). Descriptively, accuracy was highest for the short-reflexive condition (90%), followed by long-reflexives (83.33%) and short-pronouns (70%). Accuracy was lowest in the long-pronoun condition (63.33%).

5.4 Discussion

We begin our discussion with the offline sentence-picture matching performance. Participants with Broca's aphasia demonstrated above chance comprehension of sentences containing reflexives and below chance comprehension of those containing personal pronouns. Additionally, comprehension of sentences containing reflexives was significantly better than those containing pronouns. The presence of an intervening NP between a proform and antecedent in the long-distance conditions did not significantly affect comprehension accuracy, although accuracy was

numerically higher in the short relative to long distance conditions. The comprehension difficulty in sentences containing pronouns is in contrast to age-matched control participants, for whom comprehension of all sentence types was at or near ceiling. The comprehension deficits of our LHD participants align with prior studies that report comprehension deficits with binding constructions (Love et al., 1998; Edwards & Varlokosta, 2007; Thompson & Choy, 2010) and studies that report good comprehension of sentences containing reflexives relative to pronouns (Grodzinsky et. al., 1998; Love et al., 1998).

The purpose of the eye tracking-while-listening task was to investigate how the distance between a proform and antecedent, and the resultant intervening noun phrase, impact real-time sentence processing in individuals with Broca's aphasia. Specifically, we couched this inquiry with respect to the Intervener Hypothesis, support for which comes from studies of *Wh*-questions (Sheppard et al., 2015) and sentences containing unaccusative verbs (Sullivan et al., 2016) -- constructions that are examples of syntactic displacement (see also Santi, Friederici, Makuuchi & Grodzinsky, 2015, for additional support).

The current study is the first to test the Intervener Hypothesis in sentences that contain referential dependencies between two overt (i.e., spoken) sentence elements, while previous studies tested sentence constructions that involve syntactic movement. In such constructions (*Wh*-questions and unaccusative verbs), a dependency is formed between an NP and a phonologically empty trace position (referred to as *filler-gap* dependencies). In order for listeners to successfully establish the dependency chain in

sentence constructions that involve syntactic movement, they must draw on their knowledge of the syntactic structure of the sentence.

With respect to the sentence types used in the current study, we couched the Intervener Hypothesis in terms of linear distance between a proform and antecedent. Under this description, the long distance conditions contained a noun phrase (of the same structural type as the antecedent) that occurred between the proform and antecedent, while the short distance conditions did not. For example, in the long distance pronoun construction (e.g., **The grandma** said that the baker cleaned **her**) the pronoun *her* co-refers with its antecedent, *the grandma*, and an NP, *the grandma*, intervenes between the two elements of the dependency. In the short distance counterpart (e.g., The baker that helped **the grandma** cleaned **her)** there is no such intervening NP. As the current study investigated real-time processing of auditory sentences, linear distance can also be understood in terms of temporal distance. As such, in the short distance conditions, the correct referent of the proform was the noun phrase that most recently occurred in the auditory stream while the same NP (NP2) was the incorrect referent of the proform in the long distance conditions.

Results from age matched control participants suggest that listeners are sensitive to temporal distance between a proform and antecedent: In the long distance conditions, AMC participants tended to look at the picture representing the NP that most recently occurred in the auditory stream, beginning at the onset of the proform and then quickly re-oriented their gazes to the correct, long distance NP (NP1). In the short distance conditions, where the most recent NP (NP2) was also the correct referent of the proform, AMC participants directed their gaze to the picture

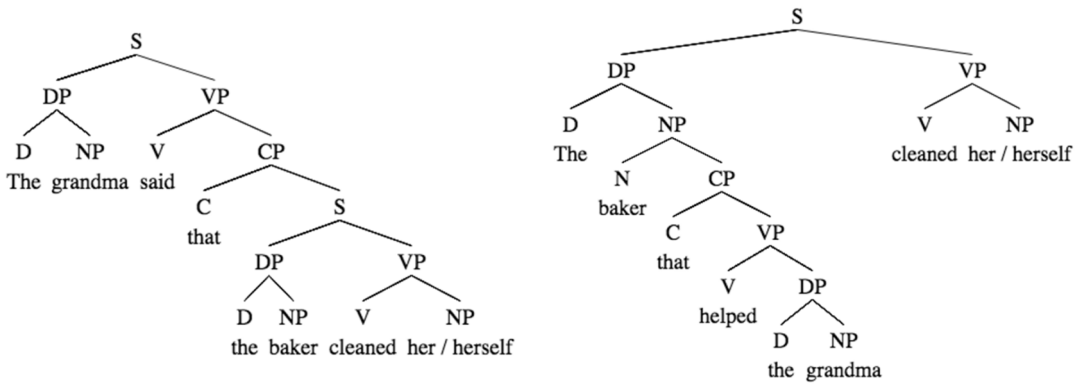
representing NP2 at a higher proportion than to NP1 beginning at the onset of the proform and continued to do so over the entire analysis window.

Results from participants with Broca's aphasia reflect a qualitatively different pattern than our AMC participants. Participants with Broca's aphasia tended to look at the picture representing the most recent NP (NP2) in the long distance pronoun condition, but showed the opposite pattern in the long distance reflexive condition, resulting in a higher proportion of gazes to the incorrect NP for long distance pronouns but a higher proportion of gazes to the correct NP for long distance reflexives. Gaze patterns in the short-distance conditions evinced a complementary pattern: LHD participants tended to look at the picture representing the most recent NP in the short-distance reflexive condition, but looked more at the picture representing the first NP (NP1) in the short-distance pronoun conditions. This pattern resulted in a higher proportion of gazes to the correct referent in the short-reflexive condition, but a higher proportion of gazes to the incorrect referent in the short-pronoun condition.

If we recast the gaze patterns of our LHD participants in terms of NP1 and NP2, rather than correct and incorrect NP, gazes to NP1 were greater for the long-reflexive and short-pronoun conditions while gazes to NP2 were greater for short-reflexive and long-pronoun conditions. Recall that the short reflexive and long pronoun conditions used a complement phrase clause structure (e.g., **The grandma** said that *the baker* cleaned **her**/*herself*) while the short pronoun and long reflexive conditions used a subject relative clause structure (e.g., *The baker* that helped **the grandma** cleaned **her**/*herself*). Thus, for complement phrase conditions, gaze patterns of LHD participants revealed a preference for the second NP (again, correct referent

for short reflexive but incorrect for long pronoun conditions). Gaze patterns in subject relative conditions revealed a preference for the first NP, and furthermore reflected that LHD participants tended to look at the picture representing NP1 as early as the onset of the proform.

Given these patterns, consider the syntactic structures (simplified) of the sentence types used in the current study, shown in Figure 5-7.



A. Complement Phrase Conditions B. Subject Relative Conditions

Figure 5-7. Syntactic tree structure of sentence types

The syntactic structure of the complement phrase constructions (Figure 5-7A) demonstrates a direct correspondence between linear and structural distance. By this we mean that the reflexive finds its antecedent (*the baker*) within the local sentential clause (*the baker cleaned herself)* and the antecedent is also the most recent NP in the auditory stream. In contrast, the pronoun *her* is deeply embedded in the overall structure of the sentence and finds its antecedent *the grandma* in the specifier position (i.e., the subject of the first determiner phrase) of the overall sentence. In the subject relative construction, the antecedent of the pronoun, *the grandma*, is deeply embedded

in the overall structure of the sentence. When we compare pronoun conditions between sentence structures, in one case (5-7A) the pronoun is deeply embedded and in the other (5-7B), the antecedent is deeply embedded. In contrast, there is no distinction between the level of embeddedness of the reflexive or its antecedent across structures. In both constructions, the reflexive is positioned within the verb phrase, *cleaned herself*, and finds its antecedent *the baker* in the adjacent determiner phrase. In the reflexive conditions, there are fewer nodes between the position of the reflexive and antecedent compared to pronoun conditions. Furthermore, both pronoun conditions require the crossing of a noun phrase of similar structure to the correct referent prior to reaching its position.

Returning to the findings of the current study, participants with Broca's aphasia demonstrated a higher proportion of gazes to the correct referent of reflexives relative to pronouns. A similar pattern was found in comprehension accuracy scores, where reflexives were significantly better than pronouns. When we frame the Intervener Hypothesis in terms of structural distance, the observed pattern of results provides clear support: gazes to the correct referent were higher in the sentence conditions where the proform and antecedent were structurally close to one another and did not contain an intervening NP of similar structure; this is also true for comprehension accuracy.

The results of the current study allow us to refine the Intervener Hypothesis as a syntactic account of the sentence comprehension deficits in individuals with Broca's aphasia. Within this account, we characterize an intervener as a sentence element of similar structure to a target referent that intervenes between two elements of a

dependency chain. Furthermore, we limit our use of *intervenes* to exclusively refer to the underlying syntactic structure of the sentence and not linear/temporal order. Importantly, this refinement allows us to test the Intervener Hypothesis in sentences that contain dependency relations between overt sentence elements, as in the current study, *and* to those between covert (or phonologically empty) *trace* positions as demonstrated in previous studies of the IH in *Wh*-questions (Sheppard et. al., 2015) and sentences containing unaccusative verbs (Sullivan et. al., 2016).

To our knowledge, no previous study has investigated the online processing of sentences containing pronouns and reflexives in individuals with Broca's aphasia using subject relative constructions. Nonetheless, the findings of the current study demonstrate a number of similarities with previous studies of online processing of proforms. Love et al. (1998) used a cross modal priming method and found that participants with aphasia demonstrated priming of the incorrect antecedent of the pronoun in complement phrase constructions. As with the current study, the incorrect antecedent was closest to the pronoun in both linear and structural distance. Taken together, the findings from these two studies provide converging evidence that the processing of pronouns in complement phrase constructions is made more difficult by the presence of intervening NP. Choy and Thompson's (2010) eyetracking-while-listening study also used complement phrase constructions containing pronouns and reflexives and found that the number of fixations to the correct antecedent were significantly greater than to the incorrect antecedent in the time window corresponding to the reflexive. The same pattern was not true for the correct antecedent of the pronoun, for which fixations to the correct antecedent were not significantly greater

than to the incorrect antecedent during the pronoun, but increased during the prepositional phrase following the pronoun. Similar to the current study, the results of Choy and Thompson (2010) reflect that when a reflexive is embedded in a complement phrase construction, and is thus structurally and temporally closer to its antecedent, gaze behavior favors the correct antecedent as early as the onset of the reflexive.

We end our discussion with a note on limitations. One caveat for the current study is the small sample size of our LHD participant group (n=6). Future work that presents data from larger participant groups may aid in verifying the results reported here. Additionally, the advantage for reflexives over pronouns demonstrated by LHD participants creates a challenge for disentangling the predictions of theories that point to discourse-linking as a source of difficulty for pronouns from the Intervener Hypothesis. Continuing investigations of multiple sentence types will serve to better separate the predictions of alternative theories.

In conclusion, the current study is the first to investigate the Intervener Hypothesis in sentences containing proforms in individuals with Broca's aphasia. This account aims to provide a single explanation for sentence comprehension and processing deficits in Broca's aphasia. Under this account, the presence of a sentence element that intervenes between two elements of a dependency chain leads to greater processing difficulty. We further specify that an *intervener* is of the same structural type as the target element in a dependency chain and that *intervene* is properly characterized in terms of the underlying syntactic structure of a sentence, rather than the more surface temporal order of the auditory stream. To our view, the strength of

the Intervener account lies in its ability to account for deficits across a wide set of sentence constructions while pointing to a single causal mechanism: interference from similarly structured sentence elements. Support for this hypothesis now comes from sentences containing filler-gap dependencies (*Wh*-questions, Sheppard et. al., 2015; unaccusative verbs, Sullivan et. al., 2016) and referential dependencies in complement phrase and subject relative constructions.

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REFERENCES

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. Journal of Memory and Language, 38, 419–439.

Avrutin S, Lubarsky S, Greene J. (1999). Comprehension of contrastive stress by Broca's aphasics. *Brain and Language*, *70*(2):163–186.

Avrutin, S. (2000). Comprehension of discourse-linked and nondiscourse-linked questions by children and Broca's aphasics. *Language and the brain: Representation and processing*, 295-313.

Avrutin, S. (2006). Weak syntax. In Y. Grodzinsky & K. Amunts (Eds.), Broca's region (pp. 49–62). Oxford, UK: Oxford University Press.

Bates, D., Maechler, M., Bolker, B., Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48.

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, 3, 572–582.

Chomsky, N. (1981). *Lectures in Government and Binding*: Dordrecht: Foris.

Choy, J.J., Thompson, C.K. (2010) Binding in agrammatic aphasia: Processing to comprehension, *Aphasiology*, 24:5, 551-579

Dink, J., Ferguson, B. (2016). _eyetrackingR. R package version 0.1.6, URL: http://www.eyetracking-R.com.

Drai, D., & Grodzinsky, Y. (2006). A new empirical angle on the variability debate: Quantitative neurosyntactic analyses of a large data set from Broca's Aphasia. *Brain and Language*, 96, 117–128.

Edwards S, Varlokosta S. (2007) Pronominal and anaphoric references in agrammatism. *Journal of Neurolinguistics, 20*: 423–444.

Goodglass H, Kaplan E, Barresi B. (2000). Boston Diagnostic Aphasia Examination-Third Edition (BDAE-3). Psychological Corporation, San Antonio, TX.

Gordon, P. C., Hendrick, R., & Johnson, M. (2004). Effects of noun phrase type on sentence complexity. *Journal of Memory and Language*, 51, 97–114.

Gordon, P. C., Hendrick, R., Johnson, M., & Lee, Y. (2006). Similarity-based

interference during language comprehension: Evidence from eye tracking during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32, 1304–1321.

Grodzinsky, Y. (1990). Theoretical perspectives on language deficits. Cambridge, MA: The MIT Press.

Grodzinsky, Y., Shapiro, L. P., & Swinney, D. (Eds.). (2000). *Language and the brain: Representation and processing* (pp. 295–313). San Diego, CA: Academic Press.

Grodzinsky Y, Wexler K, Chien YC, Marakovitz S, Solomon J. (1993) The breakdown of binding relations. *Brain and Language*, *45*(3):396–422.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of memory and language*, *59*(4), 434-446.

Kertesz, A. (2006). Western aphasia battery. San Antonio: PsychCorp.

Love, T., Nicol, J., Swinney, D., Hickok, G., & Zurif, E. (1998). The nature of aberrant understanding and processing of pro-forms by brain-damaged populations. *Brain and Language*, 65, 59–62.

Love, T., Oster, E. (2002). On the categorization of aphasic typologies: The SOAP (a test of syntactic complexity). *Journal of Psycholinguistic Research*, 31(5),503-529.

Manor, B. R., & Gordon, E. (2003). Defining the temporal threshold for ocular fixation in free-viewing visuocognitive tasks. *Journal of Neuroscience Methods*, 128, 85–93.

Mirman, D., Dixon, J. A., & Magnuson, J. S. (2008). Statistical and computational models of the visual world paradigm: Growth curves and individual differences. *Journal of Memory and Language*, 59(4), 475–494.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Santi, A., Friederici, A. D., Makuuchi, M., & Grodzinsky, Y. (2015). An fMRI Study Dissociating Distance Measures Computed by Broca's Area in Movement Processing: Clause boundary vs Identity. *Frontiers in psychology*, *6*, 654.

Sheppard, S., Walenski, M., Love, T., Shapiro. L.P. (2015). The Auditory Comprehension of Wh-Questions in Aphasia: Support for the Intervener Hypothesis. *Journal of Speech, Language and Hearing Research*. 58, 781-797.

Sullivan, N., Walenski, M., Love, T., Shapiro, L.P. (2016): The comprehension of sentences with unaccusative verbs in aphasia: a test of the intervener hypothesis, *Aphasiology*, 1-15.

Swinney, D., & Zurif, E. (1995). Syntactic processing in aphasia. *Brain and Language*, *50*(2), 225-239.

CHAPTER 6:

Conclusion

6.1 CONCLUSION

The primary goal of this dissertation was to investigate how listeners make sense of words like *her* and *herself* during auditory sentence processing and comprehension. Proforms (reflexive and personal pronouns) are of interest because unlike proper names, proforms depend on another linguistic element in order to carry meaning. Theoretical linguistics elucidates the precise syntactic constraints that govern the interpretation of proforms (Chomsky, 1981) and psycholinguistic research demonstrates that both children and adults with unimpaired language draw on their knowledge of syntactic constraints and accurately link proforms to their appropriate antecedent in real-time as young as age 4 (Nicol, 1988; McKee, Nicol & McDaniel, 1993; Love, Walenski & Swinney, 1993). Additionally, children with typical language development master the comprehension of sentences containing reflexives by age 4 and pronouns by age 7 (Chien & Wexler, 1990; Grodzinsky & Reinhart, 1993; McKee, 1992; van der Lely & Stollwerck, 1997; Friedmann, Novogrodsky & Balaban, 2010). As such, research within child language demonstrates that performance competencies captured by online measures are not always visible in offline comprehension tasks.

The requirement to link one sentence element to another is of course not limited to proforms but is a broadly occurring phenomenon within language. Sentences that are examples of filler-gap dependencies also require listeners to link sentence elements, and these elements are often at long distances from one another. Sentences that contain long-distance dependencies have been shown to be problematic for individuals with atypical language function, including children with specific

language impairment (van der Lely & Stollwerck, 1997; Deevy & Leonard, 2004; Marinis & van der Lely, 2007; Novogrodsky & Friedmann, 2006; Hestvik, Shwartz & Tornyova, 2010; Friedmann and Novogrodsky, 2011). and adults with agrammatic Broca's aphasia (Grodzinsky et al., 1993; Love, Nicol, Swinney, Hickock & Zurif, 1998; Avrutin, Lubarsky & Greene, 1999; Edwards & Varlokosta, 2007; Choy & Thompson, 2010, Grodzinsky, 1990; Caramazza & Zurif, 1976; Swinney & Zurif, 1995; Drai & Grodzinsky, 2006; Sheppard, Walenski, Love & Shapiro, 2015). Within theoretical accounts and research findings in these groups, there are inconsistencies in the comprehension patterns of sentences that contain filler-gap dependencies compared to proform-antecedent linking. That is, some researchers argue that the language impairments in these groups are limited to filler-gap constructions and that the process of proform-antecedent linking is spared. Arguments for good performance of proform-antecedent linking in children with SLI come from offline comprehension studies (Friedmann & Novogrodsky, 2011) while those in adults with Broca's aphasia have drawn on data from online processing methods (Choy & Thompson, 2010). Poor comprehension of proform-antecedent constructions has also been demonstrated for both groups by prior research (for SLI see: van der Lely & Stollwerck, 1997; for Broca's aphasia see: Love et al., 1998; Edwards & Varlokosta, 2007; Choy & Thompson, 2010). Thus, the issue of whether individuals with language impairments have difficulty processing and understanding the meaning of proforms remains equivocal.

An overarching goal of this dissertation was to investigate the potential of a recent theoretical account – the Intervener Hypothesis (IH) – to account for processing

and comprehension patterns of language impaired participants in sentences containing proform-antecedent dependencies. This account, which takes as its starting point psycholinguistic evidence demonstrating similarity-based interference in sentence processing in unimpaired participants (e.g., Gordon, Hendrick & Johnson, 2001; 2004), posits that the sentence comprehension deficits that are a hallmark of Broca's aphasia result from similarity-based interference. Given the overlap of sentence types for which individuals with Broca's aphasia and children with specific language impairment demonstrate difficulty with, this account also has the potential to account for processing and comprehension patterns within specific language impairment.

The studies described in this dissertation presented proforms in two distinct sentence constructions, subject relatives and complement phrases, thereby permitting a manipulation of both linear distance and structural distance (and the presence of an intervening NP of similar structure, predicted to result in similarity-based interference) between proforms and antecedents. Additionally, these studies employed an eyetracking-while-listening method to investigate moment-to-moment processing, and a sentence-picture matching task to measure final comprehension.

Chapter 4 investigated online processing and offline comprehension patterns in children with typical language development (TLD) and children with specific language impairment (SLI). Results from the sentence-picture matching task reflect good comprehension of all sentence types for TLD participants but significantly worse comprehension for SLI participants. The analyses of online processing revealed some similarities and a number of striking differences between groups. The gaze behavior of both groups was modulated by the type of sentence construction in which the proforms

were embedded, with better performance for complement phrase constructions compared to subject relatives in both participant groups. The performance of TLD participants showed sensitivity to both experimental factors of interest: performance was better for short compared to long distance conditions and for reflexives compared to pronouns. The disadvantage for long distance conditions was driven by the fact that TLD participants were temporarily distracted by the NP that most recently occurred, before shifting their gazes to the correct (long distance) NP. The increase in gazes to the correct referent in long distance conditions was captured in the growth curve analysis, which identified an increase in gazes to the correct referent in long distance conditions.

In contrast, SLI participants demonstrated an advantage for reflexives over pronouns but their performance did not differ based on the distance between a proform and antecedent. In a pattern similar to TLD participants, participants with SLI also demonstrated an increase in gazes to the correct (long distance) referent in the long reflexive condition and an overall higher proportion of gazes to correct referent in the short reflexive condition. The results of this study also provided insight into the moment-to-moment time course of proform-antecedent linking and reflects that the gaze patterns of SLI participants are delayed relative to TLD participants, in addition to delays for younger compared to older TLD participants. The findings presented in Chapter 4 provide support for the IH, where children with specific language impairment demonstrate a processing disadvantage for sentences containing proforms where the proform and antecedent are structurally distant and an NP of similar structure intervenes.

Chapter 5 investigated processing and comprehension patterns of the same sentence types as Chapter 4, this time in a group of adults with Broca's aphasia (LHD participants) and age-matched control (AMC) participants. Results from AMC participants reflect the same overall pattern as the TLD participants in Chapter 4. AMC participants demonstrated sensitivity to the linear distance between a proform and antecedent, as evidenced by a higher proportion of gazes to the correct referent in short distance conditions and an increase in gazes to the correct referent in long distance conditions. Also similar to TLD participants, AMC participants demonstrated near perfect comprehension of all sentence types in the sentence-picture matching task. Furthermore, the performance of LHD participants mirrors that of children with SLI. LHD participants demonstrated an advantage for reflexives over pronouns: as with the results from children with SLI, the results of LHD participants in Chapter 5 provide support for the IH, where greater processing difficulty is encountered when an NP of similar structure intervenes between a proform and antecedent. For LHD participants, the processing difficulty demonstrated via gaze behavior is also evident in offline behavior where comprehension of reflexive conditions is significantly better than pronoun conditions.

To summarize, the results of the studies included in this dissertation provide support for the IH, where individuals with language impairments encounter greater difficulty when the process of proform-antecedent linking requires the crossing of an NP of similar structure. The design employed in these studies permitted a comparison of linear versus structural distance and as such, further specifies the use of "intervener" within the IH to refer to an NP that *structurally* intervenes between a

proform and antecedent. These results contradict theories of language-impaired populations that predict that impairments are limited to filler-gap/syntactic movement constructions. Furthermore, the IH provides a single account and specifies an underlying mechanism that can account for a variety of sentence constructions known to be problematic for language-impaired populations, including proform-antecedent linking.

The studies included in this dissertation are not without their limitations. For one, the sample sizes of the language-impaired groups were small. In order to validate the findings here, these and other studies will draw on larger participant groups. In doing so, an effort should be made to identify distinct subgroups within children with SLI and adults with Broca's aphasia. To that end, the studies included here provide a model for identifying particpant groups who demonstrate specific syntactic deficits. As discussed throughout this dissertation, the strength of the IH comes from its potential to account for a variety of sentence constructions. While previous work has tested the IH in individuals with Broca's aphasia using *Wh*-questions (Sheppard, Walenski, Love & Shapiro, 2015) and unaccusative verbs (Sullivan, Walenski, Love & Shapiro, 2016), these sentence types should also be investigated in children with SLI. As the IH hinges on the premise of similarity-based interference it is also critical for future investigations to operationalize and experimentally manipulate "similarity". For example, future studies may use the same sentence types as those included here, but manipulate the semantic (e.g., animacy) or syntactic (e.g., quantifier expressions) features of interveners. If the interference effect can be mitigated with such manipulations, the IH account is strengthened while exposing a potential path to

treatment of such deficits.

The results reported in this dissertation provided data from a suite of analyses, and demonstrate the utility of drawing on a variety of analysis techniques to interpret a large dataset. However, the analysis methods included here are not exhaustive and a number of other possibilities may be considered in future investigations. In the studies included here, we narrowed our region of interest to begin at the onset of the proform and continue for 1000ms. This provided us with a rich dataset to address the process of proform-antecedent linking in real-time. Future investigations may draw on the techniques demonstrated here in addition to, for example, investigating the time course of lexical access, as measured by gaze latency to a referent during and/or following its mention, or operationalizing "interference" in terms of the number of switches between two competing referents.

In closing, this dissertation presented two novel research studies and drew data from four distinct participant groups. The results of these studies reflect similarities between individuals with normal language function across the lifespan. The "typical" pattern demonstrated by unimpaired participants is in contrast to children with SLI and adults with Broca's aphasia. The patterns of these language impaired groups, for whom the cause of language difficulty differs, demonstrate marked similarities that are in line with the predictions of the IH. It is my sincere hope that the work reported here will aid the work of fellow and future researchers and that together we may improve treatment methods and outcomes for individuals with language impairments.

REFERENCES

Avrutin, S., Lubarsky, S., & Greene, J. (1999). Comprehension of contrastive stress by Broca's aphasics. *Brain and Language*, *70*(2), 163-186.

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and language*, *3*(4), 572-582.

Chomsky, N. (1981). Lectures on binding and government. *Dordrecht: Foris*.

Choy, J. J., & Thompson, C. K. (2010). Binding in agrammatic aphasia: Processing to comprehension. *Aphasiology*, *24*(5), 551-579.

Deevy, P., & Leonard, L. B. (2004). The comprehension of wh-questions in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *47*(4), 802-815.

Drai, D., & Grodzinsky, Y. (2006). A new empirical angle on the variability debate: Quantitative neurosyntactic analyses of a large data set from Broca's Aphasia. *Brain and Language*, 96, 117–128.

Edwards, S., & Varlokosta, S. (2007). Pronominal and anaphoric reference in agrammatism. *Journal of Neurolinguistics*, *20*(6), 423-444.

Friedmann, N., & Novogrodsky, R. (2011). Which questions are most difficult to understand?: The comprehension of Wh questions in three subtypes of SLI. *Lingua*, *121*(3), 367-382.

Friedmann, N., Novogrodsky, R., & Balaban, N. (2010). The Effect of Crossing Dependencies on the Acquisition of Pronoun Comprehension. In F. P. A. Castro, J. Costa & M. Lobo (Ed.), *Language Acquisition and Development: Generative Approaches to Language Acquisition* (pp. 146–156). Newcastle, UK: Cambridge Scholars Press.

Gordon, P.C., Hendrick, R., Johnson, M. (2001). Memory interference during language processing. *Journal of Experimental Psychology: Learning, Memory and Cognition*; 27:1411–1423.

Gordon, P.C., Hendrick R., Johnson M. (2004) Effects of noun phrase type on sentence complexity. *Journal of Memory and Language*; 51: 97–114.

Grodzinsky, Y. (1990). Theoretical perspectives on language deficits. Cambridge, MA: The MIT Press.

Grodzinsky, Y., & Reinhart, T. (1993). The innateness of binding and coreference. *Linguistic inquiry*, 69-101.

Grodzinsky Y, Wexler K, Chien YC, Marakovitz S, Solomon J. (1993) The breakdown of binding relations. *Brain and Language*, *45*(3): 396–422.

Hestvik, A., Schwartz, R. G., & Tornyova, L. (2010). Relative clause gap-filling in children with specific language impairment. *Journal of psycholinguistic research*, *39*(5), 443-456.

Love, T., Nicol, J., Swinney, D., Hickok, G. and Zurif, E. (1998) The Nature of Aberrant Understanding and Processing of Pro-forms by Brain-Damaged Populations. Proceedings from the Academy of Aphasia Conference, Brain and Language.

Love, T., Walenski, M., & Swinney, D. (2009). Slowed speech input has a differential impact on on-line and off-line processing in children's comprehension of pronouns. *Journal of psycholinguistic research*, *38*(3), 285-304.

Marinis, T., & van der Lely, H. K. (2007). On-line processing of wh-questions in children with G-SLI and typically developing children. *International Journal of Language & Communication Disorders*, *42*(5), 557-582.

McKee, C. (1992). A comparison of pronouns and anaphors in Italian and English acquisition. *Language Acquisition: A Journal of Developmental Linguistics*, 2, 21–54.

McKee, C., Nicol, J., & McDaniel, D. (1993). Children's application of binding during sentence processing. *Language and Cognitive Processes*, *8*(3), 265-290.

Nicol, J. L. (1988). *Coreference processing during sentence comprehension.* PhD Thesis. Massachusetts Institute of Technology, Dept. of Brain and Cognitive Sciences.

Novogrodsky, R., & Friedmann, N. (2006). The production of relative clauses in syntactic SLI: A window to the nature of the impairment. *Advances in Speech Language Pathology*, *8*(4), 364-375.

Sheppard, S. M., Walenski, M., Love, T., & Shapiro, L. P. (2015). The auditory comprehension of Wh-questions in aphasia: support for the intervener hypothesis. *Journal of Speech, Language, and Hearing Research*, *58*(3), 781-797.

Sullivan, N., Walenski, M., Love, T., Shapiro, L.P. (2016): The comprehension of sentences with unaccusative verbs in aphasia: a test of the intervener hypothesis, *Aphasiology*, 1-15.

Swinney, D., & Zurif, E. (1995). Syntactic processing in aphasia. *Brain and Language*, *50*(2), 225-239.

Van der Lely, H. K., & Stollwerck, L. (1997). Binding theory and grammatical specific language impairment in children. *Cognition*, *62*(3), 245-290.

APPENDIX

Complete list of discourse and target sentences

Set #		
1	*Discourse*	A sheriff and a cowboy were walking in the desert.
	Target	The sheriff yelled that the cowboy scratched him/himself just below the knee.
	Discourse	A cowboy and a sheriff were walking in the desert.
	Target	The cowboy that followed the sheriff scratched him/himself just below the knee.
2	*Discourse*	A boy and a dad were swimming in a big pool.
	Target	The boy recognized that the dad splashed him/himself with the cold water.
	Discourse	A dad and a boy were swimming in a big pool.
	Target	The dad that waved at the boy splashed him/himself with the cold water.
3	*Discourse*	A teacher and a student were picking a line leader at school.
	Target	The teacher agreed that the student pointed at her/herself with the right index finger.
	Discourse	A student and a teacher were picking a line leader at school.
	Target	The student that listened to the teacher pointed at her/herself with the right index finger.
4	*Discourse*	A singer and a dancer were practicing for the TV show.
	Target	The singer believed that the dancer smacked her/herself on the back of the hand.
	Discourse	A dancer and a singer were practicing for the TV show.
	Target	The dancer that worked with the singer smacked her/herself on the back of the hand.
5	*Discourse*	A girl and a mom were swimming at the beach.
	Target	The girl noticed that the mom dried her/herself with a soft blue towel.
	Discourse	A mom and a girl were swimming at the beach.
	Target	The mom that watched the girl dried her/herself with a soft blue towel.
6	*Discourse*	A doctor and a patient were looking at paperwork.
	Target	The doctor discovered that the patient poked him/himself without realizing it.
	Discourse	A patient and a doctor were looking at paperwork.
	Target	The patient that talked to the doctor poked him/himself without realizing it.
7	*Discourse*	A grandpa and a painter were out shopping for a mirror.
	Target	The grandpa said that the painter looked at him/himself for a really long time.
	Discourse	A painter and a grandpa were out shopping for a mirror.
	Target	The painter that walked with the grandpa looked at him/himself for a really long time.
8	*Discourse*	A grandma and a baker made a big mess while baking a cake.

	Target	The grandma said that the baker cleaned her/herself with a clean new washcloth.
	Discourse	A baker and a grandma made a big mess while baking a cake.
	Target	The baker that helped the grandma cleaned her/herself with a clean new washcloth.
9	*Discourse*	A fireman and a policeman were walking in the forest.
	Target	The fireman agreed that the policeman tripped him/himself on a big fallen log.
	Discourse	A policeman and a fireman were walking in the forest.
	Target	The policeman that followed the fireman tripped him/himself on a big fallen log.
10	*Discourse*	A princess and a maid were playing a game of tag around the castle.
	Target	The princess recognized that the maid tapped her/herself gently on the shoulder.
	Discourse	A maid and a princess were playing a game of tag around the castle.
	Target	The maid that chased the princess tapped her/herself gently on the shoulder.
11	*Discourse*	A dog and a cat were relaxing under a big tree.
	Target	The dog saw that the cat licked her/herself on the paw and arm.
	Discourse	A cat and a dog were relaxing under a big tree.
	Target	The cat that looked at the dog licked her/herself on the paw and arm.
12	*Discourse*	A mouse and a bird were sitting around a puddle.
	Target	The mouse made sure that the bird washed her/herself in the warm water.
	Discourse	A bird and a mouse were sitting around a puddle.
	Target	The bird that sat with the mouse washed her/herself in the warm water.
13	*Discourse*	A boy and a builder were in the garage with some tools.
	Target	The boy screamed that the builder banged him/himself really hard on the head.
	Discourse	A boy and a builder were in the garage with some tools.
	Target	The builder that shoved the boy banged him/himself really hard on the head.
14	*Discourse*	An athlete and a coach were playing soccer in the gym.
	Target	The athlete yelled that the coach kicked him/himself in the leg on accident.
	Discourse	A coach and an athlete were playing soccer in the gym.
	Target	The coach that taught the athlete kicked him/himself in the leg on accident.
15	*Discourse*	A chef and a lunchlady were slicing bread with a sharp knife.
	Target	The chef cried that the lunchlady cut her/herself pretty badly on the thumb.
	Discourse	A lunchlady and a chef were slicing bread with a sharp knife.
	Target	The lunchlady that listened to the chef cut her/herself pretty badly on the thumb.
16	*Discourse*	A tourist and a driver went to the car wash in a taxi.
	Target	The tourist announced that the driver sprinkled him/himself with the cleaning supplies.
	Discourse	A driver and a tourist went to the car wash in a taxi.
	Target	The driver that waved at the tourist sprinkled him/himself with the cleaning supplies.

17	*Discourse*	A horse and a cow were chasing each other around the barn.
	Target	The horse discovered that the cow pushed her/herself right into some flowers.
	Discourse	A cow and a horse were chasing each other around the barn.
	Target	The cow that ran after the horse pushed her/herself right into some flowers.
18	*Discourse*	A clown and a monster were playing with a feather.
	Target	The clown shouted that the monster tickled him/himself on the neck and ear.
	Discourse	A monster and a clown were playing with a feather.
	Target	The monster that teased the clown tickled him/himself on the neck and ear.
19	*Discourse*	A king and an artist were practicing with paints and brushes.
	Target	The king loved that the artist painted him/himself on the white canvas.
	Discourse	An artist and a king were practicing with paints and brushes.
	Target	The artist that sat with the king painted him/himself on the white canvas.
20	*Discourse*	A monkey and a lion were chasing each other with a bucket.
	Target	the monkey knew that the lion soaked him/himself with the cool water.
	Discourse	A lion and a monkey were chasing each other with a bucket.
	Target	The lion that ran after the monkey soaked him/himself with the cool water.
21	*Discourse*	A grandma and a girl were baking cookies in the kitchen.
	Target	The grandma shouted that the girl burned her/herself on the corner of the stove.
	Discourse	A girl and a grandma were baking cookies in the kitchen.
	Target	The girl that thanked the grandma burned her/herself on the corner of the stove.
22	*Discourse*	A grandpa and a boy went to the park for a picnic.
	Target	The grandpa cried that the boy poked him/himself right in the eye with a stick.
	Discourse	A boy and a grandpa went to the park for a picnic.
	Target	The boy that drove the grandpa poked him/himself right in the eye with a stick.
23	*Discourse*	A mom and a baby were eating lunch at a restaurant.
	Target	The mom saw that the toddler fed her/herself with a little spoon.
	Discourse	A mom and a baby were eating lunch at a restaurant.
	Target	The toddler that pleased the mom fed her/herself with a little spoon.
24	*Discourse*	A king and a prince were fighting over the crown.
	Target	The king screamed that the prince tripped him/himself on the marble stairs.
	Discourse	A prince and a king were fighting over the crown.
	Target	The prince that shoved the king tripped him/himself on the marble stairs.
25	*Discourse*	A queen and a princess were having an argument in the bedroom.
	Target	The queen made sure that the princess dressed her/herself in a brand new silk gown.
	Discourse	A princess and a queen were having an argument in the bedroom.
	Target	The princess that teased the queen dressed her/herself in a brand new silk gown.

26	*Discourse*	A mailman and a fireman were delivering a letter.
	Target	The mailman felt that the fireman pushed him/himself into the small truck.
	Discourse	A fireman and a mailman were delivering a letter.
	Target	The fireman that drove the mailman pushed him/himself into the small truck.
27	*Discourse*	A singer and a hairdresser were curling hair with a curling iron.
	Target	The singer noticed that the hairdresser burned her/herself accidentally on the arm.
	Discourse	A hairdresser and a singer were curling hair with a curling iron.
	Target	The hairdresser that worked for the singer burned her/herself accidentally on the arm.
28	*Discourse*	A mouse and a cat were cleaning up in the tub.
	Target	The mouse knew that the cat washed her/herself with a bar of soap.
	Discourse	A cat and a mouse were cleaning up in the tub.
	Target	The cat that greeted the mouse washed her/herself with a bar of soap.
29	*Discourse*	A bird and a dog were sitting together on the porch.
	Target	The bird thought that the dog scratched him/himself on the head and ears.
	Discourse	A dog and a bird were sitting together on the porch.
	Target	The dog that looked at the bird scratched him/himself on the head and ears.
30	*Discourse*	A clown and a monkey were running around with a hose.
	Target	The clown liked that the monkey sprayed him/himself with the warm water.
	Discourse	A monkey and a clown were running around with a hose.
	Target	The monkey that chased the clown sprayed him/himself with the warm water.
31	*Discourse*	A policeman and a teacher were standing around a big hole.
	Target	The policeman reported that the teacher tripped him/himself on a jagged rock.
	Discourse	A teacher and a policeman were standing around a big hole.
	Target	The teacher that talked to the policeman tripped him/himself on a jagged rock.
32	*Discourse*	A builder and a baker were walking by the grocery store.
	Target	The builder claimed that the baker patted him/himself on the top of the head.
	Discourse	A baker and a builder were walking by the grocery store.
	Target	The baker that walked with the builder patted him/himself on the top of the head.
33	*Discourse*	A farmer and a painter were fixing a door with spray paint.
	Target	The farmer claimed that the painter painted him/himself without meaning to.
	Discourse	A painter and a farmer were fixing a door with spray paint.
	Target	The painter that helped the farmer painted him/himself without meaning to.
34	*Discourse*	A nurse and a librarian were lighting some birthday candles.
	Target	The nurse believed that the librarian burned her/herself with one of the matches.

	Discourse	A librarian and a nurse were lighting some birthday candles.
	Target	The librarian that greeted the nurse burned her/herself with one of the matches.
35	*Discourse*	A father and a child went to buy a camera.
	Target	The father announced that the child photographed him/himself by the beautiful beach.
	Discourse	A child and a father went to buy a camera.
	Target	The child that pleased the father photographed him/himself by the beautiful beach.
36	*Discourse*	A mom and a daughter were trying on clothes.
	Target	The mom loved that the daughter looked at her/herself in the full-length mirror.
	Discourse	A daughter and a mom were trying on clothes.
	Target	The daughter that thanked the mom looked at her/herself in the full-length mirror.
37	*Discourse*	A student and an artist were all messy after making pottery.
	Target	The student reported that the artist cleaned her/herself with a soft washcloth.
	Discourse	An artist and a student were all messy after making pottery.
	Target	The artist that taught the student cleaned her/herself with a soft washcloth.
38	*Discourse*	A horse and a pig were resting near a fence.
	Target	The horse thought that the pig bathed her/herself out in the sunshine.
	Discourse	A pig and a horse were resting near a fence.
	Target	The pig that watched the horse bathed her/herself out in the sunshine.
39	*Discourse*	A frog and a fish were playing together around a pond.
	Target	The frog felt that the fish splashed him/himself all over with water.
	Discourse	A fish and a frog were playing together around a pond.
	Target	The fish that played with the frog splashed him/himself all over with water.
40	*Discourse*	A baby and a grandpa were playing peek-a-boo behind a blanket.
	Target	The baby liked that the grandpa pointed at him/himself with two different fingers.
	Discourse	A grandpa and a baby were playing peek-a-boo behind a blanket.
	Target	The grandpa that played with the baby pointed at him/himself with two different fingers.