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Verb Transitivity Bias Affects On-line Sentence Reading in People with Aphasia

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Abstract

Background—Studies of sentence comprehension in non-disordered populations have convincingly demonstrated that probabilistic cues influence on-line syntactic processing. One well-studied cue is verb argument structure bias, which refers to the probability that a verb will occur in a particular syntactic frame. According to the Lexical Bias Hypothesis, people with aphasia have difficulty understanding sentences in which the verb's argument structure bias conflicts with the sentence structure (e.g., a transitively biased verb in an intransitive sentence). This hypothesis may provide an account of why people with aphasia have difficulty understanding both simple and complex sentences.

Aims—The purpose of this study was to test the Lexical Bias Hypothesis using an on-line measure of written sentence comprehension, self-paced reading.

Methods & Procedures—The participants were ten people with aphasia and ten non-brain-damaged controls. The stimuli were syntactically simple transitive and intransitive sentences that contained transitively- or intransitively-biased verbs. For example, the transitively-biased verb "called" appeared in sentences such as "The agent called (the writer) from overseas to make an offer." The intransitively-biased verb "danced" appeared in sentences such as "The couple danced (the tango) every Friday night last summer."

Outcomes & Results—Both groups' reading times for critical segments were longer when the verb's transitivity bias did not match the sentence structure, particularly in intransitive sentences.

Conclusions—The results were generally consistent with the Lexical Bias Hypothesis, and demonstrated that lexical biases affect on-line processing of syntactically simple sentences in people with aphasia and controls.

Keywords

Self-paced reading; sentence comprehension impairments; aphasia; Lexical Bias Hypothesis

Introduction

A large body of literature has demonstrated that people with aphasia have difficulty understanding sentences with non-canonical word order, such as passive sentences (e.g., Caplan et al., 2007; Grodzinsky, 2000; Thompson & Choy, 2009). Some people with aphasia also have trouble understanding relatively simple sentences that maintain canonical word order (Subject-Verb-Object or S-V-O in English) (e.g., Caplan & Waters, 1996; Berndt, Mitchum, & Wayland, 1997; Thompson & Choy, 2009). The present study

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investigated the Lexical Bias Hypothesis, which provides a way to explain why people with aphasia sometimes have difficulty understanding syntactically simple sentences.

According to the Lexical Bias Hypothesis, sentence comprehension impairments result from a mismatch between a sentence's structure and the lexical biases of the words in the sentence (Gahl, 2002). In this context, lexical biases refer to the probability that a particular word will occur in a given sentence context (e.g., the likelihood that a verb will be followed by a direct object). The Lexical Bias Hypothesis was motivated by studies of normal sentence comprehension, which have convincingly demonstrated that non-disordered individuals use multiple sources of information, including probabilistic cues, to construct a mental representation of a sentence during syntactic parsing (e.g., see MacDonald, Pearlmutter, & Seidenberg, 1994; Pickering & van Gompel, 2006 for reviews). Probabilistic cues refer to statistical regularities within a language, such as the frequency with which specific structures and lexical items occur in a language and the contexts in which particular words appear (e.g., DeDe, 2010; Garnsey et al., 1997; MacDonald et al., 1994; Pickering & Van Gompel, 2006; Trueswell & Tanenhaus, 1994). Thus, the Lexical Bias Hypothesis predicts that people with aphasia would have more difficulty understanding sentences in which the probabilistic cues do not bias the listener or reader to the correct interpretation of the sentence.

Lexical biases are one type of probabilistic cue, and this paper focuses on one type of lexical cue, verb transitivity bias. Verb transitivity bias refers to the likelihood that a given verb will occur in a transitive or intransitive sentence frame. The main difference between transitive and intransitive sentences is that the verb is followed by a direct object in transitive sentences. For example, *watch* is a transitively biased verb because it typically takes a direct object (e.g., *The parents watched the child*.) However, *watch* also occurs in intransitive frames (e.g., *The parents watched from the sidelines*.). A verb like *dance* is intransitively biased because it is not typically followed by a direct object (e.g., *The parents danced in the kitchen*.), though it can also occur in a transitive sentence frame (e.g., *The parents danced the tango*.). The fact that verb transitivity bias influences how college age adults process syntactically ambiguous sentences is well documented (e.g., DeDe, 2010; Staub, 2011). Relatively few studies have examined how verb argument structure in general, or transitivity biases in particular, influence sentence comprehension in people with aphasia.

A few studies have investigated whether people with aphasia have impaired knowledge of verb argument structure (Kim & Thompson, 2000; Shapiro, Gordon, Hack, & Killackey, 1993a; Shapiro & Levine, 1990; Shapiro, Nagel, & Levine, 1993b). For example, Shapiro and colleagues used an on-line cross modal lexical decision task to examine sensitivity to verb argument structure complexity, where complexity was defined as the number of argument structures licensed by the verb. People with non-fluent, but not fluent, aphasia showed relatively slow response times following verbs with complex argument structures, suggesting that they retained knowledge of verb argument structure (Shapiro et al., 1993b). These studies did not manipulate the match between verb argument structure and sentence type, and so did not directly test the Lexical Bias Hypothesis. The relevant point is that at least some people with aphasia seem to be sensitive to verb argument structure complexity.

A handful of studies have directly investigated the predictions of the Lexical Bias Hypothesis. Using off-line plausibility judgment tasks, Gahl and colleagues found that people with aphasia and non-brain-damaged controls made more errors about sentences in which the sentence structure conflicted with the verb's argument structure preferences (Gahl, 2002; Gahl et al., 2003). For example, error rates were higher for transitive sentences containing intransitively biased verbs than transitive sentences containing transitively biased verbs. These effects were observed in participants with fluent and non-fluent aphasia.

Importantly, the effect of mismatch was observed in syntactically simple transitive and intransitive sentences. In addition, the mismatch effect was reported for various types of intransitive verbs, including those in which the subject of the sentence is the agent of the verb (i.e. unergatives such as *swim*) and those in which the subject of the sentence undergoes the action associated with the verb (e.g., unaccusatives such as *melt*). These data suggest that comprehension impairments for simple sentences may reflect a conflict between lexical and syntactic variables, and are consistent with the Lexical Bias Hypothesis.

Russo et al. (1998) used cross modal lexical priming to examine how a mismatch between verb transitivity bias and sentence structure affected on-line sentence processing in people with aphasia. In their study, individuals with fluent aphasia listened to transitive and intransitive sentences that contained transitively and intransitively biased verbs, and made lexical decisions about written words that appeared one or two words after the verb (depending on the sentence type). The rationale was that lexical decisions would be faster when the verbs were in their preferred syntactic frames. Unlike non-brain-damaged controls, the people with fluent aphasia did not show the expected differences in response times when the verb's transitivity bias did not match the sentence structure (Russo et al., 1998). However, Russo et al. did not examine whether there were separate effects of sentence type and verb mismatch. As will be discussed below, there is reason to expect differences between transitive and intransitive sentences. Another issue is that Russo et al. only probed for processing disruptions at one point in the sentence. It is possible that the people with fluent aphasia were slowed by a mismatch between transitivity bias and sentence structure, but that the effect either preceded or followed the probe position.

Another study of on-line sentence processing suggested that people with aphasia are sensitive to verb transitivity biases. DeDe (2011) investigated whether lexical and prosodic cues influence how people with aphasia process syntactically ambiguous sentences in a self-paced listening study. The lexical cues were verb transitivity bias and plausibility; plausibility referred to whether or not the noun following the verb was a likely object for that verb. The people with aphasia showed longer listening times when the lexical and prosodic cues were biased toward different interpretations of the sentence, which suggests that the people with aphasia were sensitive to verb transitivity bias. Interestingly, the effect emerged at a later point in the sentence in people with aphasia than controls. Interpretation of the results was complicated because verb transitivity bias was confounded with plausibility (i.e., the two lexical cues were always biased toward the same interpretation of the sentence). Thus, the results showed that people with aphasia were sensitive to the presence of conflicting cues in syntactically ambiguous sentences, but did not clearly demonstrate that they were sensitive to verb transitivity bias.

In summary, there is evidence that people with aphasia are sensitive to verb argument structure. The existing off-line studies support the Lexical Bias Hypothesis, but the results of online studies are mixed.

Sensitivity to a mismatch between lexical biases and sentence structure may help explain why people with aphasia have difficulty understanding sentences with both canonical and non-canonical word order. Typically, S-V-O is assumed to be canonical word order for English, but Menn (1998) suggested that canonical word order depends on the lexical biases of the verb. Thus, transitive or intransitive sentence frames may be preferred, depending on the lexical bias of the verb. If canonicity is determined by the lexical bias of the verb, then the effects of verb mismatch should be similar across sentence types.

On the other hand, the relative frequency of S-V-O structures in English might lead to a more general preference for transitive sentences, regardless of lexical biases (cf. Van Dyke

& Lewis, 2003). Dick and Elman's (2001) corpus analysis showed that S-V-O sentences occur more frequently than S-V-Prepositional Phrase (S-V-PP) sentences in English (~1.7:1). Few studies have directly compared comprehension of simple transitive and intransitive sentences. Gahl (2002) reported that people with aphasia made more errors about intransitive than transitive sentences, but the difference was not significant. DeDe (2011) suggested that people with aphasia had a general preference for S-V-O word order based on evidence that processing was disrupted when probabilistic cues were biased to intransitive (S-V) structures. If there is a general preference for S-V-O structures (over S-V-PP), then the effects of verb mismatch may differ for transitive and intransitive sentences.

The Present Study

The present study was designed to test the Lexical Bias Hypothesis. Thus, the focus of this study was on whether people with aphasia show on-line processing disruptions associated with a mismatch between verb transitivity bias and sentence structure, and whether the effect of mismatch differs in transitive and intransitive sentences. These questions were investigated using an on-line measure of written sentence comprehension, self-paced reading. Sung and colleagues have recently demonstrated that self-paced reading times are sensitive to sentence-level effects in people with aphasia, making this an appropriate paradigm for the present research (Sung et al., 2009; Sung et al., 2012).

People with aphasia and non-brain-damaged controls read simple transitive and intransitive sentences that contained transitively and intransitively biased verbs. Taken broadly, the Lexical Bias Hypothesis predicts that people with aphasia will have trouble understanding sentences when probabilistic cues are biased towards the incorrect interpretation of a sentence. On this account, people with aphasia should read critical segments of sentences more quickly when the verb transitivity bias matches the sentence structure than when verb transitivity bias and sentence structure do not match. Further, if people with aphasia have a general preference for S-V-O structures, then the effect of a mismatch between transitivity bias and sentence structure may be more salient in intransitive than transitive sentences. Note that non-brain-damaged controls may also experience more difficulty processing sentences with conflicting probabilistic cues. However, the Lexical Bias Hypothesis predicts that the effects of conflicting cues should be greater in people with aphasia (Gahl, 2002).

Another possibility is that effects of verb mismatch might emerge later (or not at all) in people with aphasia. This would be consistent with Love and colleagues' claim that sentence comprehension deficits reflect slowed lexical processing, on the assumption that slowed lexical access should affect the time course with which lexical biases are activated (e.g., Ferril, Love, Walenski, & Shapiro, 2012; Love, Swinney, Walenski, & Zurif, 2008)

Method

Participants

The participants were people with aphasia (mean age= 49 years) and non-brain-damaged controls (mean age= 50 years) (n=10 per group). All participants were native English speakers and reported normal or corrected-to-normal vision and denied significant visual impairments (e.g., cataracts). The controls denied a history of neurological disease, speech language disorders, and reading impairments. The controls earned a minimum of 28 out of 30 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975).

The people with aphasia were at least 6 months post-onset of aphasia due to left hemisphere brain damage. They completed an extensive test battery to describe their aphasia. Background information about the people with aphasia is presented in Table 1.

The participants with aphasia had speech-language impairments and single word comprehension within normal limits. All of the participants except P10 performed two standard deviations below the mean for age-matched controls on the Boston Naming Test (BNT) (Kaplan, Goodglass, & Weintraub, 2001). The Peabody Picture Vocabulary Test (PPVT, 4th Edition, Form A) (Dunn & Dunn, 2007) assessed single word comprehension. The participants with aphasia performed within two standard deviations of the mean for age-matched controls on the PPVT. Participants also completed the written lexical decision and word picture matching subtests on the Psycholinguistic Assessment of Language (PAL) (Caplan, 1992). All participants performed above chance on the PAL subtests, showing that they did not have significant impairments in written word processing. The results of the BNT, PPVT, and PAL are presented in Table 1.

All participants with aphasia except P10 completed the short form of the Boston Diagnostic Aphasia Exam (Goodglass, Kaplan, & Barresi, 2000). Results are presented in Table 2. P10 completed the Western Aphasia Battery, and earned an Aphasia Quotient of 94.8, which places him outside of the typical cut off for someone with aphasia. The participant was included despite his strong performance on standardized tests because he had exhibited anomia in conversational speech and reported significant difficulty in reading comprehension.

Additional testing was used to identify participants with agrammatism, which is potentially of interest because this subgroup has been reported to show distinct patterns of sentence comprehension ability (e.g., Grodzinsky, 2000; Thompson & Choy, 2009). To date, no specific claims have been made regarding the relationship between agrammatism and sensitivity to verb transitivity biases. The Northwestern Naming Battery-Final was administered to calculate the verb: noun ratio (Thompson & Weintraub, unpublished). The ratios of non-canonical: canonical sentences that were correctly comprehended and produced were calculated based on the Sentence Comprehension and Sentence Production Priming subtests of the Northwestern Assessment of Verbs and Sentences (Thompson, unpublished). Ratios less than 1 are consistent with a diagnosis of agrammatism. On the basis of the results (see Table 3), all participants except P10 show some evidence of agrammatism.

Stimuli

The stimuli were pairs of sentences that contained transitively (n=10) and intransitively biased verbs (n=10). Examples are provided in Table 4, and the full set of stimuli is given in Appendix 1. Transitivity biases were obtained from Connine et al. (1984) and DeDe (2011). Each transitively and intransitively biased verb occurred in two sentence frames, a transitive sentence (S-V-O) and an intransitive sentence (S-V-PP). For any given verb, its transitive and intransitive frames were identical except for the presence of a direct object in the transitive exemplar. Transitive sentences were longer than intransitive sentences due to the presence of the direct object. However, sentence length did not differ for sentences containing transitively and intransitively biased verbs ($F < 1$). In all of the sentences (including those containing intransitively biased verbs), the subject of the sentence was the agent of the verb. The transitively biased verbs were marginally more frequent than the intransitively biased verbs, (3.8 vs. 3.2, $F(1,18)=3.9$, $p=.06$) (based on CELEX; Baayen, Piepenbrock & Gulikers, 1995). Intransitively biased verbs were longer than transitively biased verbs, but the effect was not significant (6.5 vs. 6.2 letters, $F < 1$).

Task

Self-paced reading is a task that measures on-line written sentence processing. Sentences are broken into short segments and participants press a button to request each segment. The slashes in Table 4 indicate segmentation for this experiment. During the experiment, participants saw a “Ready?” prompt, and pressed a button to indicate when they were ready to read the sentence. An E-prime button box interfaced with a computer recorded the reaction time to request each segment (Psychology Software Tools, Pittsburgh, PA). As is typical in this paradigm (e.g., Marinis et al., 2003), each trial began with a series of dashes (−) marking the length and position of the words in the sentence. When the participants pressed the button, the previously revealed segment reverted to dashes and the next segment was revealed. All sentences were followed by a yes/no comprehension question, which was presented auditorily and visually to reduce memory demands (see Table 4). Participants responded to the questions by pressing buttons on the E-prime button box (to indicate a “Yes” or “No” response), which recorded accuracy of the response.

Procedures

The stimuli were divided into 2 lists so that the members of the sentence pairs were separated. They were combined with fillers with various structures so the experimental sentences comprised less than 20% of the items in any list. The sentences were presented in pseudo-random order, with the constraint that no more than two exemplars of the same sentence type could occur in succession. All participants completed both lists in separate testing sessions, which were at least 7 days apart. Order of list presentation was counterbalanced across participants. All lists began with 10 practice items to familiarize participants with the procedure. There was a break halfway through the experiment. Testing sessions lasted approximately 1 hour. During each session, participants completed one experimental list and tests from the battery described above. Participants were offered breaks between each task.

Results

The independent variables were group (people with aphasia vs. non-brain-damaged controls), sentence type (transitive vs. intransitive), and verb match (match vs. mismatch). “Verb match” was included as the independent variable instead of “verb bias” to control for the fact that the intransitively and transitively biased verbs occurred in different sentence frames. Table 4 shows that the match and mismatch conditions included intransitively and transitively biased verbs. With respect to the analysis of self-paced reading data (see below), this means that the same lexical items were in both levels of the factor “verb match” (that is, match vs. mismatch).

Yes-No Comprehension Questions

Proportion correct on the comprehension questions was analyzed using non-parametric statistics. Table 5 presents the accuracy data for each individual with aphasia and each group.

In general, the people with aphasia produced more errors than controls and showed a marginally greater effect of verb mismatch. Wilcoxon tests for independent samples demonstrated that people with aphasia made more errors than controls in all conditions (*Transitive*- Match: $Z = 2.46$, $p=.01$, Mismatch: $Z = 3.25$, $p=.001$; *Intransitive*- Match: $Z = 2.31$, $p=.02$; Mismatch: $Z = 3.08$, $p=.001$). In addition, the effect of mismatch was greater in people with aphasia than controls ($Z=1.9$, $p=.057$).

Wilcoxon Signed Rank tests were used to examine effects of verb mismatch for each sentence type separately. The people with aphasia showed non-significant trends towards more errors in the mismatch condition in transitive sentences (*Transitive Sentences*: $S(9)=13$, $p=.09$; *Intransitive Sentences*: $S(9) =7$, $p=.53$). The controls showed no effects of verb mismatch (*Intransitive Sentences*: S(9) =1.5, p=.50, *Transitive Sentences*: S(9)=0, p=1.0).

Reading times

Overview of Analysis—The measure of on-line sentence processing was the reading time for each segment. Items associated with incorrect responses on the comprehension questions were omitted from the response time analyses. Response times that were less than 100 or greater than 5000 milliseconds were removed. Outliers greater or less than two standard deviations from the mean for each participant in each condition were replaced with the value of the upper or lower limits for that condition. These procedures affected less than 5% of the data.

Sentences containing transitively and intransitively biased verbs differed with respect to verb frequency and segment length. Variance associated with these two variables was controlled by regressing raw reading times against length (i.e., number of letters) and word frequency (Ferreira & Clifton, 1986). The residuals of these analyses were used in the ANOVAs. This procedure results in negative reading times when the observed reading times are faster than the predicted reading times.

Five segments were analyzed. Segment 1 was the first noun phrase (*The agent*, in example 1), and segment 2 was the verb (*called)*. Segment 3 was the prepositional phrase (*from overseas)*. Reading times for the direct object in the transitive sentence (*the writer*) were not initially analyzed because there was no matched word in the intransitive sentences. Segment 4 was *"to make,"* and segment 5 was the end of the sentence (*an offer*). Residual reading times for the five segments were analyzed in separate mixed 2 (group) by 2 (verb match) by 2 (sentence type) ANOVAs by participants (F1) and items (F2). The ratios of the largest to smallest variances ranged from 2.0 to 7.6, indicating that the assumption of homogeneity of variance was not violated (cf. Tabachnick & Fidell, 2001). Significant interactions were examined using Tukey post-hoc tests using a criterion of p<.05. Results are presented in the order that the words occur in the sentences. Figure 1 presents reading times for each condition and group.

Segment 1 (The agent/the couple)—People with aphasia had longer reading times than controls, F1(1,18)=4.2, p=.055, F2(1,36)=100, p<.0001. No other effects were significant (F <1).

Segment 2 (Verb: Called vs. Danced)—People with aphasia read more slowly than controls, F1(1,18)=8.6, p=.001, F2(1,36)=35.3, p<.0001. The main effect of verb match was significant, F1(1,18)=17.9, p=.001, F2(1,36)=6.47, p=.02, as was the interaction between group and verb match, F1(1,18)=8.2, p=.01, F2(1,36)=4.09, p=.05. Tukey tests showed that people with aphasia, but not controls, read more slowly in the mismatch condition. All other F's < 1.5.

Segment 3 (Every vs. From Overseas)—The main effect of group was significant, F1(1,18)=5.1, p=.04, F2(1,36)=38.4, p<.0001. There was also a trend towards a main effect of verb match, F(1,18)=2.4, p=.14, F2(1,36)=1.05, p=.31). The effect of match was larger in people with aphasia than controls, but the interaction was not significant, F1(1,18)=3.0, p=.10, F2(1,36)=2.42, p=.13. The interaction between sentence type and verb match was significant by participants and a trend by items, F1(1,18)=17.3, p<.001, F2(1,36)=3.1, p=.08. Tukey tests showed that the effect of verb match was significant in intransitive, but not transitive, sentences. There were no other significant effects (all F's ≤ 1.5, all p's ≥ .24).

The previous analysis may have missed the effect of verb mismatch in the transitive sentences. The reason is that the effect of verb mismatch may have occurred on the direct object in transitive sentences, but that segment was not included in the previous analyses. To investigate this possibility, reading times for the third segment were analyzed (e.g., the writer vs. from overseas). The results were consistent with those reported above. The interaction between sentence type and verb match was significant, $F1(1,18)=7.55$, $p=.01$, $F2(1,36)=3.6$, $p=.06$. Tukey tests confirmed that the effect of verb match was significant in intransitive sentences only. Reading times for the direct object in the transitive sentences are presented in Table 6.

Segment 4 (To make vs. Friday night)—The main effect of group was significant, $F1(1,18)=5.3$, $p=.03$, $F2(1,36)=31.4$, $p<.0001$. The interaction between group and verb match was significant by participants but not items, $F1(1,18)=4.24$, $p=.05$, $F2<1$. This effect was modified by a three-way interaction between group, sentence type, and verb match, $F1(1,18)=7.3$, $p=.01$, $F2(1,36)=2.4$, $p=.13$. There were no effects of verb match, but people with aphasia read more slowly than controls in all conditions except for transitive sentences in the match condition. There were no other significant effects (all F’s ≤ 1.7).

Segment 5 (an offer vs. last summer)—The main effect of group was significant by items but not participants, $F1(1,18)=3.63$, $p=.07$, $F2(1,36)=20.7$, $p<.0001$. People with aphasia read more slowly than the controls. There were no other significant effects (all F’s ≤ 1.2).

Summary of Group Data

The people with aphasia read more slowly than the controls. More importantly, both groups were sensitive to effects of verb mismatch and sentence type. Segment 2 was the first point at which the people with aphasia were slowed by a mismatch between verb bias and sentence structure. At segment 3, both groups showed effects of mismatch, but only in intransitive sentences. In segment 4, people with aphasia read more slowly than controls in all conditions except for transitive sentences with transitively biased verbs. In order to further explore the effect of verb match, the reading times from segment 3 were analyzed separately for each person with aphasia using the Revised Standardized Difference Test (RSDT; Crawford & Garthwaite, 2005).

Individual Data

Individual reading times were inspected to determine how many people with aphasia showed the expected effects of verb match. In addition, the RSDT was used to compute the probability that an individual with aphasia’s response time difference between the match and mismatch conditions was greater than what would be expected on the basis of the control group’s mean and standard deviations in both conditions. The results are presented in Figure 2.

In the *intransitive* sentences, nine of ten participants with aphasia showed a trend toward longer response times in the mismatch condition. The exception was P5, who read somewhat slower in the match than mismatch condition. The RSDT showed that two participants (P6 and P10) showed significantly greater effects than would be expected based on the control data.

In the *transitive* sentences, the controls had slightly, but not significantly, longer reading times in the match than mismatch condition. In contrast, six of ten participants with aphasia showed a trend towards longer reading times in the mismatch condition. The RSDT revealed that four participants (P4, P8, P9, and P10) showed significantly greater effects than would be expected based on the control data. Like the controls, P9 had longer reading times in the match condition. P4, P8, and P10 all showed significantly longer reading times in the mismatch condition.

Discussion

The results support Gahl's (2002) Lexical Bias Hypothesis, which claims that sentence comprehension impairments result from a mismatch between sentence structure (here, transitive or intransitive) and lexical biases (here, verb transitivity) associated with the words in the sentence. Both people with aphasia and non-brain-damaged controls' reading times were disrupted when verb transitivity bias conflicted with the sentence structure. For people with aphasia, reading times for the verb were slowed in the mismatch condition for both transitive and intransitive sentences. Following the verb, both groups showed an effect of verb mismatch, but only in intransitive sentences. That is, both healthy controls and people with aphasia read more slowly when a transitively biased verb occurred in an intransitive sentence.

These results are generally consistent with those reported by Gahl and colleagues (2002, 2003) and DeDe (2011), which reported that people with aphasia were sensitive to verb transitivity biases. One difference is that DeDe (2011) reported that effects related to verb transitivity bias appeared to be delayed in people with aphasia relative to controls. The effects may have emerged later in DeDe (2011) because that study focused on syntactically ambiguous sentences, which are more complex than the simple transitive and intransitive sentences used in the present study.

The results are not consistent with those reported by Russo et al. (1998), who reported that people with aphasia did not show on-line sensitivity to verb transitivity biases in simple transitive and intransitive sentences. One possible explanation is that Russo et al only studied individuals with fluent aphasia. In this study (as well as DeDe, 2011 and Gahl, 2002), both people with fluent and non-fluent aphasias showed effects of verb mismatch, making this account relatively unlikely. Another possibility is that there is a modality difference: Russo et al. studied auditory sentence comprehension, whereas this study examined reading comprehension. However, studies of non-disordered individuals have revealed effects of verb transitivity bias in both auditory and written sentence comprehension (e.g., DeDe, 2011; Staub, 2007). Further, Sung et al. (2009 Further, Sung et al. (2012) have shown that self-paced reading is an effective tool to study sentence-level processes in people with aphasia. For this reason, it is unlikely to be a modality difference. The most probable explanation is that Russo et al. (1998) collapsed across transitive and intransitive sentences, whereas a different pattern of results was observed for the two types of sentences in this study.

Importantly, these data point to two factors that may influence how well people with aphasia understand syntactically simple sentences. The first factor is whether or not the verb's transitivity bias matches the sentence structure. There also seems to be a comprehension advantage for simple transitive over intransitive sentences. Deficits affecting sentences with non-canonical word order may also be partly attributable to lexical biases of the words in the sentences (or other probabilistic cues). Clinicians may want to consider these factors when evaluating and treating sentence-level comprehension deficits in people with aphasia. For example, these data suggest that people with aphasia would have more difficulty understanding simple intransitive sentences than simple transitive sentences. In addition, these data suggest that one way to increase the complexity of a sentence-level task is to include items in which the verb's transitivity bias does not match the sentence structure.

Given that the match and mismatch conditions did not differ at the verb, it was surprising that the processing disruption emerged at that point in the sentence in people with aphasia. One possibility is that the people with aphasia used the available visual cues to predict whether the sentence was transitive or intransitive. As is typically the case in self-paced reading, the sentences were depicted by a series of dashes that marked the length and position of the words in the sentence. In transitive sentences, the verb was always followed by a noun phrase, which consisted of three dashes followed by dashes representing the noun (e.g., --- ------ for *the writer*). Because the people with aphasia had longer overall reading times than controls, they may have had more opportunity to use this cue than the controls.

Marinis (2003) argued that including dashes in self-paced reading is advantageous because the dashes provide a means of predicting how the sentence will continue. In this sense, self-paced reading is more similar to naturalistic reading, where preview effects are relatively common (e.g., Staub, 2011). It is also worth noting that some self-paced reading studies have reported effects at unexpected segments, but they are usually treated as spurious. For example, Kaan (2001) found that self-paced reading times were faster for object than subject relative sentences in the segment directly preceding the point of disambiguation.

In this study, the reading time results at the verb must be interpreted with caution. From a methodological standpoint, a future study might investigate this issue using a self-paced reading paradigm without the dashes. However, from a psycholinguistic perspective, the more interesting questions pertain to how people with aphasia read in naturalistic settings. Thus, future studies might use eye tracking to examine how people with aphasia read these types of sentences. Eye tracking during reading is more natural because it does not require segmentation of the sentence, so it is possible that a different pattern of results will be observed. Nonetheless, the present results suggest that the people with aphasia were able to predict that sentences were transitive based on the available visual cues. Importantly, these results suggest that the effects of mismatch initially affected both transitive and intransitive sentences for people with aphasia.

For both people with aphasia and non-brain-damaged controls, the effects of verb mismatch differed in transitive and intransitive sentences. As discussed in the introduction, there may be a processing advantage for S-V-O sentences due to relative frequency of transitive compared to intransitive structures (Dick & Elman, 2001). However, even if S-V-O sentences are relatively easy to process, this does not fully explain why the effect of verb mismatch was greater in intransitive than transitive sentences.

Van Dyke and Lewis's (2003) cue-based retrieval account of syntactic parsing provides one way to understand the advantage for transitive structures in this study. This parsing account claims that the verb in a sentence provides retrieval cues to facilitate identification of its grammatical dependencies. For example, a transitively biased verb may set retrieval cues for both intransitive and transitive structures, but the transitive frame will be more accessible. The opposite is true for an intransitively biased verb: the intransitive sentence frame will be more accessible. Van Dyke and Lewis operationalized accessibility as the presence of interfering clauses. Consider the sentence "*The executive assistant forgot that the student who knew that the exam was important was standing in the hallway*." They found that self-paced reading times for "*was standing*" were relatively long when the verb was separated from its agent ("*the student*") by an intervening clause ("*who knew that the exam was important*").

In the present study, there were no interfering clauses: the verb was followed immediately by the object or prepositional phrase. However, it could be argued that the relative frequency of S-V-O (i.e. S-V-Noun Phrase, or S-V-NP) sentences makes that clausal structure more accessible than other sentence frames (i.e. S-V-PP). On this account, the difference between transitive and intransitive sentences reflects the relative difficulty associated with accessing more or less frequent frames (i.e. S-V-NP vs. S-V-PP), particularly when the retrieval cues set by the verb need to be overridden. Here, reading an intransitively biased verb would cue retrieval of an intransitive frame, but the presence of an object following the intransitively biased verb would necessitate activation of the relatively accessible S-V-O structure. The results of this study suggest that the processing demands associated with replacing a less frequent structure with a more frequent structure are relatively low. In contrast, reading a transitively biased verb would serve as a retrieval cue for the more frequent structure, while the prepositional phrase would necessitate activation of a relatively inaccessible structure. The results of this study suggest that overriding the activation of a more frequent structure is relatively demanding. Thus, the different effects of verb mismatch in transitive and intransitive sentences may reflect the relative accessibility of the two frames, which in turn reflects the relative frequency of the two structures.

This study demonstrates that probabilistic cues affect on-line sentence comprehension in both people with aphasia and controls. However, the effects of verb mismatch were not identical in the two groups. As discussed above, the effects of verb mismatch emerged early in people with aphasia, but then resolved more quickly for transitive than intransitive sentences. There was also some evidence that people with aphasia showed a greater effect of mismatch than the controls on the comprehension questions. Finally, even though the people with aphasia were generally slower than controls, the two groups' reading times for the fourth segment (*to make vs. Friday night*) did not differ for transitive sentences in the match condition. Taken together, these results indicate that the effects of verb mismatch were somewhat exaggerated in the people with aphasia relative to the controls. According to the Lexical Bias Hypothesis, aphasic errors in sentence comprehension arise because they have more difficulty accessing low-probability patterns than non-brain-damaged controls (Gahl, 2002). The results of this study are consistent with the idea that people with aphasia have more difficulty overcoming lexical biases than controls.

The fact that people with aphasia had longer overall reading times than the controls is broadly consistent with the claim that slowed lexical access interferes with sentence processing (e.g., Ferril et al., 2012; Love et al., 2008; Swinney et al., 1996). However, even if the effects of verb mismatch were spurious, the people with aphasia showed significant effects of mismatch at the same point in the sentence as non-brain-damaged controls. Thus, it is unlikely that slowed lexical access disrupted their on-line written language processing. Previous studies investigating the slowed lexical access theory have focused on auditory sentence comprehension. In the auditory modality, comprehenders cannot control the rate of lexical input in the same way they can in reading. In the present study, the people with aphasia may have spent more time looking at individual words, providing the opportunity to access the word before moving on. The ability to control the rate of presentation in reading may confer an advantage of written language processing for at least some people with aphasia. It is also possible that the overall slowed reading times reflect a compensatory mechanism for slowed lexical access in people with aphasia.

In conclusion, the results suggest that the people with aphasia were sensitive to a mismatch between verb transitivity bias and sentence structure. In addition, the results at the verb suggest that people with aphasia may have experienced a longer period of processing disruption than non-brain-damaged controls. This type of processing disruption may account for difficulty comprehending sentences with non-canonical word order, particularly when the verbs are not biased to occur in that syntactic frame. These results also provide a possible account for impairments affecting syntactically simple sentences. Finally, these results support the claims of the Lexical Bias Hypothesis, and provide further evidence that sentence comprehension impairments in people with aphasia may reflect sensitivity to the violation of expectations set up by probabilistic cues within a language.

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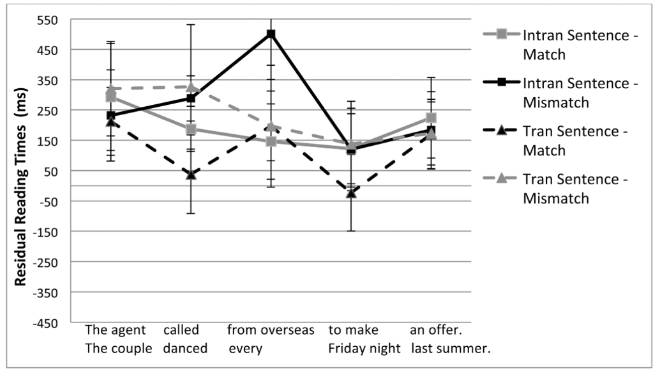
Panel A: People with Aphasia



Panel B: Non-brain-damaged Controls

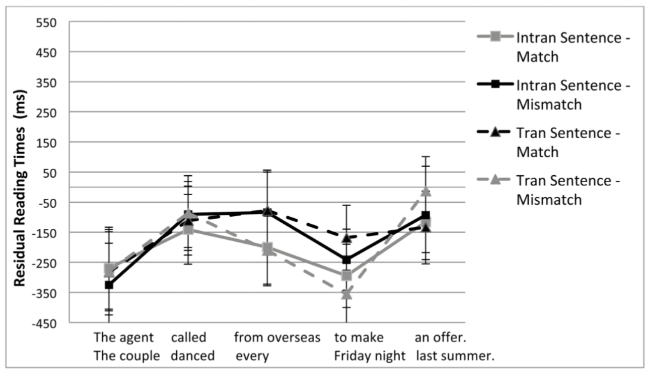


Figure 1.

Mean and Standard Error of the Residual Reading Times (controlled for frequency of verb and segment length)

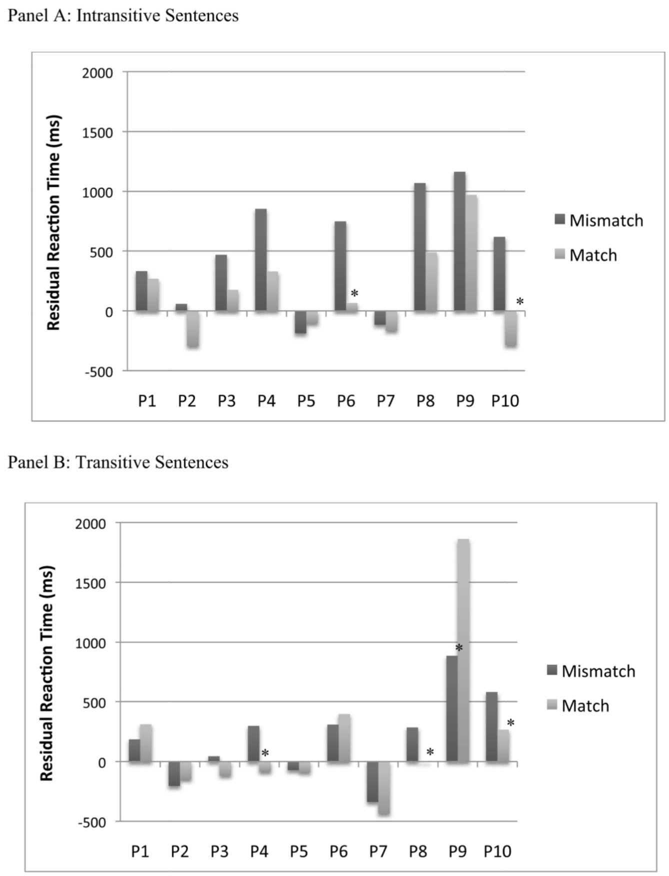


Figure 2.
Individual Reading Times for People with Aphasia

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Table 1

Participant Demographic and Test Performance Data

	Age	Gender	Years Edu	BDAE Aphasia Type	Etiology	BNT*	PPVT**	PAL Lexical Decision	PAL Word Picture Match
P1	65	M	16	Conduction	CVA	3	91	.85	1.0
P2	65	M	12	Broca	CVA	4	99	.70	0.97
P3	70	M	16	Anomic	CVA	41	98	.88	1.0
P4	31	M	12	Mixed	Gunshot Wound	7	77	.63	0.94
P5	54	F	12	Broca	CVA	20	80	.78	1.0
P6	55	F	14	Anomic	CVA	46	91	1.0	1.0
P7	38	M	14	Anomic	CVA	51	96	1.0	1.0
P8	32	M	12	Mixed	CVA	1	70	.73	0.88
P9	64	F	15	Anomic	CVA	14	94	.95	1.0
P10	50	M	18	Borderline Anomic***	CVA	54	113	1.0	1.0

*Max score = 60

**Standard Score, all within 2 SD of mean for age-matched controls

***Based on WAB Aphasia Quotient

Table 2

Boston Diagnostic Aphasia Exam (Short Form)*

	Auditory Comprehension			Repetition		Oral	Reading Comprehension	
	Word (/16)	Commands (/10)	Comp Idea (/6)	Word (/5)	Sent (/2)	Reading (/15)	Word Picture Match (/4)	Sent & Para (/4)
P1	14	7	2	2	0	1	2	4
P2	16	7	6	3	0	1	3	3
P3	13	4	3	3	0	15	3	4
P4	9	6	2	3	0	0	3	0
P5	11	6	4	3	0	9	3	1
P6	16	8	5	4	0	12	4	3
P7	15	9	4	4	1	15	4	4
P8	11	5	2	2	0	0	2	2
P9	15	7	6	3	1	14	4	4

*P10 completed the Western Aphasia Battery, AQ = 94.8.

Table 3

Accuracy by Stimulus Type and Relevant Ratios on the Northwestern Naming Battery and Northwestern Assessment of Verbs and Sentences

	Naming Battery			Assessment of Verbs and Sentences					
				Comprehension			Production		
	Noun	Verb	Verb: Noun	Canonical	Non- Canon	Non-Can: Canon	Canonical	Non- Canon	Non-Can: Canon
P1	10	8	0.80	13	11	0.85	0	0	N/A
P2	5	0	0.00	14	13	0.93	0	0	N/A
P3	15	7	0.47	8	10	1.25	10	7	0.70
P4	6	4	0.67	10	10	1.00	0	0	N/A
P5	11	9	0.82	8	7	0.88	1	0	0.00
P6	16	16	1.00	13	7	0.54	10	2	0.20
P7	16	16	1.00	15	11	0.73	15	10	0.67
P8	6	3	0.50	12	10	0.83	0	0	N/A
P9	12	15	1.25	12	5	0.42	13	10	0.77
P10	16	16	1.00	15	15	1.00	15	14	0.93

Table 4

Sample Stimuli by Condition

Verb Bias	Sentence Type	Match	Example
Intransitive	Intransitive	Yes	1a. The couple/danced/every/Friday night/last summer.
	Transitive	No	1b. The couple/danced/the tango/every/Friday night/last summer.
	Comprehension Question		Did the couple dance every Friday?
Transitive	Intransitive	No	2a. The agent/called/from overseas/to make/an offer.
	Transitive	Yes	2b. The agent/called/the writer/from overseas/to make/an offer.
	Comprehension Question		Was the agent overseas?

*Shading marks cells in which the verb bias matches the sentence structure

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Table 5

Proportion Correct (Mean and Standard Deviation) by Group and Condition*

	Intransitive Sentences		**Transitive Sentences**	
People with Aphasia	**Intrans Verb**	**Trans Verb**	**Intrans Verb**	**Trans Verb**
P1	1.0	0.8	0.9	1.0
P2	0.8	0.7	0.7	0.8
P3	1.0	0.8	0.9	0.8
P4	0.7	0.9	0.7	0.7
P5	0.8	0.7	0.5	0.6
P6	0.9	1.0	0.7	1.0
P7	0.8	0.9	0.7	1.0
P8	0.8	0.6	0.6	0.8
P9	1.0	0.9	1.0	0.9
P10	0.8	1.0	0.9	0.9
Group Means (Std)				
People with Aphasia	.86 (.11)	.83 (.13)	.76 (.16)	.85 (.14)
Control Group	.97 (.07)	.99 (.03)	.98 (.04)	.98 (.04)

*Shading marks cells in which the verb bias matches the sentence structure

Table 6

Mean (Standard Error) Residual Reading Times for the Direct Object in Transitive Sentences

Group	Transitive Bias (Match)	Intransitive Bias (Mismatch)
People with Aphasia	259.5 (149.0)	199.8 (147.1)
Control	−85.1 (149.2)	−128.6 (119.4)

Appendix 1

Stimuli

Intransitively Biased Verbs

Sentence	Verb Bias*
The athlete swam (the lake) every day before the race.	(78, 18)
The boy studied (his notes) before his math test on Tuesday.	(61, 29)
The children played (the game) late into the night.	(62, 38)
The choir sang (the song) during the festival on Saturday.	(57, 39)
The couple danced (the tango) every Friday night.	(73, 15)
The girl ran (the race) to help her friend get in shape.	(73, 19)
The model fought (the artist) for a seat because there were too few.	(67, 12)
The professor escaped (the soldier) at midnight to avoid being seen.	(73, 27)
The thief jumped (the fence) to escape from the police.	(67, 7)
The woman tripped (the man) in the parking lot because she wasn’t paying attention.	(73, 8)

Transitively Biased Verbs

Sentence	Verb Bias
The agent called (the writer) from overseas to make an offer.	(12, 79)
The company hired (the staff) to meet the demands of the big event	(0, 81)
The director visited (the actor) before the movie to discuss a new project.	(10, 87)
The doctor wrote (the teacher) about the procedure because it was confusing.	(31, 62)
The lady walked (the dog) after school because it was good exercise.	(12, 83)
The minister watched (the president) on television from his office.	(17, 75)
The mother taught (the child) on weekends because she enjoyed it.	(6, 90)
The police helped (the man) after the accident on the highway.	(10, 77)
The secretary phoned (the team) about the appointment before leaving for the weekend.	(13, 75)
The servant killed (the enemy) in self defense after being attacked.	(12, 85)

*Verb bias values are percentage of intransitive and transitive usages from Connine et al. (1984) and DeDe (2010).