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Lexical and Prosodic Effects on Syntactic Ambiguity Resolution in Aphasia

Gayle DeDe

Department of Speech, Language, and Hearing Sciences, University of Arizona, 1131 East 2nd Street, Building 71, Tucson, AZ 85721

Abstract

The purpose of this study was to determine whether and when individuals with aphasia and healthy controls use lexical and prosodic information during on-line sentence comprehension. Individuals with aphasia and controls ($n = 12$ per group) participated in a self-paced listening experiment. The stimuli were early closure sentences, such as “*While the parents watched(,) the child sang a song.*” Both lexical and prosodic cues were manipulated. The cues were biased toward the subject- or object- of the ambiguous noun phrase (*the child*). Thus, there were two congruous conditions (in which both lexical cues and prosodic cues were consistent) and two incongruous conditions (in which lexical and prosodic cues conflicted). The results showed that the people with aphasia had longer listening times for the ambiguous noun phrase (the child) when the cues were conflicting, rather than consistent. The controls showed effects earlier in the sentence, at the subordinate verb (watched or danced). Both groups showed evidence of reanalysis at the main verb (sang). These effects demonstrate that the aphasic group was sensitive to the lexical and prosodic cues, but used them on a delayed time course relative to the control group.

Keywords

Syntactic ambiguity resolution; aphasia; on-line sentence processing; prosody

1. Introduction

Although language comprehension generally seems effortless, the underlying processes are by no means simple. The moment-to-moment (on-line) parsing operations that build syntactic and semantic representations are typically automatic and astonishingly fast. Disruptions of these processes are well-documented in people with aphasia, resulting in communication impairments such as difficulty participating in conversations. Studies have shown that these processing disruptions affect how people with aphasia understand sentences that are syntactically complex due to manipulations that affect word order. For example, compare sentences (1) and (2):

1. The dog chased the cat. (Active Sentence)
2. The cat was chased by the dog. (Passive Sentence)

Sentence (1) might be interpreted correctly without a complete syntactic analysis because it contains canonical word order for English (subject-verb-object, or SVO). In contrast, understanding sentences with non-canonical word order (as in 2) requires an accurate syntactic analysis because strategies based on English word order patterns lead to the wrong

interpretation. The typical finding for these types of structures is that aphasic individuals who demonstrate good comprehension of sentences with canonical word order perform poorly on sentences with non-canonical word order (Caplan, Baker, & Dehaut, 1985; Caplan, Waters, DeDe, Michaud, & Reddy, 2007; Caramazza & Zurif, 1976; Grodzinsky, 2000).

1.1 Probabilistic Cues in Sentence Comprehension

Studies of normal sentence processing have demonstrated that non-brain-damaged individuals also have more trouble understanding sentences with non-canonical word order (e.g., Waters & Caplan, 1999). However, this body of work has also identified other types of complexity that may be important factors in aphasic sentence comprehension. For example, there is extensive evidence that the on-line parsing operations that build syntactic and semantic representations are influenced by probabilistic cues (see MacDonald, Pearlmutter, & Seidenberg, 1994; Pickering & van Gompel, 2006 for reviews). Such cues act as constraints on the interpretation of a sentence by narrowing the pool of possible and likely syntactic structures and meanings. Probabilistic cues refer to information such as the likelihood that a word will occur in a particular context (e.g., Trueswell & Tanenhaus, 1994), the plausibility of the possible meanings of a sentence (e.g., Garnsey, Pearlmutter, Myers, & Lotocky, 1997), prosodic contours (e.g., DeDe, 2010; Kjelgaard & Speer, 1999) and other types of information that bias the reader/listener toward a particular structure or interpretation of a sentence. However, the available cues are not always biased towards the same interpretation of the sentence. Studies of unimpaired populations have convincingly demonstrated that probabilistic cues influence the online construction of syntactic representations and that conflicting cues slow down sentence processing (e.g., Frazier & Clifton, 1996; Garnsey et al., 1997; MacDonald et al., 1994; Pickering & Van Gompel 2006; Staub, 2007; Trueswell & Tanenhaus, 1994). This evidence suggests that it is important to understand how conflicting probabilistic cues affect sentence comprehension in people with aphasia.

Sentences with temporary syntactic ambiguities, such as the early and late closure sentences in examples 3-5 below, provide one means of studying the use of probabilistic cues during sentence processing. In sentences with early and late closure syntax, the second noun phrase “*the child*” is temporarily ambiguous because it may be the beginning of a new clause (early closure, examples 3 & 4) or the object of the subordinate verb (late closure, example 5). The main verb “*sings*” is the point of disambiguation for early closure sentences. At that point, it is clear that “*the child*” must be the subject for the main verb. In late closure sentences such as example 5, “*she*” is the point of disambiguation because it cannot be integrated into the subordinate clause (e.g., Frazier & Rayner, 1982; Staub, 2007). The critical question in processing early and late closure sentences is understanding what determines how people initially interpret the ambiguous noun phrase.

Early Closure Examples

1. While the parents watch (,) the child sings a song with her grandmother.
2. While the parents dance (,) the child sings a song with her grandmother.

Late Closure Example

1. While the parents watch the child (,) she sings a song with her grandmother.

1.1.1 Lexical Cues in Sentence Comprehension—The contrasting sentences in examples (3) and (4) illustrate two types of cues that may affect the initial interpretation of early closure sentences: *verb transitivity bias* and *plausibility*. Verb transitivity bias refers to

the likelihood that a verb will take a direct object. For example, the verb “*watch*” is transitively biased, meaning that it is usually followed by a direct object. In contrast, “*dance*” is intransitively biased because it seldom takes a direct object. Examples (3) and (4) also vary in how likely it is that the subordinate verb (*watch* or *dance*) would take the ambiguous noun phrase (*the child*) as its direct object. In example (3), the combination of the transitively biased verb “*watch*” and a plausible object (“*the child*”) increases the likelihood that the *object* interpretation will be pursued initially. In example (4), the intransitively biased verb “*danced*” is followed by an implausible direct object (“*the child*”). This increases the likelihood that the ambiguous noun phrase will initially be interpreted as the *subject* of a new clause. The effects of manipulations of verb transitivity bias and plausibility on reading sentences with early closure ambiguities have been well-documented in unimpaired populations (Adams, Clifton, & Mitchell, 1998; Mitchell, 1987; van Gompel & Pickering, 2001; Staub, 2007).

There is some evidence that people with aphasia are sensitive to cues such as verb transitivity bias and plausibility. Shapiro and colleagues examined whether individuals with fluent and non-fluent aphasia were sensitive to verb argument structure complexity and preferences using a cross-modal lexical decision task (Russo, Peach, & Shapiro, 1998; Shapiro, Gordon, Hack, & Killackey, 1993a; Shapiro & Levine, 1990; Shapiro, Nagel, & Levine, 1993b). In people with non-fluent aphasia and non-brain-damaged controls, the processing load for verbs with multiple possible argument structures was greater than the processing load for verbs with only one possible argument structure (Shapiro et al., 1990, 1993a, 1993b). Individuals with fluent aphasia were not sensitive to this type of verb complexity (Shapiro et al., 1993b, also cf. Russo et al., 1998).

However, studies using end-of-sentence judgment tasks have reported that people with both fluent and non-fluent aphasia made more accurate plausibility judgments about structurally simple sentences when the syntactic structure of the sentence was consistent with the verb's transitivity bias (Gahl, 2002; Gahl et al., 2003). Gahl and colleagues' results were generally consistent with the on-line data reported by Shapiro and colleagues (Shapiro et al., 1993b, also cf. Russo et al., 1998) for the non-fluent group, but not for the fluent group. Taken together, the results from the on-line and end-of-sentence studies suggest that individuals with non-fluent aphasia are sensitive to verb transitivity biases. In contrast, individuals with fluent aphasia may activate and/or integrate information about verb argument structure and subcategorization biases too slowly to influence on-line measures, but quickly enough to influence performance on end-of-sentence measures.

There are no demonstrations that people with aphasia are sensitive to plausibility cues during on-line sentence processing. However, there is evidence that individuals with Broca's and conduction aphasia perform relatively well on end-of-sentence comprehension measures when plausibility constrains interpretation, for example “*The apple that the boy is eating is red.*” Such data indicate that people with aphasia are sensitive to plausibility information, but do not address the time course with which they use it (e.g., Caramazza & Zurif, 1976; Deloche & Seron, 1981; Dickey & Thompson, 2004; Grodzinsky, 2000).

To sum up, there is evidence that verb transitivity bias and plausibility influence syntactic ambiguity resolution in unimpaired populations. There is also reason to believe that people with aphasia are sensitive to verb transitivity biases and plausibility cues, at least based on end-of-sentence judgment tasks. Importantly, there are no data regarding how people with aphasia use these types of cues during syntactic ambiguity resolution.

1.1.2 Prosodic Cues in Sentence Comprehension—Most studies of sentence comprehension in aphasia have focused on the auditory modality because it is the more

“natural” modality for language (in the sense that it does not require explicit instruction to learn). As a result, another important probabilistic cue to consider is prosodic contour. In the simplest sense, prosodic boundaries can be conceptualized as marking syntactic clause boundaries using the auditory analog of written symbols such as commas and periods. For example, marking the syntactic boundary following the subordinate verb (“*watch*” or “*dance*” in examples 3 & 4 above) with a prosodic boundary increases the likelihood that “*the child*” would be interpreted as the subject of the main clause. There is extensive evidence that the presence or absence of prosodic boundaries influences syntactic ambiguity resolution in college-age adults (e.g., Blodgett, 2004; DeDe, 2010; Kjelgaard & Speer, 1999; Marslen-Wilson, Tyler, Warren, Grenier, & Lee, 1992; Nagel, Shapiro, Tuller, & Nawy, 1996; Schepman, 1997; Snedeker & Yuan, 2008; Speer, Kjelgaard, & Dobroth, 1996; Warren, Grabe, & Nolan, 1995).

End of sentence judgment tasks suggest that people with aphasia are less sensitive to prosodic cues than non-brain-damaged controls (e.g., Pell & Baum, 1997; Perkins, Baran, & Gandour, 1996; see Baum & Pell 1999, for review). In contrast, the few studies using on-line measures suggest that people with aphasia are sensitive to prosodic cues, but use them differently than controls. Walker, Fongemie, and Daigle (2001) reported that both people with aphasia and controls made judgments more quickly and accurately when sentences were pronounced with prosodic contours that matched their syntactic structure than when the prosodic contour was inconsistent with the syntactic structure. Using a cross modal lexical task, Baum and Dwivedi (2003) found that people with aphasia responded more quickly to stimuli when the prosodic contour conflicted with the final interpretation of the sentence than to stimuli with prosodic contours consistent with the sentence structure. This effect goes in the ‘wrong’ direction, since prosodic contours that contradict the actual sentence structure are predicted to cause longer reaction times than prosodic contours that match the sentence structure. Baum and Dwivedi concluded that aphasic individuals perceived the prosodic cues but did not use them in the same way as non-brain-damaged controls. Thus, there is reason to believe that people with aphasia are sensitive to prosodic contour during on-line sentence processing, but how they use this information is not clear.

1.1.3 Interaction between Lexical and Prosodic Cues—Given the number of potential probabilistic cues, it is important to determine how sentence processing is affected when the available cues bias the listener to different interpretations of the sentence. A small number of studies have investigated the interactions between prosodic contour and lexical cues in college age adults during syntactic ambiguity resolution (Blodgett, 2004; DeDe, 2010; Kjelgaard & Speer, 1999; Pynte & Prieur, 1996; Snedeker & Yuan, 2008). Based on this work, there is a growing consensus that prosodic cues interact with lexical cues such as verb bias and plausibility in non-disordered populations (Blodgett, 2004; DeDe, 2010; Snedeker & Yuan, 2008).

DeDe (2010) examined how conflicting lexical and prosodic cues affect on-line processing of early closure sentences using the self-paced listening task, which is sensitive to online syntactic processes. In this task, the listening time for each segment of the sentence is interpreted as a measure of its processing demand. To be comparable to existing studies of this sentence structure in the written modality, DeDe combined information about verb transitivity bias and plausibility into a single “lexical” factor (as in examples 3 and 4). The intonational cue consisted of the presence or absence of a prosodic boundary marking the subordinate verb.

The results showed that the lexical and prosodic cues at the ambiguous noun phrase (i.e., “*the child*” in examples 3 & 4) influenced how college-age adults processed the sentences online (DeDe, 2010). At the ambiguous noun phrase, conflicting cues resulted in longer

listening times than consistent cues, suggesting that the listeners attempted to resolve the conflict between alternative interpretations. When both types of cues were consistent with the (correct) *subject* interpretation, processing times were short compared to other conditions at both the ambiguous noun phrase and disambiguating main verb. In contrast, consistent cues toward the (incorrect) *object* interpretation resulted in short processing times at the ambiguous noun phrase but long processing times at the disambiguating main verb (i.e., “*sings*” in examples 3 & 4). This indicates that the listeners reinterpreted the ambiguous noun phrase as the subject of the main clause after realizing that it could not be the object of “*watch*.” Listening times for the subordinate verb (i.e., “*danced/watched*” in examples 3 & 4) were also longer when the two cues available at that point in the sentence - verb transitivity bias and prosodic contour - were conflicting. These results suggest that the listeners were sensitive to the presence of conflicting cues at the subordinate verb, which is the earliest point in the sentence with any conflict.

Together, the data demonstrate the probabilistic cues influenced the listeners' parsing decisions. When the cues were consistent with one another, the initial interpretation of the ambiguous noun phrase followed the cues' bias. Additionally, the college age adults were slowed by the presence of conflicting cues, suggesting that the participants integrated the cues on-line.

1.2 The Present Study

Given the evidence that probabilistic cues play an important role in normal sentence processing, any theory concerning the nature of sentence comprehension impairments in aphasia must account for changes in how individuals with aphasia use these types of cues. The present experiment investigated whether people with aphasia experience difficulty resolving conflicts between probabilistic cues during syntactic ambiguity resolution. People with aphasia and non-brain-damaged controls listened to early closure sentences that varied by whether the lexical and prosodic cues were biased toward the subject or object interpretation of the ambiguous noun phrase in a self-paced listening task. The materials and methods were identical to those used by DeDe (2010), which was described above.

The pattern of listening times expected for the non-brain-damaged controls is similar to that observed in DeDe (2010). Specifically, longer listening times would be predicted for the ambiguous noun phrase (*the child* in examples 3 & 4) when the lexical and prosodic cues were biased toward conflicting interpretations of that segment (i.e., subject vs. object). Relatively short listening times would be predicted when the cues available at the ambiguous noun phrase were biased towards the same interpretation. At the main verb (*sings*), longer listening times would be predicted if the listeners initially treated the ambiguous noun phrase as the object of the subordinate verb (*dance/watch*). In this case, the longer listening times would be taken as evidence that the listener reinterpreted the ambiguous noun phrase as the subject of the main verb. If the listener interprets the ambiguous noun phrase as the subject of a new clause, then listening times for the main verb should be relatively fast.

People with aphasia are likely to perform differently than the control group on these types of sentences. There are two general classes of theories that attempt to explain sentence comprehension impairments in people with aphasia: *representational* and *processing* accounts. Although neither class of theory has previously been extended to syntactic ambiguity resolution in people with aphasia, it is possible to generate general predictions based on the principles underlying each approach.

Representational accounts typically ascribe sentence comprehension impairments to deficits affecting an individual's knowledge of syntactic structures or rules (e.g., Trace Deletion

Hypothesis, Grodzinsky, 2000). This class of theory might generate the prediction that people with aphasia would be insensitive to certain probabilistic cues. For example, if people with aphasia do not use prosodic contour as a probabilistic cue, then they might only show effects of the lexical manipulation in syntactic ambiguity resolution.

All *processing* accounts share the basic idea that structural knowledge is retained in people with aphasia, but that the ability to apply that knowledge is impaired. However, the nature of the processing deficit remains controversial. Some researchers have argued that people with aphasia build syntactic representations more slowly than non-brain-damaged controls (Haarmann & Kolk, 1991; Zurif et al., 1993). Another view is that people with aphasia build syntactic structures on a normal time course, but are slow to integrate lexical meanings based on that structure (Thompson & Choy, 2009). These types of processing theories might predict that people with aphasia would be sensitive to prosodic and lexical cues, but access or integrate different sources of information more slowly than controls.

2. Methods

2.1 Participants

People with aphasia and non-brain-damaged controls ($n = 12$ per group) participated in the study. The groups were matched by age and education level. The mean age was 63.1 years (range: 54 - 81) for the aphasic group and 65.6 years (range: 56 - 75) for the control group. Mean education level was 16.9 years for the aphasic group and 16.4 years for the control group (range: 12 - 20 years for both groups).

All participants were native English speakers and denied any history of central nervous system disease (other than stroke for the people with aphasia), substance abuse, learning disabilities, psychiatric illness, or serious medical illness. For the people with aphasia, this was confirmed by reviewing their medical records. The control group completed the Mini-Mental State Exam to rule out the presence of dementia (Folstein, Folstein, & McHugh, 1975). All participants had normal hearing for their age group, as determined by pure tone audiometry at 500, 1000, 2000, and 4000 Hertz (Harford & Dodds, 1982).

The people with aphasia were at least six months post-onset from single left-hemisphere lesions. Table 1 presents demographic and clinical information. All had been diagnosed with aphasia by their medical doctor (established by reviewing medical records). This diagnosis was confirmed based on testing completed by a licensed speech-language pathologist. The participants were not selected on the basis of aphasia type,¹ but the results of the testing battery were used to characterize the aphasic individual's language capacities (Table 2).

The presence of a speech-language disorder was confirmed by documenting the presence of anomia, which is a symptom of all aphasia types (Goodglass et al., 2000), in spontaneous speech or on the Boston Naming Test (BNT; Kaplan et al., 2001). Two of the 12 participants

¹Although many studies focus on aphasic individuals with specific syndrome classifications, there are problems with this approach. First, there is a lot of variability in the profile of symptoms observed in people within each syndrome classification, meaning that syndrome classifications do not provide systematic or reliable information about the functioning of psycholinguistic processes such as lexical access (e.g., Berndt, Mitchum, & Wayland, 1997; Caplan & Waters, 2001). Second, there is evidence that individuals with different syndrome classifications show similar types of sentence comprehension impairments (e.g., Balogh & Grodzinsky, 2001; Berndt et al., 1996). Studies restricted a priori to individuals with a particular syndrome cannot detect such cross-syndrome similarities. Third, groups defined on the basis of syndrome classification differ from one another and non-brain-damaged controls as a matter of degree, rather than qualitatively (e.g., Dick, Bates, & Wulfeck, 2001). Given these types of evidence, a mixed group of people with aphasia were recruited in the present study. These participants were tested to determine aphasia type and subgroup analyses by aphasia type were conducted. None of these analyses produced coherent, distinct patterns of results, providing further evidence against the utility of aphasia syndromes to explain psycholinguistic processing deficits. Interested readers are referred to DeDe (2008).

with aphasia (50003 and 50010) scored within the normal range for their age group, but were included because they demonstrated significant anomia in spontaneous speech and required extra time to correctly name items during the test.

Individuals with aphasia were required to perform within two standard deviations of the mean for age-matched peers on the Peabody Picture Vocabulary Test Form IIIA in order to be included in the study (PPVT; Dunn & Dunn, 1997). The purpose was to ensure that they did not have significantly impaired word level comprehension. The PPVT includes normative data for non-brain-damaged individuals from 2 to 90 years of age. The vocabulary items are drawn from multiple parts of speech, including adjectives, adverbs, nouns, and verbs. Participants pointed to the picture (from a field of 4) that matched a verbal label provided by the examiner.

The short form of the Boston Diagnostic Aphasia Examination (BDAE-3; Goodglass et al., 2000) was administered to characterize the participants' aphasia profiles. The rating scale profile of speech characteristics was completed on the basis of two spontaneous speech samples (free conversation and description of the Cookie Theft Picture), the sentence repetition score, and the mean percentile of the three auditory comprehension subtests.

Severity of the people with aphasia's sentence comprehension impairments was characterized using accuracy scores on a self-paced listening version of Gahl's (2002) sentence comprehension task. This task examines comprehension of active transitive and intransitive sentences that contain transitively and intransitively biased verbs. Sample items and comprehension probes are in Table 3. Following Gahl (2002), there were two “verb match” conditions. In the *concordant* condition, transitively biased verbs occurred in transitive sentences and intransitively biased verbs occurred in intransitive sentences. That is, the verb's transitivity bias matched the sentence structure. In the *discordant* condition, intransitively biased verbs occurred in transitive sentences and transitively biased verbs occurred in intransitive sentences. That is, the verb's transitivity bias was mismatched with the sentence structure. Unlike Gahl (2002), True/False probes were used to assess comprehension.

The results are presented in Table 2. All of the aphasic participants performed above chance on the comprehension questions in the *concordant* condition, demonstrating that their comprehension of simple sentences was relatively good. The people with aphasia also answered more questions correctly in the *concordant* than *discordant* condition, $F(1, 11)=11.50$, $p<.01$. This demonstrates that they had more difficulty understanding sentences when the verb's transitivity bias did not match the sentence structure.

2.2 Experimental Materials

The experimental materials consisted of 15 sentence pairs containing early closure syntax (see examples 3 & 4, which are repeated below as 6 & 7 for ease of exposition). Two independent variables were manipulated: a lexical cue, which combined verb transitivity bias and plausibility, and the prosodic contour of the sentence. The stimuli were identical to those described by DeDe (2010). The full set of stimuli, with transitivity and plausibility ratings, appears in Appendix A. For a full description of how the stimuli were developed, readers are referred to DeDe (2010) and DeDe (2008).

1. While the parents / watched / the child / sang / a song / with her grandmother.
2. While the parents / danced / the child / sang / a song / with her grandmother.

Lexical Cues—The lexical cues in each pair of sentences were biased toward the subject or object interpretation of the ambiguous noun phrase. The object-biased member of the

sentence pair contained a transitively biased subordinate verb followed by a plausible direct object (example 6). The subject-biased member of the sentence pair contained an intransitively biased verb followed by an implausible direct object (example 7).

Prosodic Contour—A female speaker of American English produced each experimental item with two different intonational contours in order to create prosodic conditions biased toward the subject and object interpretations of the ambiguous noun phrase (cf., Blodgett, 2004; Kjelgaard & Speer, 1999; Walker et al., 2001) (see Figure 1). Subject-biased prosodic contours were consistent with the early closure interpretation of the sentence. The clausal boundary following the subordinate verb was marked with (1) a high pitch accent on the subordinate verb followed by falling pitch and (2) increased duration of the clause-final syllable (Kjelgaard & Speer, 1999). In the object-biased prosodic condition, neither potential syntactic clause boundary was marked by a clear prosodic boundary. The sentences were produced with a high pitch accent on the subject of the subordinate clause with deaccentuation of the remainder of the clause.

Summary of Experimental Conditions—The lexical and prosodic cues were crossed to create four conditions:

1. Subject Prosody-Intransitive Bias (consistent cues): Items with subject-biased prosodic contours ('auditory comma') and intransitively-biased subordinate verbs paired with implausible objects (example 7). The manipulated cues all supported the subject (early closure) interpretation of the ambiguous noun phrase, which was the correct interpretation.
2. Subject Prosody-Transitive Bias (conflicting cues): Sentences with subject-biased prosodic contours ('auditory comma') and transitively-biased subordinate verbs paired with plausible objects (example 6). The prosodic cue was biased toward the subject interpretation of the ambiguous noun phrase, and the lexical cue supported the object interpretation.
3. Object Prosody-Intransitive Bias (conflicting cues): Sentences with object-biased prosodic contours (no 'auditory comma') and intransitively-biased subordinate verbs paired with implausible objects (example 7). The prosodic cues supported the object (late closure) interpretation, and the lexical cue supported the early closure interpretation.
4. Object Prosody-Transitive Bias (consistent cues): Sentences with object-biased prosodic contours (no 'auditory comma') and transitively biased verbs paired with plausible objects (example 6). In this condition, all the manipulated cues supported the object (late closure) interpretation of the ambiguous noun phrase, which would always turn out to be the incorrect analysis for the experimental sentences.

2.2.1 True/False Comprehension Probes—Four comprehension probes were generated for each sentence pair so that each stimulus was associated with a different question. For example, two of the comprehension probes for examples (6) and (7) were "*The parents danced together.*" and "*The children danced together.*" Lexical items in the comprehension probes were matched across conditions for word frequency and length. The comprehension probes were recorded by a male speaker of American English who was instructed to read the sentences "naturally."

2.3 Experimental Task: Self-Paced Listening

On-line sentence processing was measured using a self-paced listening task (Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996; Ferreira, Anes, & Horine, 1996). On each

trial, participants listened to a sentence that had been digitized and segmented into phrases. Participants paced themselves through each segment of the sentence by pressing a button on a button box interfaced with a Macintosh laptop computer. They were instructed to press the button to request each segment of the sentence as quickly as possible without sacrificing comprehension. Comprehension probes were presented both auditorily and visually following the last segment of the sentence. This multi-modal presentation was intended to reduce the effect of memory demands on performance. Reaction times for each button press and accuracy for the comprehension probe were recorded in PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993).

Creation of Auditory Stimuli—Sentences and comprehension probes were recorded in a sound-attenuated booth as 16-bit sound files sampled at 44.1 kHz using Praat (Boersma & Weenink, 2007). Segmentation for self-paced listening was determined by areas with low signal amplitude at the end of words and the breaking point that maximized intelligibility (see examples 6 & 7, where slashes indicate location of breaks). Pilot studies ensured that the stimuli were acceptable to naïve listeners, that the acoustic signals in the prosodic conditions only differed in expected ways, and that the prosodic cues were effective (DeDe, 2008; 2010).

Rationale for Self-Paced Listening Task—Self-paced listening is sensitive to on-line effects of sentence complexity that have been observed using both self-paced reading (e.g., Waters & Caplan, 2004; Caplan, DeDe, Waters, & Michaud, in press) and eye-tracking (e.g., Kemper & Liu, 2007). This task is sensitive to effects of prosodic contour in sentences with early and late closure ambiguities (DeDe, 2010; Ferreira et al., 1996; Titone et al., 2006) and to effects of syntactic complexity in people with aphasia (e.g., Caplan & Waters, 2003). Finally, DeDe's (2010) study of college-age adults, which used the same materials and methods as the present experiment, found effects similar to those reported in studies of written processing using both self-paced reading and eye-tracking (with some exceptions due to the prosodic manipulation).

The advantage of self-paced listening, relative to other behavioral measures of auditory sentence comprehension, is that it permits measurement of processing load at multiple points of the sentence within a single trial. This is important because previous work demonstrated that it is important to measure processing demands at (minimally) two critical segments in early closure sentences: the ambiguous noun phrase and the main verb (e.g., Mitchell, 1987; Staub, 2007; van Gompel & Pickering, 2001).

2.4 Procedures

The procedures were identical to those described by DeDe (2010). The stimuli (15 sentence pairs recorded in the two prosodic conditions) were assigned to four lists and combined with filler sentences so that the experimental items comprised fewer than 20% of the items in each list. There was a total of 93 items in each list. The conditions could not be balanced within each list because there were 15 stimuli in each condition. However, because all participants saw all lists, the conditions were balanced across the experiment. Each list contained 15 filler sentences with late closure syntax to guard against development of expectations for early closure syntax. Late closure sentences were also recorded with two prosodic conditions. In the first condition, a prosodic boundary marked the syntactic boundary between the ambiguous noun phrase and the subject of the main clause. The second prosodic condition was identical to the object-biased prosodic condition for the early closure sentence. As a result, the presence of the object-biased prosodic contour was equally likely to occur in early and late closure sentences.

All participants were tested on all four lists (i.e., all stimuli) in testing sessions that were separated by at least one week. There were ten practice items at the beginning of each list. Order of list presentation was counterbalanced across participants. Stimuli were presented in pseudorandom order, with the constraint that no more than two sentences of the same type occurred in succession. All participants were paid a nominal fee for their participation.

3. Results

Accuracy and listening time data were analyzed in mixed 2 (Group: Aphasic vs. Control) $\times$ 2 (Prosody: Subject- vs. Object-Biased) $\times$ 2 (Lexical: Transitive- vs. Intransitive- Biased) ANOVAS by participants and items, with the lexical and prosodic conditions as within-participants variables. 95% confidence intervals were computed following Masson and Loftus (2003). Scheffe tests examined predicted effects in significant interactions with a cut-off of $p < .05$. In the interests of brevity, only significant results are presented.

3.1 Comprehension Probe Accuracy

Mean accuracy rates for each condition and group are in Table 4. The control group was significantly more accurate than the aphasic group, $F(1, 22) = 14.54$, $p < .001$, $F(1, 14) = 64.66$, $p < .001$. The overall mean was .88 for the control group and .69 for the aphasic group, effect size = .19, with a 95% confidence interval of $\pm .11$.

3.2 Self-Paced Listening Times

Reaction times for the button presses to request each segment included the duration of the spoken segment, so listening times were calculated by subtracting the spoken segment duration from the reaction time. Following methods described by DeDe (2010), listening times greater than 2.5 seconds were deleted, as they are unlikely to reflect normal sentence processing. In addition, outliers greater or less than three standard deviations from the mean for each participant in each condition were replaced with the value of the upper or lower limits. These procedures accounted for less than 1% of the data. The assumption of homogeneity of variance was tested by calculating the ratio of the largest to the smallest variance, with the criterion that it be less than 10 (Tabachnick & Fidell, 2001). All of the comparisons of interest for the present study met this criterion (range = 1.2 - 8.8).

Critical segments were identified based on previous studies in the written modality. These included the ambiguous noun phrase, the main verb, and the spillover region, which follows the main verb. Listening times for each of the critical segments were analyzed separately. The results for the ambiguous noun phrase and main verb are presented in Figure 2. There were no significant effects in the spillover region, so those results are not presented here.

Effects of Session—Because all participants completed all lists in multiple sessions, it is possible that there would be practice effects across the four sessions. To investigate this possibility, the data were analyzed in 2 (lexical condition) $\times$ 2 (prosodic condition) $\times$ 4 (session) ANOVAs separately for the two groups. For the non-brain-damaged controls, there were no main effects or interactions with session number (all F 's ≤ 1.82). For the people with aphasia, there was a marginal main effect of session at the ambiguous noun phrase, $F(3, 31) = 2.81$, $p = .06$. A similar trend occurred in the listening times for the main verb, $F(3, 31) = 2.49$, $p = .08$. The people with aphasia's listening times tended to become faster across the four sessions. However, there were no interactions with the lexical or prosodic conditions, all F 's ≤ 2.02 . On this basis, data from all four sessions were combined in the subsequent analyses.

Ambiguous Noun Phrase—The interaction of group and lexical condition was significant in the analysis by participants, $F(1, 22) = 5.46$, $p < .05$, and at the level of a trend in the analysis by items, $F(1, 14) = 3.32$, $p = .09$. This effect was qualified by the interaction of group, lexical condition, and prosodic contour, which was also significant by participants, $F(1, 22) = 4.66$, $p < .05$, and at the level of a trend by items, $F(1, 14) = 3.01$, $p = .10$. There were no other significant effects (all other F 's < 1.40).

The three-way interaction was examined with separate 2×2 ANOVA's by group. Contrary to expectation, there were no significant differences in the control group's listening times (all F 's < 2.4).² For the aphasic group, the main effects of prosodic contour and lexical condition were significant by items but not participants (prosody: $F(1, 11) = 2.34$, $p = .15$, $F(1, 14) = 9.35$, $p < .01$; lexical: $F(1, 11) = 1.36$, $p = .27$, $F(1, 14) = 4.68$, $p < .05$). The interaction between the lexical and prosodic conditions was significant by participants but not items, $F(1, 11) = 5.02$, $p < .05$, $F(1, 14) = .11$, NS . The interaction effect was 86 msec, with a 95% confidence interval of ± 84 . Scheffe tests showed that the aphasic adults had shorter listening times in the Object Prosody-Transitive Bias (consistent cues) than in any other condition. This pattern suggests that, like the young adults in DeDe (2010), the aphasic group responded relatively slowly when there were conflicting cues. However, unlike the young adults, the aphasic group also had slow processing times for the Subject Prosody-Intransitive Bias condition, in which all cues supported the subject interpretation.

Disambiguating (Main) Verb—The main effect of prosodic contour approached significance by participants, $F(1, 22) = 3.77$, $p = .06$, $F(1, 14) = .40$, $p = .54$. The main effect of lexical condition was significant, $F(1, 22) = 10.22$, $p < .001$, $F(1, 14) = 8.85$, $p < .01$, effect size = 40 msec, 95% confidence interval ± 26 . This effect was qualified by the interaction between lexical condition and prosody, which was significant in the analysis by participants, $F(1, 22) = 8.03$, $p < .01$, and at the level of a trend in the items analysis, $F(1, 14) = 3.99$, $p = .06$. The effect size for the interaction was 58 msec, with a 95% confidence interval of ± 42 . Listening times were significantly longer in the Object Prosody-Transitive Bias condition than they were in the Subject Prosody-Transitive Bias or Subject Prosody-Intransitive Bias using the criterion of $p < .05$ on the Scheffe test. Listening times were numerically longer in the Object Prosody-Transitive Bias than Object Prosody-Intransitive Bias condition, but the contrast only reached the level of a trend ($p = .08$). There were no other significant effects (including no effects of group: all F 's < 1.4 , all p 's $> .25$). These results suggest that, for both groups, there was only reanalysis at the main verb when all of the cues available at the ambiguous noun phrase conflicted with the correct interpretation of the sentence (cf., DeDe, 2010).

3.3 Sensitivity to Verb Transitivity Bias at the Subordinate Verb

There are a number of issues regarding the pattern of listening times observed in the aphasic and control groups. With respect to the control group, it is unclear whether the lexical and prosodic cues were integrated before the main verb because there were no significant differences in their listening times for the ambiguous noun phrase. For the aphasic group, the pattern of listening times at the ambiguous noun phrase and main verb suggest that they were sensitive to the lexical and prosodic cues. However, it is unclear whether the aphasic group was sensitive to both verb transitivity bias and plausibility because these cues were varied together. One way to address these issues is by examining listening times at the subordinate verb, because at that point, only information about prosody and transitivity bias

²Given the relatively small sample size, the lack of significant effects in the control group could represent a lack of power. However, DeDe (2008) reported the same pattern of results at the ambiguous noun phrase in a group of 24 older adults (aged 60-81). DeDe (2008) did not interpret this finding as evidence that older adults do not use lexical and prosodic cues because there was evidence that, like younger adults, the older adults were sensitive to conflicting cues at the subordinate verb.

are available. DeDe (2010) demonstrated that younger adults were sensitive to conflicts between prosodic contour and transitivity bias at the subordinate verb. Thus, listening times for the subordinate verb were analyzed to determine whether the older and aphasic groups were sensitive to potential conflicts at that point in the sentence.

Unlike the previous comparisons, the lexical items in the subordinate verb differed. For this reason, it was necessary to control for effects of lexical frequency on listening times (Ferreira et al., 1986).³ To do so, raw listening times were regressed against word frequency to determine the predicted response times for each individual based on word frequency alone. The residuals of this analysis were used in these analyses (cf., Caplan & Waters, 2003; Ferreira et al., 1986). Note that the use of residuals sometimes results in negative listening times, which indicate that the listening times for a given word were faster (on average) than would be predicted on the basis of word frequency alone. The two prosodic conditions could not be directly compared because the difference in the duration of the subordinate verbs was too great across conditions. For these reasons, and following DeDe (2010), data for the subject- and object- biased prosodic condition were analyzed separately.

The data were analyzed with mixed 2 (transitivity bias) by 2 (group) ANOVAs, with transitivity bias as the within-subjects factor and group as the between-subjects factor. Results are in Table 5.

Object-Biased Prosodic Condition—As predicted, residual listening times did not differ as a function of transitivity bias or group (all F 's < 1).

Subject-Biased Prosodic Condition—Listening times were longer for transitively-biased verbs than intransitively-biased verbs. However, the main effect of transitivity bias was only significant in the analysis by subjects, $F(1, 22) = 4.44$, $p < .05$, $F(2) < 1$. The interaction of transitivity bias and participant group was significant, $F(1, 22) = 7.49$, $p < .01$, $F(2, 28) = 5.80$, $p < .05$. Scheffe tests using a criterion of $p < .05$ showed that the listening time difference for transitively- and intransitively biased verbs was significant in the control group, effect size = 83 msec, 95% confidence interval ± 53 . These results suggest that the control group was sensitive to the presence of conflicting cues at the subordinate verb. This is similar to the pattern observed in college age adults (reported in DeDe, 2010).

In contrast, the aphasic group showed no significant differences as a function of transitivity bias, suggesting that they were not slowed by the conflict at the subordinate verb. This finding raises the question of whether individuals with aphasia were sensitive to verb transitivity biases at all. This question was further investigated using correlational analyses.

3.3.1 Sensitivity to Verb Transitivity Bias: Post Hoc Correlational Analyses—

Recall that the aphasic individuals completed a testing battery that included a modified version of Gahl's (2001) stimuli. These stimuli included structurally simple sentences in which the verb's transitivity bias matched the sentence structure (i.e., the *concordant* condition) and sentences in which there was a mismatch between verb bias and sentence structure (i.e., the *discordant* condition). For example, consider two sentences containing the intransitively-biased verb “burst.” In the concordant condition, “burst” occurred in an intransitive frame (“The balloon burst behind the boy”) and in the discordant condition it occurred in a transitive frame (“The boy burst the balloon”).

Individuals with aphasia who better understood simple sentences in the discordant condition could be more sensitive to lexical cues, and thus might show effects of verb transitivity bias

³The same pattern of results was found with raw reaction times.

at the ambiguous noun phrase. This possibility was investigated by correlating accuracy on the Gahl materials and on-line sensitivity to the lexical condition in the experimental task. If the aphasic group's interaction between lexical and prosodic conditions at the ambiguous noun phrase reflected sensitivity to the verb transitivity bias, then there should be a significant positive correlation.

The measure of accuracy on the Gahl materials was the percent correct for each participant with aphasia on the true/false probes in the *discordant* (mismatch) condition; this provided a measure of comprehension ability when the verb's transitivity bias conflicts with the sentence structure (see Table 2).

The measure of on-line sensitivity to the main effect of lexical condition was calculated at the ambiguous noun phrase. To compute the main effect of lexical condition, listening times in the subject- and object- biased prosodic conditions were averaged together. The difference score was calculated for each participant as the average listening time for sentences with intransitively biased verbs minus the average listening time for sentences with transitively biased verbs.⁴

The correlation between off-line accuracy and sensitivity to the effect of lexical condition was positive and significant ($r=.80$, $p<.01$). This correlation demonstrates that people with aphasia who were less able to cope with the mismatch between verb transitivity bias and sentence structure in the simple sentences showed a relatively small effect of lexical condition at the ambiguous noun phrase.

An alternative interpretation is that the correlation reflects a general factor such as aphasia severity. For example, less severely impaired individuals might be more accurate on the Gahl stimuli and show more sensitivity to probabilistic cues, resulting in a positive significant correlation. To rule out this possibility, the percent correct scores on the discordant Gahl stimuli were correlated with difference scores reflecting the main effect of prosodic contour. The main effect of prosodic condition was computed by averaging listening times for sentences containing transitive and intransitive verbs. The difference scores were calculated by subtracting the average listening time for items pronounced with subject-biased prosody from items pronounced with object-biased prosody.⁵

If the previous result is due to a general factor such as aphasia severity, then correlations with prosodic contour should also be positive and significant. However, the correlation between percent correct on the Gahl stimuli and the main effect of prosodic contour was non-significant (and negative), $r = -.32$, $p=.31$, suggesting that the previous result is related to verb transitivity bias rather than a more general factor.

4. Discussion

These data represent the first on-line examination of syntactic ambiguity resolution in people with aphasia. The results demonstrated that people with aphasia are sensitive to lexical and prosodic cues, but use them more slowly than age- and education- matched controls. The control group was sensitive to conflicting cues at the subordinate verb, but not

⁴*Example of Calculation of Difference Score for Effect of Lexical Condition (Diff Score 1):* Participant 50001's average listening time for the ambiguous noun phrase in items in the Subject Prosody-Intransitive Bias and Object Prosody-Intransitive Bias conditions was 583.9 msec. His average listening time for items in the Subject Prosody-Transitive Bias and Object Prosody-Transitive Bias conditions was 542.5 msec. Therefore, his difference score for the effect of transitivity bias at the ambiguous noun phrase was 41.4.

⁵*Example of Calculation of Difference Score for Effect of Prosody (Diff Score 2):* Participant 50001's average listening time for the ambiguous noun phrase in items in the Subject Prosody-Intransitive Bias and Subject Prosody-Transitive Bias conditions was 563.6 msec. His average listening time for items in the Object Prosody-Intransitive Bias and Object Prosody-Transitive Bias conditions was 562.8 msec. Therefore, his difference score for the effect of transitivity bias at the ambiguous noun phrase was .8.

at the ambiguous noun phrase. The aphasic group showed the opposite pattern: sensitivity at the ambiguous noun phrase but not at the subordinate verb. The aphasic and control groups' pattern of listening times did not differ at the main verb. The pattern of listening times at the main verb suggested that both groups had to revise their initial interpretation when all of the cues at the ambiguous noun phrase were consistent with the object interpretation.

One interesting result was that the people with aphasia showed different patterns of listening times for the ambiguous noun phrase in the two conditions in which the lexical and prosodic cues were consistent with one another. The people with aphasia had relatively long listening times when both the lexical and prosodic cues were biased towards the – ultimately correct – subject interpretation of the ambiguous noun phrase (i.e., the Subject Prosody-Intransitive Bias condition). In contrast, listening times for the ambiguous noun phrase were relatively short when both cues were biased towards the object interpretation (i.e., the Object Prosody-Transitive Bias condition).

The different pattern of results for the conditions with consistent cues was surprising given that processing times are expected to be relatively short when cues do not conflict. This pattern suggests that the people with aphasia had difficulty whenever there were lexical or prosodic cues that were biased towards the intransitive interpretation of the subordinate verb. That is, the aphasic group had a preference for Subject-Verb-Object (SVO) word order and any cue indicating that the noun phrase following the verb was not a direct object disrupted sentence processing, resulting in longer listening times. On this account, listening times for the ambiguous noun phrase in all of the other conditions were relatively long because they each contained at least one cue that was inconsistent with the SVO interpretation. In contrast, listening times for the ambiguous noun phrase were short in the Object Prosody-Transitive Bias condition because all of the cues in that condition were consistent with the (preferred) SVO interpretation.

This interpretation is congruent with existing research about normal and aphasic sentence processing. It is consistent with studies of college age adults' sentence processing, which have reported a processing advantage for the object interpretation of the ambiguous noun phrase in early closure ambiguities (e.g., Frazier & Clifton, 1996; van Gompel & Pickering, 2001, also cf. Dick & Elman, 2001). It also fits with previous claims that individuals with aphasia have a processing advantage for SVO structures, even relative to other syntactically simple structures (such as intransitive sentences, e.g., “The girl was singing.”) (Gahl, 2002; Menn et al., 1998). Finally, the results replicate the robust body of evidence demonstrating that people with aphasia perform better on sentence structures in which movement operations do not result in violations of the bias towards SVO structures in English (e.g., actives vs. passives, subject vs. object-relative clauses, etc) (e.g., Caplan et al., 2007). Thus, these results provide new evidence regarding previous claims in the literature.

In addition, the results demonstrate that syntactic movement is not the only type of complexity that affects sentence comprehension in aphasia. Sentences containing lexical or prosodic cues that are biased against an SVO interpretation of a sentence also create comprehension difficulty. Importantly, this claim has two parts. First, people with aphasia have more difficulty understanding sentences that do not conform to the bias toward SVO word order in English. Second, people with aphasia are sensitive to the biases represented by lexical and prosodic cues during sentence comprehension.

However, there is evidence that people with aphasia used the probabilistic cues on a different time course than the controls. Unlike the controls, the people with aphasia did not show sensitivity to conflicting cues at the subordinate verb, suggesting that they processed the cues more slowly than the controls. This analysis is consistent with slowed processing

accounts of aphasic sentence comprehension, which claim that individuals with aphasia build syntactic structures more slowly than age-matched controls (e.g., Haarmann & Kolk, 1991; Zurif et al., 1993). There are also converging data from ERP studies showing that individuals with aphasia integrate lexical information into sentential contexts more slowly than controls (e.g., Swaab, Brown, & Hagoort, 1998). The present results suggest that slowed integration of lexical and prosodic cues into the sentential context affects the time course of syntactic ambiguity resolution, and indicate that aberrant lexical integration affects on-line syntactic parsing in addition to end-of-sentence interpretation (cf. Thompson & Choy, 2009). More generally, these findings add to a growing body of evidence that aphasic sentence comprehension deficits are best understood in terms of a processing deficit rather than an absolute inability to construct certain types of structures (cf. Caplan et al., 2007; Thompson & Choy, 2009).

The fact that the people with aphasia did not show effects of verb transitivity bias at the subordinate verb calls into question whether they were sensitive to this cue at all. It is possible that the effects at the ambiguous noun phrase reflected plausibility, but not verb transitivity bias. This issue cannot be fully resolved based on the present data because verb transitivity bias and plausibility were manipulated together in the present experiment. This choice was made to maximize the similarity to materials used in previous studies of syntactic ambiguity resolution in early closure sentences in young adults in both the spoken and written modalities (e.g., DeDe, 2010; Staub, 2007; van Gompel & Pickering, 2001). This design allowed the results of the present study to be compared more easily to the previous work, which permits an analysis of how the aphasic pattern deviates from normal patterns.

Nonetheless, there is evidence from the present study that people with aphasia were sensitive to verb transitivity bias. First, consider the significant effect of *verb match* on the modified version of Gahl's (2002) materials (see Table 2). People with aphasia answered comprehension questions more accurately when the verb's transitivity bias matched the sentence structure (i.e., the *concordant* condition) than when there was a mismatch between verb bias and sentence structure (i.e., the *discordant* condition). Additionally, the correlation between accuracy on the discordant sentences and effect size in the lexical condition suggest that sensitivity to verb transitivity biases at least partly contributed to the effects observed at the ambiguous noun phrase. These are important results because they demonstrate that the aphasic group was sensitive to verb bias but used it more slowly than controls.

The present study provides the first demonstration of on-line effects of syntactic ambiguity resolution in people with aphasia. Although these results require replication and extension to a larger group of individuals with aphasia, the data suggest that the people with aphasia had slowed access to and/or integration of the lexical and prosodic cues. In addition, the people with aphasia had more difficulty when the lexical or prosodic cues conflicted with the preferred SVO interpretation of the sentence. The implication is that people with aphasia are sensitive to lexical and prosodic cues, and that difficulty resolving syntactic ambiguities reflected the time course with which probabilistic cues were integrated into emerging syntactic and semantic representations.

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Appendix A: Experimental Stimuli

Items after each stimulus encode the Verb Class-Proportion of transitive or intransitive verb uses-Plausibility Rating.

While the parents danced, the child sang a song with her grandmother. Intran-0.90-2.6

While the parents watched, the child sang a song with her grandmother. Tran-0.94-6.79

While the girl swims, her aunt makes lunch for everyone. Intran-0.78-1.05

While the girl visits, her aunt makes lunch for everyone. Tran-0.94-6.75

When the bear growled, the hiker called the ranger for help. Intran-0.96-1.55

When the bear attacked, the hiker called the ranger for help. Tran-0.88-6.7

When the man listened, his wife told him about her new job. Intran-0.96-2.65

When the man phoned, his wife told him about her new job. Tran-0.88-6.95

As the child coughed, the milk spilled on the kitchen counter. Intran-0.84-2.6

As the child poured, the milk spilled on the kitchen counter. Tran-0.90-6.75

As the woman laughed, the dog stole a hamburger off the table. Intran-0.98-1.7

As the woman called, the dog stole a hamburger off the table. Tran-0.79-6.65

Because the teacher fell, the boy gave her a present. Intran-0.9-1.5

Because the teacher helped, the boy gave her a present. Tran-0.88-6.8

As the baby sobbed, her sister tried to calm her with a lullaby. Intran-0.88-1.3

As the baby kicked, her sister tried to calm her with a lullaby. Tran-0.92-5.65

While the parents snored, the children played cards in the kitchen. Intran-0.98-1.15

While the parents hugged, the children played cards in the kitchen. Tran-0.85-6.8

After the woman stood, her dress needed to be ironed for the party. Intran-0.69-1.25

After the woman packed, her dress needed to be ironed for the party. Tran-0.82-6.4

As the woman screamed, the ladder started to tip and fell over. Intran-0.88-1.3

As the woman climbed, the ladder started to tip and fell over. Tran-0.9-6.8

After the chef sneezed, the cake needed to be decorated by his assistant. Intran-0.96-1.45

After the chef baked, the cake needed to be decorated by his assistant. Tran-0.94-6.65

As the gardener complained, the leaves blew around the yard in the wind. Intran-0.92-1.3

As the gardener raked, the leaves blew around the yard in the wind. Tran-0.96-6.95

When the sisters giggled, their mother smiled at them happily. Intran-0.92-1.35

When the sisters kissed, their mother smiled at them happily. Tran-0.82-6.65

When the musician bowed, the students admired his enthusiasm and his talent.
Intran-0.92-1.95

When the musician taught, the students admired his enthusiasm and his talent. Tran-0.86-6.8

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A. Subject-Biased Prosodic Condition

B. Object-Biased Prosodic Condition

Figure 1.

Acoustic waveforms, spectrograms, fundamental frequency, and TOBI transcription (see Appendix A) for sample stimuli in the (A) Subject-Biased and (B) Object-Biased Prosodic conditions

A. Aphasic Group **B. Control Group** **Figure 2.**

Listening times for critical segments for individuals with aphasia and control group. Error bars in this figure indicate one standard error above the mean.

Table 1
Demographic Characteristics of Aphasic Participants

ID	Age (Yrs)	Gender	Time Post-Onset (Yrs)	Clinical/Medical Diagnoses (at time of stroke)
50001	73.5	M	6.5	Intra-cerebral hemorrhage (left basal ganglion); Expressive Aphasia
50003	56.4	F	14	Left MCA territory stroke; Fluent but effortful speech w/ poor initiation and word finding
50004	80.4	M	4.7	Left MCA CVA (infarction involving Wernicke's area), mod-severe aphasia w/ apraxia of speech
50008	59.3	M	3.8	Left MCA temporal-parietal CVA; severe expressive and receptive aphasia
50009	58.9	M	3.8	CVA; fluent expressive and receptive aphasia
50010	62.6	M	6.0	Left occipital-parietal CVA
50011	61.7	M	4.7	Left thalamic/ subthalamic nucleus CVA
50012	54.5	M	9.3	Left MCA CVA; left basal ganglia hemorrhage; severe expressive and receptive aphasia
50013	55.3	M	8.5	L MCA distal infarction; fluent expressive and severe receptive aphasia
50017	54.9	M	2.8	Left internal carotid artery dissection; Left MCA CVA; aphasia
50018	63.8	F	6.3	Left MCA CVA including basal ganglia and left frontal regions; Global Aphasia
50019	64.8	F	8.0	Broca's aphasia

Table 2
Results of Aphasic Participants' Background Testing & Subgroup Classification

ID	Boston Diagnostic Aphasia Exam				PPVT Word Comp		Sentence Comprehension (Gahl)*	
	BNT	Word Comp	Commands	Comp Idea	Sent Rep		Concord	Discordant
50001	0.60	0.94	0.90	0.50	0.50	185	0.72	0.66
50003	0.90	1.00	1.00	1.00	1.00	193	0.97	0.88
50004	0.63	0.94	0.90	1.00	0.00	185	0.84	0.66
50008	0.00	0.63	0.80	0.67	0.00	172	0.91	0.88
50009	0.58	1.00	0.80	0.83	0.00	182	0.94	0.88
50010	0.92	1.00	0.90	1.00	1.00	186	1.00	1.0
50011	0.68	0.81	0.90	0.67	1.00	174	0.81	0.84
50012	0.08	0.88	0.80	0.50	0.50	170	0.91	0.88
50013	0.48	0.94	0.80	0.83	0.50	176	0.84	0.59
50017	0.05	0.66	0.70	0.83	0.50	169	0.78	0.69
50018	0.52	1.00	1.00	1.00	1.00	174	0.97	0.91
50019	0.67	0.81	0.70	0.50	0.50	190	0.75	0.69

* Main effect of condition (concordant vs. discordant), $F(1, 11)=11.50$, $p<.01$. *Abbreviations:* BNT = Boston Naming Test, Word Comp= Word Comprehension, Comp Idea=Complex Ideational, Sent Rep= Sentence Repetition.

Table 3
Sample Items for Comprehension Task based on Gahl (2002)

Sentence Type	Verb Match	Example
Transitive	Concord	The professor/ shut/ the door/ with a bang.
		True/False Question: The door closed gently.
	Discord	The boy/ burst/ the balloon/ loudly.
		True/False Question: The balloon burst.
Intransitive	Concord	The balloon/ burst/ behind the boy/ loudly.
		True/False Question: There was a quiet noise.
	Discord	The door/ shut/ behind the professor/ with a bang.
		True/False Question: The door closed loudly.

Table 4
Mean (STD) Proportion Correct for Comprehension Probes

Group	Subject-Biased Prosody		Object-Biased Prosody	
	Intransitive	Transitive	Intransitive	Transitive
	danced the child	watched the child	danced the child	watched the child
Older	.91 (.10)	.87 (.17)	.88 (.13)	.89 (.14)
Aphasic	.67 (.21)	.73 (.17)	.67 (.15)	.69 (.12)

Table 5
Residual Listening Times (msec) for the Subordinate Verb*

	Subject-Biased Pros		Object-Biased Pros	
	Intransitive	Transitive	Intransitive	Transitive
	danced	watched	danced	watched
Control	-33.6	49.4	-14.8	5.0
Aphasic	-12.1	-22.9	5.87	17.9

* Note that the use of residual listening times sometimes results in negative values, as seen above. This essentially means that the raw listening times were (on average) faster than would be expected on the basis of word frequency alone.