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Supplement Article

Online Sentence Reading in People With Aphasia: Evidence From Eye Tracking

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Purpose: There is a lot of evidence that people with aphasia have more difficulty understanding structurally complex sentences (e.g., object clefts) than simpler sentences (subject clefts). However, subject clefts also occur more frequently in English than object clefts. Thus, it is possible that both structural complexity and frequency affect how people with aphasia understand these structures.
Method: Nine people with aphasia and 8 age-matched controls participated in the study. The stimuli consisted of 24 object cleft and 24 subject cleft sentences. The task was eye tracking during reading, which permits a more fine-grained analysis of reading performance than measures such as self-paced reading.
Results: As expected, controls had longer reading times for critical regions in object cleft sentences compared with subject cleft sentences. People with aphasia showed the predicted effects of structural frequency. Effects of structural complexity in people with aphasia did not emerge on their first pass through the sentence but were observed when they were rereading critical regions of complex sentences.
Conclusions: People with aphasia are sensitive to both structural complexity and structural frequency when reading. However, people with aphasia may use different reading strategies than controls when confronted with relatively infrequent and complex sentence structures.

People with aphasia often have difficulty understanding complex sentences, especially sentences that do not follow the canonical, or typical, word order for their language (e.g., Dick et al., 2001). In English, sentences typically follow subject–verb–object word order. Sentences with noncanonical word order are both more syntactically complex and less common than sentences with canonical word order (e.g., Roland, Dick, & Elman, 2007). Studies of sentence comprehension impairments in people with aphasia have focused on the contributions of structural complexity (e.g., Caplan, Waters, DeDe, Michaud, & Reddy, 2007; Dick et al., 2001; Grodzinsky, 2000; Thompson & Choy, 2009). However, research from adults without brain damage suggests that the relative frequency of syntactic structures also influences processing difficulty (e.g., Levy, 2008; Staub, 2010). Thus, it is possible that people with aphasia have trouble understanding sentences with noncanonical word order at least in part because such sentences occur relatively infrequently compared with sentences with canonical word order. The purpose of the present study was to determine whether sentence comprehension impairments in people with aphasia reflect sensitivity to the frequency of the structure as well as structural complexity.

A lot of evidence regarding effects of structural complexity comes from studies investigating how people with aphasia process sentences with object and subject relative clauses, such as the object and subject clefts in examples 1 and 2:

1. It was the girl who the boy hugged on Sunday morning. (Complex Sentence, Object Cleft)
2. It was the boy who hugged the girl on Sunday morning. (Simple Sentence, Subject Cleft)

Sentences 1 and 2 both convey the idea "the boy hugged the girl," but object clefts such as in sentence 1 are more difficult to process than subject clefts such as in sentence 2. The underlying difference between the object and subject clefts can be captured in several ways. First, object cleft sentences deviate from canonical word order for English. The syntactic structure of object clefts is such that the undergoer of the action (the girl) precedes the agent (the boy). In addition, the memory demands associated with integrating the verb *hugged* with its arguments differ for object and subject clefts (Gibson, 1998). The distance between the undergoer of the relative clause verb (the girl) and the verb itself is greater in sentence 1 than in sentence 2. As a result, the processes involved in retrieving the relevant noun

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phrases and determining the relationship between the noun phrases and the verb exert greater memory demands in object clefts than subject clefts. Given these differences, it is not surprising that many online studies have reported evidence of increased processing difficulty in object clefts compared with subject clefts (e.g., Caplan, DeDe, Waters, Michaud, & Tripodis, 2011; Grodner & Gibson, 2005; Staub, 2010). This difficulty is often localized to the verb because that is the point in the sentence at which the comprehender identifies the relationship between the nouns and verbs. It is important to note that this processing difficulty can be attributed to differences in structural complexity between the two sentence types.

Another variable that might make object clefts more difficult than subject clefts is the relative frequency of these two structures. Object cleft sentences occur less frequently in spoken and written English than subject clefts (Roland et al., 2007). English speakers are likely to expect the more frequent sentence structure (subject clefts) on the basis of the relative distributions of the sentence types. The surprisal theory (Levy, 2008) posits that processing disruptions occur when there is a mismatch between the expected (frequent) syntactic structure and the actual structure. On this account, it may take longer to process object cleft than subject cleft sentences not only because of the relative complexity of the structures but also because subject clefts are more frequent than object clefts.

Levy's (2008) expectation-based account can be situated within a larger theoretical framework that posits that sentence comprehension is highly influenced by probabilistic cues (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994). Probabilistic cues include features such as the relative distribution of different words and structures in a language. The relative frequency of different sentence structures is one sort of cue. However, readers and listeners are sensitive to many different types of cues, including the frequency with which verbs occur in specific constructions, the plausibility of relationships among the nouns and verbs in a sentence, and contextual information (e.g., DeDe, 2013b; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Trueswell, Tanenhaus, & Kello, 1993; for a review, see MacDonald & Seidenberg, 2006).

Staub (2010) investigated how structural frequency and structural complexity contribute to the processing difficulty associated with object relatives. College students read object relative (e.g., "The father that the baby entertained was happy") and subject relative (e.g., "The father that entertained the baby was happy") sentences while a camera recorded their eye movements. As predicted on the basis of previous studies (e.g., Caplan et al., 2011; Grodner & Gibson, 2005), Staub (2010) found that participants read the embedded verb (*entertained*) more slowly in sentences with object compared with subject relative clauses. Staub interpreted longer reading times for the verb as evidence of the higher memory demands associated with integrating the noun phrases in object compared with subject relatives (Gibson, 1998).

Staub (2010) reasoned that effects of structural frequency would be observed at the second noun phrase in object relatives (e.g., *the baby*). His rationale was that the presence of a noun phrase immediately after the relative clause pronoun is the first cue that the sentence does not follow the most likely (i.e., most frequent) structure. As predicted, Staub's (2010) participants showed greater processing disruptions at the noun phrase *the baby* in object relative sentences than subject relative sentences. More specifically, it took college-age adults longer to read past the second noun phrase in object relative clauses than subject relative clauses. Staub interpreted this finding as evidence that readers were surprised by the presence of a noun phrase after the relative clause pronoun (cf. Levy, 2008). Differences in reading times for the second noun phrase were taken to reflect the relative frequency of object and subject relative clauses, including recognition of the less frequent structure and the need to construct an alternate mental representation of the sentence.

Taken together, Staub's (2010) results suggest that young adults without brain damage are sensitive to both structural frequency and structural complexity when processing sentences. It is unknown whether people with aphasia are sensitive to these variables. There is evidence that people with aphasia are sensitive to structural complexity (e.g., Caplan et al., 2007; DeDe, 2013a; Thompson & Choy, 2009). The previous studies generally report that people with aphasia, like controls, show processing disruptions at the verb in sentences that are object clefts compared with subject clefts (e.g., DeDe, 2013a). In addition, some studies have shown that people with agrammatic aphasia have difficulty integrating information about argument structure into a meaningful representation when reading or listening to complex sentences (e.g., lexical integration hypothesis; Hsu, Yoshida, & Thompson, 2014; Thompson & Choy, 2009). Thus, existing studies are consistent with the idea that people with aphasia are sensitive to structural complexity.

No studies have investigated whether people with aphasia are also sensitive to structural frequency, as Staub's (2010) college students were. However, a small number of studies have investigated how other probabilistic cues contribute to sentence comprehension impairments in aphasia (DeDe, 2012, 2013b; Gahl, 2002; Russo, Peach, & Shapiro, 1998). Gahl (2002) proposed the lexical bias hypothesis, which claims that people with aphasia rely on probabilistic knowledge about verb bias to a greater extent than individuals without brain damage. Verb bias is a probabilistic cue that is based on the frequency with which given verbs occur in particular syntactic structures. For example, the verb *watch* is typically followed by a direct object, making it transitively biased. Gahl (2002) found that people with aphasia made more comprehension errors about sentences in which there was a mismatch between the verb's transitivity bias and the sentence structure (e.g., transitively biased verbs in intransitive sentences). In a recent self-paced reading study, DeDe (2013b) found that people with aphasia had slower reading times when transitively biased verbs occurred in intransitive sentence frames. These types of data are consistent with the lexical bias hypothesis.

The evidence from both Gahl (2002) and DeDe (2013b) suggests that people with aphasia are sensitive to at least some information about frequency—namely verb bias—and that people with aphasia rely more heavily on these types of cues than controls. The previous studies also suggest that people with aphasia are sensitive to structural frequency at the phrase level (i.e., the likelihood that a certain verb will take a direct object). However, it is unknown whether people with aphasia are sensitive to information about the relative frequency of object and subject clefts. The present study examined whether the lexical bias hypothesis could be extended to include information about the relative frequency of these types of sentences.

The aims of the present study were twofold. The first aim was to investigate whether people with aphasia show sensitivity to both structural complexity and structural frequency when reading subject cleft and object cleft sentences. Subject and object cleft sentences were chosen because, like the object and subject relatives studied by Staub (2010), they provide a way to investigate processing disruptions associated with structural complexity and structural frequency. However, cleft sentences are shorter than the object and subject relatives, which may reduce potential effects of working memory on comprehension (cf. Caplan et al., 2011).

Object and subject clefts were also chosen because previous studies of these structures generated predictions regarding effects of structural complexity in people with aphasia (e.g., Caplan & Waters, 2003; Caplan et al., 2007; DeDe, 2013a; Dickey, Choy, & Thompson, 2007). Previous research reported longer listening and reading times for the verb (*hugged* in examples 1 and 2) in object cleft versus subject cleft sentences in people with aphasia and in controls without brain damage (e.g., Caplan, Michaud, & Hufford, 2013; Caplan et al., 2007; DeDe, 2013a). Thus, we predicted that both people with aphasia and controls would show effects of structural complexity as evidenced by longer reading times for the verb in complex compared with simple sentences.

On the basis of the results from Staub (2010), people with aphasia and age-matched controls were also expected to show effects of structural frequency, as evidenced by processing disruptions when reading the second noun phrase in object cleft compared with subject cleft sentences. If the lexical bias hypothesis can be extended to include sentence structure frequency, then people with aphasia should rely more heavily than controls on structural frequency cues. In the results, this would manifest as a larger difference between reading times for the second noun phrase in object clefts versus subject clefts for people with aphasia compared with controls.

A secondary goal of this study was to investigate whether eye tracking during reading provides a valid measure of sentence comprehension in people with aphasia. Very few studies have examined online sentence reading in people with aphasia, and those that did used self-paced reading (e.g., DeDe, 2013a; Sung et al., 2011). Eye tracking while reading has been shown to reflect online sentence processing mechanisms in individuals without brain damage (Rayner, 1998). In studies of eye tracking while reading, participants silently read sentences on a computer screen while a camera records their eye movements. In contrast to self-paced reading, eye tracking allows participants to read in a more naturalistic way. The reason is that the full sentence is available to be read during the entirety of each trial as opposed to the segmented text used in self-paced reading. In addition, eye tracking while reading allows reading times from the first pass through the sentence to be analyzed separately from reading times on subsequent passes. In this way, eye tracking while reading provides a way to distinguish patterns reflecting lexical access and syntactic reanalysis (cf. Rayner, 1998).

Since the 1970s, studies of sentence processing in populations without brain damage have used eye tracking while reading (for a review, see Rayner, 1998). In addition, several studies have used eye tracking during listening to study sentence comprehension in aphasia (e.g., Thompson & Choy, 2009). A small number of studies have used eye tracking during reading in people with aphasia, but most of those studies examined less fine-grained measures than are typical in studies of online sentence processing (e.g., total number of fixations across an entire sentence; Chesneau, Joanette, & Ska, 2007; Donders & Vlugt, 1986). One exception is a recent study by Hsu et al. (2014), who used eye tracking to examine processing of cataphora in people with aphasia. To our knowledge, the present study is the first to use eye tracking while reading to provide a fine-grained analysis of online processing of subject and object cleft sentences in people with aphasia.

Method

Participants

Nine people with aphasia (mean age = 55 years; range = 34–69 years) and eight neurologically healthy controls (mean age = 57 years; range = 48–65 years) participated in the study. Two additional participants with aphasia completed the study but were excluded due to a coding error (P01) and severe word-level comprehension deficits (P07). All participants were native English speakers and were screened for visual deficits. In addition, people with aphasia completed a letter cancellation task to screen for visuospatial neglect. Control participants were screened for cognitive deficits using the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975), with a cutoff of 28 of 30 points.

All participants with aphasia were at least 1 year postonset and were premorbidly right handed. They completed a battery of language assessments to characterize their aphasia and ensure that word comprehension was adequate for completion of the task. All participants with aphasia demonstrated significant word retrieval impairments on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 2001). Single-word comprehension was assessed with the Peabody Picture Vocabulary Test–Fourth Edition

Table 1. Participant demographic and test performance data.

Participant number	Age (years)	Education (years)	Gender	Aphasia type	Etiology	Boston Naming Test (maximum = 60)	Peabody Picture Vocabulary Test[a]	Written word–picture matching
P02	52	12	M	Anomic[b]	CVA	50	97	.97
P03	39	14	M	Anomic	CVA	51	99	.97
P09	57	12	F	Anomic[b]	CVA	46	96	1.00
P10	60	13	F	Anomic	CVA	48	94	—
P04	56	12	F	Broca's	CVA	22	80	1.00
P06	68	15	M	Broca's	CVA	29	99	1.00
P08	68	12	M	Broca's	CVA	8	89	.97
P12	34	12	M	Broca's	Gunshot wound	5	72	.94
P11	69	18	M	Conduction[b]	CVA	0	91	1.00

Note. M = male; CVA = cerebrovascular accident; F = female. Em dash indicates data not obtained.

[a]Standard score; all within 2 *SD* of the mean for age-matched controls. [b]Determined using Western Aphasia Battery–Revised. All other participants were classified on the basis of the Boston Diagnostic Aphasia Examination–Short Form.

Form A (Dunn & Dunn, 2007). All participants scored within 2 *SD* of the mean for their age-matched peers on the Peabody Picture Vocabulary Test, suggesting that their single-word comprehension was adequate to complete the task. All participants with aphasia except P10 also completed the written word–picture matching subtest from the Psycholinguistic Assessment of Language (PAL; Caplan, 1992). P10 discontinued testing due to an unrelated illness and was unable to return to complete the PAL subtest. All of the other participants performed above chance on the PAL written word–picture matching test. These results suggest that the participants had adequate ability to read for comprehension at the single-word level, meaning that it is unlikely that an acquired dyslexia, such as deep dyslexia, accounts for differences in sentence reading. Syndrome classification was based on performance on the Boston Diagnostic Aphasia Examination–Short Form (Goodglass, Kaplan, & Barresi, 2000) or the Western Aphasia Battery–Revised (Kertesz, 2006). Demographic and test performance data on these measures are displayed in Table 1.

Additional testing was done to identify symptoms of agrammatism in the participants with aphasia. Agrammatism was assessed because some authors (e.g., Grodzinsky, 2000) have argued that individuals with agrammatism show distinct features of sentence comprehension difficulty. Participants with aphasia completed the Sentence Comprehension and Sentence Production Priming subtests of the Northwestern Assessment of Verbs and Sentences (Cho-Reyes & Thompson, 2012). These subtests were used to calculate the ratio of noncanonical (e.g., passives, object relatives) to canonical (e.g., actives, subject relatives) sentences that were correctly understood and produced. The Northwestern Naming Battery was used to calculate the ratio of verbs to nouns produced in confrontation naming (Thompson, Lukic, King, Mesulam & Weintraub, 2012). Results for these three measures are presented in Table 2.

We averaged the three ratios to determine the agrammatism ratio (see Table 2). Individuals with an average agrammatism ratio $\leq .80$ were considered to fit the agrammatic profile, and individuals with an average agrammatism ratio $\geq .90$ were considered to fit the anomic profile.[1] The criteria were based on data reported by Thompson and colleagues for individuals with agrammatic and anomic aphasia on these three measures (Cho-Reyes & Thompson, 2012; Thompson et al., 2012). The participants who fit the agrammatic profile were P02, P04, P06, P08, and P09. Only two participants' (P03 and P11) profiles were consistent with the anomic profile. Two participants' (P10 and P12) ratios fell between .08 and .09 and were not considered to fit either profile.

Stimuli

The stimuli consisted of 48 experimental items and 176 filler sentences for a total of 224 sentences. The experimental items were 24 object cleft sentences and 24 subject cleft sentences, which were constructed in pairs and varied only with respect to word order (see the following examples).

1. It was the father that entertained the baby during the party last week. (Subject Cleft)
2. It was the baby that the father entertained during the party last week. (Object Cleft)

Each sentence was semantically reversible (i.e., fathers and babies can both entertain and be entertained by one another), so participants could not use heuristics on the basis of plausibility to determine the relationship between the critical nouns. *T* tests showed that the agents and patients (e.g., *baby* and *father*) did not differ with respect to lexical frequency, number of syllables, orthographic neighborhood density or frequency, or phonological neighborhood density or frequency (all $ts < 1.1$). Thus, it is unlikely that word-level differences would cause processing differences across sentence types. Filler items consisted of a variety of

[1]Note that we do not intend to classify these participants as having the anomic syndrome. In fact, P03 was classified as anomic, whereas P11 was classified as having conduction aphasia.

syntactically simple and complex sentences and were included to minimize the likelihood that participants would develop expectations for particular sentence types. Each sentence was followed by a comprehension question that required accurate assignment of thematic roles (e.g., "Did the baby entertain the father?" or "Did the father entertain the baby?").

Procedure

Participants were instructed to read the sentences silently and naturally, as if they were reading a newspaper. Sentences were presented individually on a single line in the center of the computer screen. Text was presented in black, 14-point courier typeface on an off-white background. Participants indicated that they had finished reading the sentences by pressing a button on a button box. When they pressed the button, the sentence disappeared and the *yes–no* comprehension question appeared. Sentences were presented for a maximum of 30 s. If the participant did not finish reading the sentence within that time, the sentence disappeared from the screen and the trial was discarded. There were 10 practice items before the experimental items.

The experimental items and fillers were separated into two lists. Each list contained half of the items and was constructed to ensure that sentence pairs did not occur in the same list—that is, examples 1 and 2 would be in different lists. All participants read both lists in two testing sessions that were separated by at least 1 week. If participants wore glasses to read, they were instructed to wear their glasses for the task.

While the participant read, eye movements were recorded using an SR Research (Kanata, Ontario, Canada) Eyelink 1000 eye tracker with a sampling rate of 1000 Hz. The Eyelink 1000 consists of a control unit, camera, and display computer. Participants were seated in an adjustable chair and positioned their head on a headrest to minimize head movements. The participants were seated approximately 65 cm from the display monitor.

Prior to beginning the experiment, the camera was calibrated using a three-point calibration system. During calibration, the participant looked at a series of three targets displayed on one line in the center of the screen. The purpose of calibration is to ensure that the camera is accurately measuring the pupil location. During validation, the calibration is checked by comparing the camera's measurement of the pupil's location when the participant is looking at known fixation points.

Each sentence was preceded by a calibration target in the center of the screen followed by a fixation box on the left side of the screen. The fixation box was gaze contingent, meaning that it would not disappear until the participant fixated on it for 300 ms. The purpose of the fixation box was to ensure that the first fixation would be at the beginning of the sentence. The eye tracker was calibrated before and after the practice sentences, every 40 trials, or whenever there was significant difficulty triggering the fixation box.

Design and Analysis

Four reading measures were analyzed: gaze duration, go-past time, rereading time, and total reading duration. For ease of explanation of the reading measures, an example sentence is included below. In this example, the sentence is divided into five regions of interest, as indicated by the square brackets. The superscript numbers represent the order of the first seven fixations in the sentence. In example 3, the first, third, fifth, and seventh fixations were on *the baby*.

3. [It was^{2}] [the baby^{1,3,5,7}] [that^{4}] [the father^{6}] [entertained].

Gaze duration is the sum of all fixations in a region before the eyes fixate on a region that is either before or after the current one. For example, gaze duration for the phrase *the baby* would be the total duration of fixations to that phrase until there was a fixation to the previous portion of the sentence (*It was*) or to the next portion of the sentence (*that*). It would include only fixation 1 from the example sentence. Gaze duration is considered to be a relatively early measure of processing and is thought to reflect processing mechanisms related to lexical access.

Table 2. Accuracy by stimulus type and relevant ratios on the Northwestern Assessment of Verbs and Sentences (NAVS) and Northwestern Naming Battery.

Participant number	NAVS Production subtest			NAVS Comprehension subtest			Northwestern Naming Battery			Agrammatism ratio[a]
	Canonical	Noncanonical	Ratio	Canonical	Noncanonical	Ratio	Nouns	Verbs	Ratio	
P02	13	3	0.23	13	15	1.15	16	16	1.00	0.79
P03	15	12	0.80	13	12	0.92	16	16	1.00	0.91
P09	13	1	0.08	14	6	0.43	16	15	0.94	0.48
P10	14	7	0.50	14	14	1.00	16	15	0.94	0.81
P04[b]	0	0	0.00	11	7	0.64	13	12	0.92	0.78
P06	3	0	0.00	13	9	0.69	14	11	0.79	0.49
P08[b]	0	0	0.00	13	13	1.00	6	3	0.50	0.75
P12[b]	0	0	0.00	10	7	0.70	5	5	1.00	0.85
P11[b]	0	0	0.00	9	10	1.11	10	8	0.80	0.96

[a]Calculated by averaging the three ratios. [b]Participant could not complete the NAVS Production subtest. This ratio was excluded from the agrammatism ratio for these participants. In general, ratios less than 1 are consistent with agrammatism.

Go-past time is the sum of all fixations before the eyes make a progressive movement to the right of a given word. In the example sentence, this would include fixations to the phrase *the baby* as well as regressive eye movements to the previous phrase *it was.* Go-past time would include fixations 1, 2, and 3 in the example above. It is important to note that go-past time would not include the duration of fixation 5 because it occurred after the reader made a progressive eye movement to the word *that*. Go-past times are of particular interest because Staub (2010) claimed that longer go-past times for the second noun phrase in object compared with subject relative sentences were evidence of sensitivity to structural frequency.

Rereading time and total reading duration are considered to reflect syntactic processing and reanalysis (Rayner, 1998). *Rereading time* is the amount of time that is spent rereading portions of a critical region after the region has been exited to the right. For example, if the reader fixated on the phrase *that* and then made a regressive eye movement to the phrase *the baby*, the time spent fixating after the regressive saccade would constitute rereading time for *the baby*. In the example above, rereading time for *the baby* would include the duration of fixations 3, 5, and 7. Total reading duration is the total amount of time spent fixating in a critical region. For *the baby*, total reading time would include fixations 1, 3, 5, and 7 from the example sentence.

Results

Comprehension Question Accuracy

Proportion correct for the comprehension questions was analyzed in a 2 (sentence type: object vs. subject cleft) × 2 (group: people with aphasia vs. controls) analysis of variance (ANOVA). Proportion correct on comprehension questions is presented in Table 3. Overall, the controls answered comprehension questions more accurately than the people with aphasia, $F(1, 15) = 22.63$, $p < .001$. Both groups answered comprehension questions about subject cleft sentences more accurately than those about object cleft sentences, $F(1, 15) = 8.11$, $p = .012$. There was no significant interaction between group and sentence type, $F(1, 15) = 0.32$, $p = .58$, suggesting that people with aphasia, although less accurate, generally follow the same pattern of accuracy as age-matched controls.

Table 3. Proportion correct on the comprehension questions.

Variable	Subject cleft	Object cleft
Participant number		
P02	.67	.75
P03	.96	.88
P04	.58[a]	.72
P06	.80	.67
P08	.67	.67
P09	.96	.63[a]
P10	.92	.67
P11	.75	.58[a]
P12	.71	.75
Group data		
Aphasia	.77 (.14)	.70 (.09)
Control	.97 (.03)	.86 (.12)

Note. Group data values are means (standard deviations).

[a]With 24 exemplars of each sentence type, scores ≥ .67 are considered above chance performance on the binomial distribution.

Reading Time Data

Sentences for which participants did not correctly answer comprehension questions were excluded from analysis of online reading times. Analyses were conducted on five regions: the first noun phrase (e.g., *the father* in example 1), the relative clause pronoun (e.g., *that*), the second noun phrase (e.g., *the baby* in example 1), the verb (e.g., *entertained* in examples 1 and 2), and the end of the sentence.

Inspection of the raw data showed that the reading times of people with aphasia were numerically longer than the reading times of controls. However, group could not be included in the model because the variance across groups violated the assumption of homogeneity of variance. According to Tabachnik and Fidell (2001), the maximum variance ratio allowable for an ANOVA is 10. With group in the model, the variance ratios ranged from 2 to 172 on the reading measures. When the groups were analyzed separately, the variance ratios ranged from 1 to 4. For this reason, reading time data for critical segments were analyzed separately for each group in separate repeated measures ANOVAs with sentence type (object vs. subject cleft) as the within-subject variable.

Reading times were transformed using reverse reciprocal reading times (i.e., –1/time) to correct for violations of normality, which are common in reaction time data. The transformed reading times were entered in the ANOVAs, but raw reading times are presented in the tables and figures for ease of exposition. ANOVAs on the raw and transformed reading times revealed similar patterns of effects.

Results for the reading measures for each of the critical regions are described below. Raw reading times are displayed in Tables 4 (controls) and 5 (people with aphasia). Segments are presented in the order in which they occur in the more complex object cleft sentences.

First Noun Phrase

For the first noun phrase (*the father* in example 1 and *the baby* in example 2), neither group was predicted to show reading time differences because the structures do not differ at this point. As predicted, controls did not show significant effects of sentence type for gaze duration, $F(1, 7) = 2.44$, $p = .16$; go-past time, $F(1, 7) = 0.91$, $p = .37$; rereading duration, $F(1, 7) = 0.71$, $p = .43$; or total reading duration, $F(1, 7) = 0.71$, $p = .42$. Likewise, there were no significant differences in people with aphasia's reading times for object cleft versus subject cleft sentences as measured by gaze duration, $F(1, 8) = 0.0$, $p = .97$; go-past time, $F(1, 8) = 1.91$, $p = .20$; rereading duration, $F(1, 8) = 0.02$, $p = .89$; and total reading duration, $F(1, 8) = 0.18$, $p = .68$.

Table 4. Reading times measures for controls.

Variable	First noun phrase	Relative cause pronoun	Second noun phrase	Verb	End of sentence
Gaze duration					
Object cleft	270.0 (149)	165.0 (150)	339.1 (174)	291.5 (155)	1022.9 (583)
Subject cleft	281.3 (140)	151.5 (126)	327.6 (148)	236.5 (149)	1052.2 (529)
Difference	–11.3	13.5	11.5	55.0*	–29.3
Go-past time					
Object cleft	377.9 (273)	178.0 (173)	457.6 (309)	392.4 (322)	2064.7 (1598)
Subject cleft	366.8 (210)	163.6 (144)	378.4 (234)	275.8 (197)	1777.0 (1228)
Difference	11.1	14.4	79.2**	116.6*	287.7
Rereading time					
Object cleft	339.8 (436)	199.6 (296)	446.6 (455)	263.7 (320)	1059.8 (625)
Subject cleft	263.3 (336)	83.0 (144)	278.6 (335)	183.6 (262)	1070.3 (613)
Difference	76.5	116.6	168.0*	80.1	–10.5
Total duration					
Object cleft	529.6 (430)	345.1 (327)	661.9 (452)	487.5 (329)	1285.7 (636)
Subject cleft	455.7 (331)	227.0 (187)	500.4 (339)	378.8 (277)	1291.0 (623)
Difference	73.9	118.1	161.5*	108.7*	–5.3

Note. Values are means (standard deviations). Difference is calculated as object cleft minus subject cleft. All reading times are in milliseconds.
$^*p < .05$. $^{**}p = .06$.

This result suggests that effects of sentence type observed at the second noun phrase do not reflect differences between the lexical items because the same lexical items are involved in both analyses.

Relative Clause Pronoun

Reading time differences were not predicted at the relative clause pronoun (*that*). The control group did not show effects of sentence type as measured by gaze duration, $F(1, 7) = 0.08$, $p = .79$; go-past time, $F(1, 7) = 0.05$, $p = .83$; rereading duration, $F(1, 7) = 0.86$, $p = .39$; or total reading duration, $F(1, 7) = 2.43$, $p = .16$. People with aphasia did not show effects of sentence type for gaze duration, $F(1, 8) = 0.24$, $p = .64$; rereading duration, $F(1, 8) = 0.80$, $p = .40$; and total reading duration, $F(1, 8) = 0.48$, $p = .51$. People with aphasia had longer go-past times for this region in the object cleft compared with subject cleft sentences, $F(1, 8) = 11.2$, $p = .01$, meaning that it took them longer to read past this word in the sentence.

Second Noun Phrase

The second noun phrase refers to *the baby* in example 1 and *the father* in example 2. According to Staub (2010), longer go-past times for the second noun phrase in object cleft compared with subject cleft sentences reflect sensitivity to structural frequency, as the second noun phrase is the first point at which it is clear that the sentence follows noncanonical word order. Controls did not show significant effects

Table 5. Reading times measures for people with aphasia.

Variable	First noun phrase	Relative cause pronoun	Second noun phrase	Verb	End of sentence
Gaze duration					
Object cleft	362.5 (236)	203.1 (171)	480.3 (252)	383.4 (239)	1401.6 (1063)
Subject cleft	353.6 (214)	177.5 (156)	495.0 (276)	411.4 (305)	1246.3 (818)
Difference	8.9	25.6	–14.7	–28.0	155.3
Go-past time					
Object cleft	766.7 (551)	353.8 (461)	774.8 (606)	683.8 (644)	7891.8 (3274)
Subject cleft	791.6 (474)	298.6 (422)	615.9 (440)	772.9 (784)	8209.6 (3952)
Difference	–24.9	55.2*	158.9*	–89.1	–317.8
Rereading time					
Object cleft	1123.8 (747)	466.7 (520)	1868.6 (1059)	2038.3 (1063)	4042.0 (1929)
Subject cleft	1216.6 (927)	410.1 (386)	2478.8 (1350)	1475.9 (967)	4077.1 (1995)
Difference	–92.8	56.6	–610.2*	562.4*	–35.1
Total duration					
Object cleft	1325.6 (743)	641.6 (540)	2094.2 (1067)	2279.5 (1073)	4283.8 (1940)
Subject cleft	1431.6 (907)	560.6 (410)	2699.8 (1355)	1716.5 (983)	4311.6 (2015)
Difference	–106.0	81.0	–605.6*	563.0*	–27.8

Note. Values are means (standard deviations). Difference is calculated as object cleft minus subject cleft. All reading times are in milliseconds.
$^*p < .05$.

of sentence type in the earliest measure, gaze duration, $F(1, 7) = 3.15$, $p = .12$. They showed a trend toward longer go-past times in object compared with subject cleft sentences, $F(1, 7) = 5.07$, $p = .059$.[2] Controls also showed significant effects of sentence type at the second noun phrase for later measures. Both rereading times, $F(1, 7) = 7.91$, $p = .03$, and total reading duration, $F(1, 7) = 15.96$, $p = .01$, were longer for object cleft compared with subject cleft sentences.

Like controls, people with aphasia did not show significant effects of sentence type for gaze duration at the second noun phrase, $F(1, 8) = 0.73$, $p = .42$. People with aphasia were sensitive to structural frequency, as evidenced by longer go-past times, $F(1, 8) = 6.35$, $p = .04$, for the second noun phrase in object cleft compared with subject cleft sentences. It was surprising that people with aphasia spent more time rereading the second noun phrase in the simpler subject cleft sentences compared with the more complex object cleft sentences: rereading times, $F(1, 8) = 33.34$, $p < .001$; total reading times, $F(1, 8) = 15.96$, $p = .005$.

Our extension of the lexical bias hypothesis predicted that people with aphasia would show greater effects of structural frequency than controls. As noted above, variance in the data precluded the inclusion of the variable group in the ANOVAs. To examine group effects, difference scores were computed by subtracting each individual's go-past times for subject clefts from their reading times for object clefts. The resulting difference scores met the assumption of homogeneity of variance (ratio = 1.6). A one-way ANOVA with group as the independent variable and the difference scores as the dependent variable revealed no significant effect of group on the magnitude of the difference scores ($F < 1$). Thus, the effect of structural frequency was not greater in people with aphasia than in controls.

Verb

According to Staub (2010), longer reading times for object cleft compared with subject cleft sentences at the verb (*entertained*) reflect sensitivity to structural complexity. Controls displayed the predicted reading patterns at the verb. When they read object cleft compared with subject cleft sentences, they had longer gaze durations, $F(1, 7) = 20.17$, $p = .003$; go-past times, $F(1, 7) = 19.38$, $p = .003$; and total reading durations, $F(1, 7) = 8.16$, $p = .02$. There was no significant effect of sentence type on rereading durations, $F(1, 7) = 0.33$, $p = .59$. This may be due to a lack of rereading in general at this position in the sentence.

People with aphasia showed effects of structural complexity in later measures of reading time. At the verb in object cleft compared with subject cleft sentences, they had longer rereading times, $F(1, 8) = 11.71$, $p = .009$, and total reading times, $F(1, 8) = 11.03$, $p = .01$. There were no significant differences in reading times for the verb on go-past time, $F(1, 8) = 0.01$, $p = .93$, or gaze duration, $F(1, 8) = 0.78$, $p = .40$.

End of Sentence

The end of the sentence was analyzed as an entire critical region to assess effects of complexity that carried over once participants finished reading (spillover effects) after the relative clause. There were no significant effects of sentence type for any of the reading measures in either group (all Fs < 1.1; all ps $> .11$).

Relative Clause Region

People with aphasia spent more time rereading the final word of the relative clause in both object cleft sentences, in which the verb is the clause-final word, and subject cleft sentences, in which the second noun phrase is the clause-final word. These results raise the possibility that people with aphasia did not show effects of structural complexity. Instead, it could be that apparent effects of structural complexity (i.e., longer reading times for the verb in object cleft vs. subject cleft sentences) reflect end-of-clause effects rather than structural complexity effects. Direct comparison of the clause-final words (the second noun phrase and the verb) is complicated due to differences in word class, frequency, and length. In order to further investigate whether people with aphasia showed effects of structural complexity, reading times for the entire relative clause were compared for object and subject clefts. Raw reading times for the relative clause region are displayed in Figure 1.

Controls showed effects of structural complexity in all reading times measures. Their reading times were longer for object clefts than for subject clefts in gaze duration, $F(1, 7) = 7.16$, $p = .03$; go-past times, $F(1, 7) = 15.52$, $p < .001$; rereading duration, $F(1, 7) = 38.72$, $p < .001$; and total reading duration, $F(1, 7) = 33.89$, $p < .001$. People with aphasia did not show effects of structural complexity in gaze duration, $F(1, 8) = 0.58$, $p = .47$. However, the aphasic group showed longer rereading times, $F(1, 8) = 5.56$, $p = .04$, and total reading times, $F(1, 8) = 5.56$, $p = .04$, for object cleft sentences than for subject cleft sentences. The people with aphasia showed a trend toward longer go-past times for object cleft sentences, $F(1, 8) = 4.39$, $p = .07$.

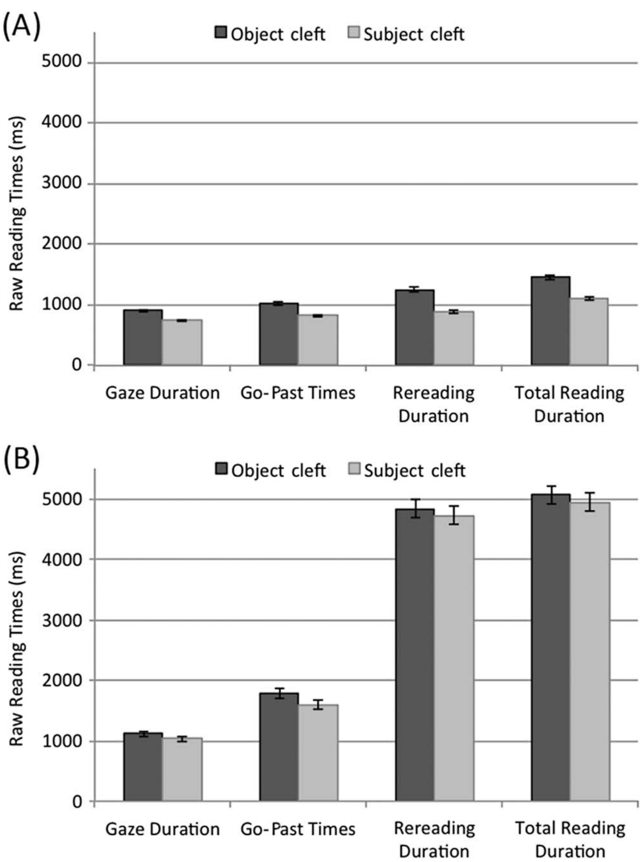
Analysis of Individual Data

Analyses of individual data were conducted to determine how many individuals with aphasia showed the same pattern as the overall group. The Revised Standardized Difference Test (Crawford & Garthwaite, 2005) was used to provide a measure of whether the difference between object and subject cleft sentences observed in each person with aphasia was greater than the difference that would be expected on the basis of the control data.

First, go-past times for the second noun phrase were analyzed because they are indicative of sensitivity to structural frequency. The data are presented in Figure 2. The group data suggested that people with aphasia and

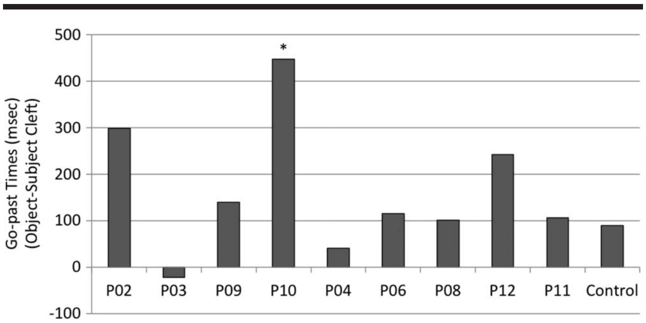
[2]The effect of sentence type for the second noun phrase in go-past times was significant in controls in the raw reading times, $F(1, 7) = 6.25$, $p = .04$, but not in the transformed reading times reported here.

Figure 1. Reading times for relative clause. Error bars show standard error of the mean. (A) Controls. (B) People with aphasia.



age-matched controls were sensitive to structural frequency. This pattern was relatively uniform across people with aphasia. Only P10 showed a greater difference between go-past times for the second noun phrase in object cleft versus subject cleft sentences than would be expected on the basis of the control data. This result suggests that P10 was more sensitive to structural frequency than the controls. However, in general, the results of the Revised Standardized Difference Test are consistent with the idea that the participants with aphasia were not more sensitive to structural frequency than the controls.

Figure 2. Go-past times for the second noun phrase: effects of structural frequency.



Second, rereading times for the second noun phrase and verb were analyzed (see Figure 3). The second noun phrase is the last word of the relative clause in subject cleft sentences, whereas the verb is the last word of the relative clause in object cleft sentences. People with aphasia showed the unexpected pattern of longer rereading times for the second noun phrase in simple (subject cleft) compared with more complex (object cleft) sentences. All participants with aphasia except P09 had longer rereading times for the second noun phrase in the subject cleft compared with object cleft sentences than controls. Similar to the control group, all of the participants with aphasia spent more time rereading the verb in object clefts than subject clefts. Five of the participants with aphasia (P03, P04, P06, P10, and P11) showed a significantly greater difference in reading times for the verb when compared with controls.

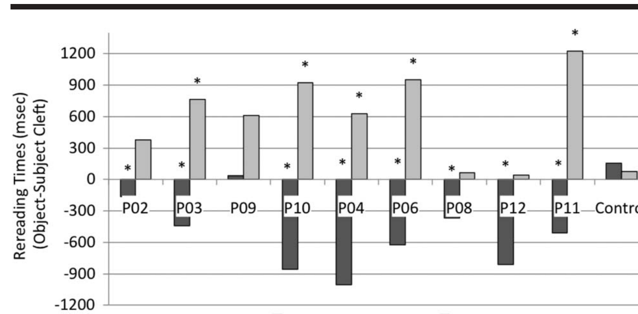
Individual Differences Associated With Agrammatism

As noted above, some authors have argued that people with agrammatic aphasia show distinct patterns of comprehension for object and subject cleft sentences. Five participants (P02, P04, P06, P08, and P09) had agrammatism ratios consistent with Thompson and colleagues' agrammatic participants, and two (P03 and P11) had ratios consistent with Thompson and colleagues' anomic participants (Cho-Reyes & Thompson, 2012; Thompson et al., 2012). Inspection of the data in Figures 2 and 3 did not reveal distinct reading patterns for participants with agrammatic and anomic profiles. For example, P03 showed small (and reverse) effects of structural frequency in the go-past times for the second noun phrase, but P11 showed effects of structural frequency very similar to those seen in agrammatic participants such as P06, P08, and P09. These data do not suggest that people with agrammatic and anomic profiles show substantially different patterns of reading times.

Discussion

The primary goal of this study was to examine whether people with aphasia and controls differed in their

Figure 3. Rereading times for the second noun phrase and the verb.



sensitivity to structural complexity and structural frequency when reading object and subject cleft sentences. First consider the effects of structural complexity, which were more straightforward in the control group than in the people with aphasia. The controls had longer gaze durations, go-past times, and total reading times for the verb in the object cleft versus subject cleft sentences. This finding was predicted and reflected timely integration of the verb with its arguments. In contrast, the people with aphasia showed greater processing disruptions for object cleft versus subject cleft sentences in rereading times and total reading duration but not in the first pass through the sentence (i.e., not in gaze duration or go-past times). That is, people with aphasia spent approximately the same amount of time reading the verb in complex and simple sentences on the first pass through the sentence but then spent more time rereading this segment in complex sentences on subsequent passes through the sentence.

The finding that effects of sentence type emerged only in rereading times for people with aphasia raises the concern that these effects do not reflect structural complexity. This concern arises because people with aphasia had longer rereading times for the last word of the relative clause in both sentence types: the second noun phrase in subject clefts and the verb in object clefts. Longer rereading times for the clause-final word in both sentence types could reflect end-of-clause wrap-up processes rather than online structure-building operations. On this account, people with aphasia may have required more time to integrate the meaning of the relative clause before moving on to the next phrase of the sentence regardless of sentence type.

A direct comparison of the magnitude of the end-of-clause effects in object and subject clefts was not possible due to differences in lexical items at that point in the sentence (i.e., nouns vs. verbs). For this reason, we analyzed reading times for the entire relative clause to determine whether people with aphasia showed differences in reading times as a function of sentence type. Analyzing the entire relative clause provides a way to control for differences in the lexical items because the verbs are the same and the nouns are well matched, as evidenced by the absence of reading time differences for the first noun phrase. The results showed that the people with aphasia spent more time rereading the relative clause in object cleft than subject cleft sentences. The fact that we observed effects of structural complexity in rereading times and total reading duration for the entire relative clause suggests that, minimally, the end-of-clause wrap-up effects are greater for object clefts than subject clefts. Thus, the data suggest that people with aphasia were sensitive to structural complexity.

However, the people with aphasia's rereading times were very long, which further complicates the interpretation of reading time differences associated with structural complexity. Here, the issue is to what extent the rereading times reflected online parsing operations involved in building the mental representation of a sentence rather than end-of-clause integrative processes. It is unclear how to distinguish online syntactic parsing operations from clause-final processes. The two types of processes might be expected to show a different time course, with clause-final effects occurring after syntactic parsing effects. However, aspects of the two types of processes could also occur in parallel. In addition, rereading times and total reading duration are typically taken to reflect online sentence processing, albeit later processes (e.g., reanalysis) than those reflected by gaze duration or go-past time (cf. Rayner, 1998). Thus, it is unclear at what point—if any—very long rereading times cease to reflect online syntactic parsing operations.[3] A related issue is that studies about end-of-clause effects tend to focus on word position (i.e., clause-final words) rather than the type of measure (i.e., gaze duration vs. rereading times), making it difficult to disentangle the time course of the two sets of processes (e.g., Rayner, Kambe, & Duffy, 2000; Warren, White, & Reichle, 2009). It is likely that longer rereading times for the object cleft compared with subject cleft sentences reflect a combination of online syntactic parsing operations and end-of-clause wrap-up effects, but further research is needed to clarify these issues.

Regardless, people with aphasia did not appear to construct an online mental representation of the sentence on the same time course as controls. Effects of structural complexity emerged on the first pass through the sentence for controls but only in rereading times for people with aphasia. These results are inconsistent with previous studies, which reported that people with aphasia show sensitivity to structural complexity at the same point in the sentence as controls (e.g., Caplan et al., 2007; DeDe, 2013b; Thompson & Choy, 2009). In one study, people with aphasia showed longer listening and reading times for the verb in object cleft compared with subject cleft sentences in self-paced tasks (DeDe, 2013b). However, the previous studies used methods that do not allow for backtracking during presentation of a sentence. In self-paced reading and listening, readers cannot revisit earlier segments of a sentence. In studies of auditory comprehension using eye tracking, sentences are presented once. The use of eye tracking while reading may have allowed participants the flexibility to use different reading strategies. It is important to note that these strategies are likely to more closely mirror how people read outside of the laboratory. If this interpretation is correct, then eye tracking while reading likely reflects sentence comprehension strategies used during reading but might not generalize to auditory comprehension.

Previous studies about sentence comprehension in aphasia have not focused on end-of-clause wrap-up effects. However, the idea that people with aphasia show greater effects of structural complexity at the end of the clause than controls is consistent with the lexical integration hypothesis.

[3]In an effort to tease these apart, we analyzed second-pass rereading times separately from total rereading time. People with aphasia showed effects of structural complexity on the second pass, suggesting that these effects emerge relatively early in the rereading process. Although such results are suggestive, they are not reported here in the interest of brevity and because differences in the total number of passes for each person with aphasia differed, making the results difficult to interpret.

According to the lexical integration hypothesis, people with aphasia have difficulty integrating lexical items to determine the meaning of a sentence (cf. Dickey & Warren, 2015; Thompson & Choy, 2009). In the present study, effects of structural complexity emerged later in people with aphasia than in controls and at least partly reflect end-of-clause integration processes. Effects associated with disordered lexical integration are not necessarily limited to the end of the clause, but evidence of exaggerated end-of-clause wrap-up effects for complex sentences is consistent with the idea that people with aphasia have disordered lexical integration.

Now consider the effects of structural frequency. Both the control group and the people with aphasia showed effects of structural frequency, as evidenced by longer reading times at the second noun phrase in object cleft compared with subject cleft sentences. In object cleft sentences, this is the first point in the sentence at which the reader is able to recognize that the sentence follows noncanonical word order. These results, similar to those reported by Staub (2010), demonstrate that people with aphasia are sensitive to information about structural frequency during sentence processing.

Our extension of the lexical bias hypothesis predicted that people with aphasia rely on structural frequency to a greater extent than controls. In contrast, the results showed that the effects of structural complexity were comparable in the two groups. The analysis of difference scores for go-past times at the second noun phrase did not reveal a significant interaction of group and sentence type. Thus, the results did not support our prediction.

Instead of showing a greater reliance on structural frequency, people with aphasia may have used the information about structural frequency in a different way than controls. For controls, longer go-past times for the second noun phrase in object clefts versus subject clefts probably reflect the mismatch between participants' expectations and the actual sentence structure (Levy, 2008; Staub, 2010). Readers without impairment may also begin to revise their mental representation of the sentence immediately upon recognizing the mismatch. For people with aphasia, the longer go-past times are also likely to reflect surprisal. However, people with aphasia may use structural frequency as a cue to trigger a different set of reading strategies for sentences with noncanonical word order or other less common syntactic structures.

One question is what sort of alternate reading strategies people with aphasia might adopt when they encounter complex sentences. As discussed above, people with aphasia did not show effects of structural complexity on the same time course as controls. Thus, the results of the present study suggest that people with aphasia do not build a complete mental representation of a sentence's structure on the first pass through the sentence. One possibility is that people with aphasia first read through the sentence to access lexical items without attempting to determine syntactic relationships. With respect to the present study, a focus on lexical access would account for null complexity effects at the verb on the first pass through the sentence (e.g., in gaze duration and go-past times) because the lexical items were the same in both sentence types. Having accessed the critical words, people with aphasia could reread the sentence to determine the relationship between the critical elements, resulting in effects of structural complexity in rereading and total reading times. In this way, people with aphasia would be able to use all of the available semantic cues to facilitate recovery of the syntactic structure. Consider the sentence "The ball was chased by the dog." In a sentence such as this, it might be easier to identify the agent and theme of the verb after accessing both of the noun phrases. The reason is that *dog* is a more felicitous agent for the verb *chased*, whereas *ball* is more likely to be the theme. Accessing all of the critical words prior to establishing these types of relationships provides semantic cues to support the effort of interpreting the sentence. This alternate reading strategy could be used to compensate for slowed lexical access (e.g., Thompson & Choy, 2009) or slowed or inefficient syntactic processing (e.g., Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011).

The reading patterns adopted by people with aphasia did not seem to be universally successful, as evidenced by overall lower accuracy scores on comprehension questions when compared with controls. Inspection of the individual accuracy data in Table 3 and the individual rereading times in Figure 3 suggests that the benefits of time spent rereading varied across participants. For example, P11 showed very long rereading times for the verb in object cleft sentences but performed at chance on the comprehension questions for those sentences. In contrast, P03 also showed relatively long rereading times for the verb in object clefts and achieved comprehension scores just above the control group's mean. Thus, it is possible that time spent rereading is a successful compensatory strategy for some people with aphasia but not others. It is interesting to note that both P03 and P11 met the criteria for an anomic profile on the basis of the tests of agrammatism (see Table 2), suggesting that performance on those measures may not be the best way to predict whether a given individual with aphasia will benefit from long rereading times.

The present study was not designed to determine whether people with agrammatic aphasia show distinct patterns of reading comprehension. Nonetheless, we inspected individual data for participants who fit the agrammatic and anomic profiles. The data did not suggest that there were differences between individuals with agrammatic and anomic profiles. However, the present study provides only a weak test of the hypothesis that there are differences as a function of agrammatism ratio. The study was not designed to investigate this issue, and only a small number of participants met the criterion for an anomic profile. In addition, it is worth noting that all of the participants (including P03 and P11) showed symptoms of agrammatism on at least one of the three measures included in the agrammatism profile. Therefore, these results should be interpreted cautiously.

A potential concern is that some participants' overall low accuracy performance may limit the interpretability of the online data. Inspection of the data in Table 3 shows that P04 performed at chance on the subject cleft sentences, whereas P09 and P11 scored at chance on the object cleft sentences. There are two reasons to include these participants' data in the group analysis. First, there is evidence that participants with aphasia can display normal patterns of online sentence comprehension even when they answer comprehension questions inaccurately (Dickey et al., 2007). One reason may be that comprehension question accuracy depends in part on working memory, whereas online sentence comprehension tasks more closely reflect syntactic structure-building operations. Second, in the present study, inspection of the individual data in Figures 2 and 3 indicates that P04, P09, and P11 showed very similar patterns of reading times compared with the other individuals with aphasia. For this reason, their online reading time data were included in the group analyses.

An unexpected finding was that people with aphasia had longer go-past times at the relative clause pronoun (*that*) in object clefts than in subject clefts. At this point, the object and subject cleft sentences did not differ. One possible interpretation is that the longer reading times are due to the presence of deep dyslexia, which might lead to longer reading times for function words. However, it is unlikely that deep dyslexia accounts for the results because it would not explain a difference in reading times for the same function word in two different sentence types. Another possible explanation is that people with aphasia used parafoveal preview to begin processing the word after *that*. Although no published studies have investigated this topic, this result suggests that people with aphasia might benefit from parafoveal preview in sentence processing (also cf. DeDe, 2013a).

The secondary goal of this study was to validate the use of eye tracking while reading as a method for examining sentence comprehension impairments in people with aphasia. Although there were differences in how people with aphasia and controls read the complex sentences, the results were interpretable with respect to previous studies. Thus, eye tracking during reading appears to provide a valid measure of reading—but not necessarily auditory—comprehension in people with aphasia. Although speculative, it may be that studies using self-paced reading generalize to auditory comprehension more easily than studies using eye tracking during reading. The reason is that self-paced reading prevents backtracking, similar to auditory comprehension. More research is needed to answer this question.

In conclusion, people with aphasia were sensitive to both structural complexity and structural frequency when reading object cleft and subject cleft sentences. The results suggest that the lexical bias hypothesis cannot be extended directly to include structural frequency because the people with aphasia did not show greater surprisal effects than controls. Instead, people with aphasia may have used different strategies to understand complex and simple sentences. Thus, people with aphasia may use information about structural frequency in different ways than controls. To fully understand these strategies, it is important to consider multiple factors that contribute to sentence comprehension impairments.

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