APHASIOLOGY, 2002, *16* (12), 1173–1198

Lexical biases in aphasic sentence comprehension: An experimental and corpus linguistic study

Susanne Gahl

Harvard University, Cambridge, MA, USA

Background: This study investigates the role of lexical information in normal and aphasic sentence comprehension. Effects of verb biases in normal comprehension have been well documented in previous studies (e.g., Spivey-Knowlton & Sedivy, 1995; Trueswell, Tanenhaus, & Kello, 1993), but their role in aphasic language processing has largely been ignored (with the exceptions of Menn et al., 1998, and Russo, Peach, & Shapiro, 1998).
Aims: The aim of the study is to test the lexical bias hypothesis, i.e., the hypothesis that sentence comprehension is influenced by lexical biases in aphasic listeners, as well as in normals.
Method & Procedures: Using a sentence plausibility judgement task, we probe for sensitivity to verb transitivity bias, i.e., the likelihood, as estimated from corpus counts, that a verb will be transitive, rather than intransitive. Five normal controls and eighteen participants with aphasia (six with Broca's aphasia, four with Wernicke's aphasia, two with conduction aphasia, and six with anomic aphasia) are included in the study. Based on the lexical bias hypothesis, we predicted that participants would make more errors in sentences with a mismatch of verb bias and syntactic structure, such as a transitive sentence containing a verb with intransitive bias.
Outcomes & Results: Both the group of normal controls and the mixed group of aphasic patients make significantly more errors on sentences in which there is a mismatch between verb bias and syntactic structure, as predicted by the lexical bias hypothesis. Specifically, patients with fluent aphasia types, particularly anomic aphasia, show a sensitivity to verb bias, contrary to earlier findings.
Conclusions: These results are consistent with the view that lexical factors, not purely syntactic ones, are to blame for many previously observed patterns in aphasic comprehension. The results are further consistent with the view that many aphasic errors differ not qualitatively but quantitatively from normal comprehension errors.

The discovery that sentence comprehension in aphasia may be impaired in the face of relatively well-preserved single word comprehension (Caramazza & Zurif, 1976) represents one of the most significant milestones in the study of aphasic sentence

---

Address correspondence to: Susanne Gahl, 2143, Beckman Institute, University of Illinois, Urbana, Illinois 61801, USA. Email: gahl@icsi.berkeley.edu

I am grateful to the aphasic patients and their families who have taught me much about language, and about many other things besides. Thank you. I also wish to thank two anonymous reviewers for their thoughtful comments. Very special thanks are due to Dan Jurafsky, for advice and encouragement throughout this project. I am also grateful for discussions with Lise Menn, Charles J. Fillmore, Terry Regier, and audiences at Rochester University, Harvard University, MIT, and the Beckman Institute at the University of Illinois, where I presented earlier versions of this research. The research reported in this paper formed part of my UC Berkeley doctoral dissertation (Gahl, 2000). Large portions of this manuscript were completed while I was a lecturer in the Department of Linguistics at Harvard University.

http://www.tandf.co.uk/journals/pp/02687038.html DOI:10.1080/02687030244000428

comprehension. In the wake of this discovery, studies of aphasic sentence comprehension have tended to focus on syntax alone, rather than on lexical factors. Syntactic factors in aphasic comprehension continue to be the subject of numerous studies in this area. Of particular interest have been syntactic contrasts that are accompanied by a difference in major constituent order, such as active and passive, or subject extraction and object extraction in relative clauses. Examining such contrasts, many researchers have concluded that aphasic comprehension difficulties are most marked with structures that deviate from the canonical order of major constituents in a language. In English, this canonical order is Agent–Verb–Undergoer. While there is indeed strong evidence for the privileged status of the canonical word order, both in normal and in aphasic language processing (see e.g., Bates, Friederici, & Wulfeck, 1987), such evidence does not constitute an explanation of what it is that makes some sentence types easier to understand than others. Menn (2000) raises this question explicitly in a paper entitled ''What makes canonical form simple?''.

Part of the answer may lie in lexical factors, rather than in syntactic structure alone. Despite the importance that has been accorded to purely syntactic factors in aphasic sentence comprehension, researchers have increasingly come to recognise that subtle disturbances at the lexical level may be to blame for many sentence comprehension difficulties. For example, Berndt, Mitchum, Haendiges, & Sandson (1997b) found that a group of four patients who were impaired in the production of verbs (though not nouns) performed poorly on comprehension of ''reversible'' sentences, i.e., on sentences that cannot be correctly interpreted based on lexical meanings alone. By contrast, among a group of six patients without such verb-specific retrieval difficulties, only one patient performed poorly on the sentence comprehension tasks. Numerous other studies have sought to relate aphasic sentence comprehension deficits to abnormalities in accessing or utilising lexical information (e.g., Blumstein et al., 1998; Friederici, 1988; Haarmann & Kolk 1991, 1994; Hagoort, 1993, 1997; Jones, 1984; Shapiro & Levine, 1990; Swaab, Brown, & Hagoort, 1995, 1997; Swinney, Zurif, Nicol, 1989; Tyler & Ostrin, 1994; Tyler, Ostrin, Cooke, & Moss, 1995). While earlier studies assumed that any breakdown in producing or compreending words in sentences was due to a breakdown of syntactic operations, these more recent proposals hold that a failure to process lexical information can result in impairments at the sentence level.

These insights parallel a line of inquiry that has been pursued in the study of normal sentence comprehension. So-called constraint-based models of language processing, in particular, (e.g., MacDonald 1994, 1997; Trueswell et al., 1993) have focused on the interaction of lexical information, syntactic structure, and extra-linguistic information in language comprehension.

One type of lexical information that has been the focus of many studies of normal sentence comprehension is argument structure frequency, which gives rise to argument structure preferences, or lexical biases (e.g., Spivey-Knowlton & Sedivy, 1995; Trueswell et al., 1993). The lexical bias of a verb is the likelihood that the verb will occur in a particular type of syntactic environment. As an example, consider the verb *remember*. The verb *remember* can take a direct object, as in *The professor remembered the student*, or a finite clause, as in *The professor remembered the student was coming at four o'clock*, or an infinitival complement, as in *The professor remembered to turn in the grades*. When a verb occurs in one type of syntactic structure more frequently than in another type, the verb is said to have a lexical bias towards the more frequent structure.

Evidence from normal language processing suggests that lexical biases affect sentence processing: Structures that match the lexical biases of the words in the sentence are processed faster and with greater accuracy than structures that do not match lexical biases. Although the precise workings of such frequency-based factors continue to the subject of lively debate (see e.g., Frazier & Clifton, 1996; Stevenson & Merlo, 1997), evidence for the role of lexical biases in sentence processing has been found in subjects' performance using a variety of methods, such as self-paced reading tasks (Boland, Tanenhaus, Garnsey, & Carlson, 1995; Ferreira & Henderson, 1990; Spivey-Knowlton & Sedivy, 1995; Trueswell et al., 1993), grammaticality judgement tasks (McElree, 1993), sentence continuation tasks (Spivey-Knowlton & Sedivy, 1995), and eye-tracking (Ferreira & Henderson, 1990; Garnsey, Pearlmutter, & Lotocky, Trueswell et al., 1993). Even models of normal language processing that do not regard frequency information as a guiding force during the initial stages of the comprehension process grant frequency effects a role during later stages (see e.g., Ferreira & Henderson, 1990; Frazier, 1995; Mitchell, 1989).

Despite the attention lexical biases have received in studies of normal language processing, their role in aphasic language processing has largely been ignored, with few exceptions (Menn et al., 1998; Russo et al., 1998). Menn et al. (1998) propose that aphasic speech production may be influenced by lexical biases. In discussing the difficulties many aphasic speakers appear to encounter when attempting to use the passive voice, Menn et al. (1998) propose that, when a verb is activated, the syntactic frame in which it occurs most frequently will have a lower activation threshold than the other frames and hence be more easily activated, facilitating production of a clause instantiating that frame. For example, if the most frequent syntactic frame for the verb *open* were an active transitive frame, then an active transitive sentence, such as *Dora opened the box*, would be easier to produce than a sentence using a different frame, such as the intransitive *The box opened*.

Extended to comprehension, this line of reasoning offers an intriguing alternative explanation for a variety of observed effects in aphasic comprehension. Could it be the case that sentence types that have tended to elicit poor performance from aphasic speakers represent infrequent syntactic frames for the verbs appearing in them?

The purpose of the present study is to explore the hypothesis that aphasic sentence comprehension is influenced by lexical biases, and that lexical biases are responsible for some aphasic comprehension errors. We will refer to this hypothesis as the lexical bias hypothesis. For an example of how lexical biases might give rise to comprehension errors, consider the following examples from a highly influential study by Caplan, Baker, and Dehaut, 1985):

(1) The lion hit the tiger and the bear.
(2) The lion hit the tiger to the bear.

Caplan et al. (1985) found that aphasic subjects had more difficulty understanding sentences like (2) in which the verb *hit* occurs in an [_NP PP] frame than sentences like (1) in which the verb occurs in a simple transitive ([_NP]) frame. Caplan et al. (1985) attribute the differential difficulty of these two sentence types to the differences in structure. However, lexical biases may also explain this finding. The greater difficulty with sentences like (2) could be related to the fact that *hit* and other verbs in the materials used by Caplan et al. are encountered far more often in [_NP] structures than in [_NP PP] structures. Corpus evidence is consistent with this idea: According to the argument structure probabilities collected by the COMLEX project (Grishman, Macleod, & Meyers, 1994; Meyers, Macleod, & Grishman, 1995), of the first 100 occurrences of *hit* in the Brown corpus, only 8 involve an [_NP PP] frame, compared to 76 occurrences of *hit* in an [_NP] frame. Perhaps, then, the greater difficulty patients had with sentences like (2) has to do with argument structure preferences of verbs like *hit*, rather than the [_NP PP] structure *per se*.

Argument structure preferences, or lexical biases, represent a type of frequency effect. Other types of frequency effects are well documented for aphasic patients, lending additional motivation to the lexical bias hypothesis. For example, effects of single word frequency are well documented in aphasia and parallel those found in normals: High-frequency words tend to elicit faster and more accurate performance than low-frequency ones, both in comprehension and in production (see e.g., Gerratt & Jones, 1987; Silver & Halpern, 1992).

We therefore hypothesise that aphasic listeners will be sensitive to lexical biases, and that lexical biases may account for observed difficulties in aphasic comprehension. In the discussion to follow, we will refer to the hypothesis that sentence comprehension is influenced by lexical biases in aphasic listeners, as well as in normals, as the lexical bias hypothesis.

The only previous study (Russo et al., 1998) to probe for sensitivity to argument structure preferences in aphasic patients failed to find an effect. We believe this negative finding to be an artifact, masking an actual effect of lexical bias. We will examine Russo et al.'s argument in more detail in a later section. We will argue that the particular experimental task employed in that study may yield an apparent absence of the effect precisely for those subjects whose parsing strategies are most heavily influenced by lexical biases.

The purpose of the present study is to probe for effects of lexical biases in normal and aphasic comprehension. The specific type of lexical bias this on which experiment focuses is verb transitivity bias, i.e., the likelihood that a verb will be transitive (as in *The sun melted the snow*), as opposed to intransitive (as in *The snow melted*). We will be focusing on the effects of transitivity bias on the comprehension of three types of sentences: (1) active (A), (2) passive (P), and (3) intransitive with Undergoer subjects (IU).[1]

Passive sentences are generally found to give rise to greater comprehension difficulties than active sentences, even for listeners without any history of neurological disorder (Obler, Fein, Nicholas, & Albert, 1991). In aphasia, poor comprehension of passives, compared to relatively well-preserved comprehension of actives, was first discussed for patients with agrammatic sentence production, particularly patients with Broca's aphasia (Caramazza & Zurif, 1976; Goodglass, 1968; Schwartz, Saffran, & Marin, 1980), but was subsequently found for many different types of patients (see Berndt, Mitchum, & Wayland, 1997 for a review). The difficulty of passives has variously been attributed to syntactic structure, or to the fact that the word order typically found in English passives is noncanonical, i.e., does not correspond to an Agent–Action–Undergoer sequence (e.g., Bates et al., 1987; Caramazza & Zurif, 1976; Goodglass, 1968). By focusing on actives, passives, and intransitives with Undergoer subjects, we are in a position to study the effect of verb bias on the comprehension of syntactic structures with canonical (Agent–Verb–Undergoer) and noncanonical (Undergoer–Verb–Agent) constituent order, in both active and passive voice.

[1] All passive verb uses are transitive, as are all of the sentences labelled ''active'' in the current study. All intransitive sentences are in the active voice. For simplicity's sake, I will be referring to the three sentence types as active, passive, and intransitive.

Intransitive sentences have not been studied nearly as much as passives in the literature on aphasic sentence comprehension, and the available evidence has yielded variable and conflicting findings. Some studies comparing the relative difficulty of transitive and intransitive verbs or sentences in aphasia have concluded that transitives are more difficult (e.g., Kim & Thompson, 1998), whereas others report the opposite finding (e.g., Jonkers & Bastiaanse, 1996, 1997 for Dutch). We believe that the variability found with intransitive verbs may have to do with the heterogeneity of the stimuli that have been tested. For example, only very few studies (Gottfried, Menn, & Holland, 1997) have attempted to differentiate intransitive verbs with Undergoer subjects from intransitive verbs with Agentive subjects. This, in combination with the factor under discussion in the current study may have contributed to the observed variation. We will return to this point in the discussion later.

The role of aphasia type in aphasic patterns of lexical and syntactic comprehension difficulties is unclear, based on the available evidence. Yet major differences have often been hypothesised to exist between two broad categories of aphasia syndromes: nonfluent vs fluent aphasia (see e.g., Blumstein et al., 1998; Goodglass & Menn, 1985; Milberg, Blumstein, & Dworetzky, 1988, 1995). Nonfluent types include Broca's aphasia, transcortical motor aphasia, and some cases of anomic aphasia, whereas fluent types include Wernicke's and conduction aphasia, transcortical sensory aphasia, and some cases of anomic aphasia.

Fluency may conceivably affect the degree to which aphasic patients will be sensitive to verb biases, for the following reason. It has frequently been observed that some aphasic patients tend to have greater processing difficulties with verbs than with nouns (e.g., Kohn, Lorch, & Pearson, 1989; Miceli, Silveri, Villa, & Caramazza, 1984; Miceli, Silveri, Nocenti, & Caramazza, 1988; Williams & Canter, 1987). Such category-specific deficits have important bearings on the current discussion, as sensitivity to verb bias presupposes the ability to access and process information associated with verbs. However, the observation that verbs cause more difficulty than nouns does not hold universally for all patients or all aphasia types. Selective deficits affecting verbs have been reported both in fluent and in nonfluent aphasia (e.g., Berndt, Haendiges, Mitchum, & Sandson, 1997a; Berndt et al., 1997c; Kohn et al., 1989; Miceli et al., 1984, 1988; Williams & Canter, 1987), whereas selective deficits affecting nouns have only been reported in fluent aphasia, most often in patients with anomic aphasia (e.g., Damasio & Tranel, 1993; Zingeser & Berndt, 1988). The picture that emerges from the literature is that fluency may well affect the degree to which patients will be sensitive to verb biases, but the available evidence does not motivate any strong prediction to the effect that only particular patient groups should be sensitive to verb biases. We will therefore assess the effect of verb bias in a mixed group of aphasic patients. However, the differences between fluent and nonfluent patients groups, and the difference between patients with anomic aphasia and other fluent aphasic patients, motivate additional separate analyses of fluent and nonfluent patients, and of fluent patients with anomic aphasia.

PREDICTIONS OF THE CURRENT STUDY

The present study focuses on the role of lexical biases in aphasic sentence comprehension. Consider the sentences in (3): If syntactic structure were the sole determinant of comprehension difficulty, the sentences in the left-hand column should be no more or less difficult to comprehend than the sentences in the right-hand column:

(3)

The teacher opened the box.	The children crumbled the crackers.
The box was opened by the teacher.	The crackers were crumbled by the children
The crackers crumbled in our hands.	The box opened after a short while.

Corpus counts of transitive and intransitive uses of the verbs *open* and *crumble* show that *open* is more likely to be transitive, whereas *crumble* is more likely to be intransitive. If lexical biases *do* exert some influence on the comprehension process, therefore, we would expect the sentences in the left-hand column in (3) to be easier to process than the ones in the right-hand column.

OUTLINE OF THE PAPER

In the sections to follow, we will report the results of two experiments probing for the effect of the match or mismatch between syntactic structure and lexical bias. Both experiments use a plausibility judgement task to probe for this effect. The first experiment probes for this effect in a group of normal subjects. The second experiment probes for the same effect in a mixed group of aphasic patients. We report the results for the group of aphasic participants as a whole, and then conduct separate analyses of the data from participants with nonfluent and fluent aphasia types, and finally from participants with fluent anomic aphasia versus other types of fluent aphasia. We discuss the implications of our results for theories of aphasic language processing.

EXPERIMENT 1

This study examines the effect of lexical bias on normal sentence comprehension. The goal is to identify such effects on listeners' interpretation of relatively simple sentences. As indicated earlier, there is ample evidence for the role of lexical biases in normal comprehension. However, most of this evidence has come from on-line tasks, such as eye-tracking studies, or from tasks requiring subjects to read (which was not feasible with the group of aphasic patients tested in Experiment 2). Also, most studies of lexical biases have examined sentence types that far exceed the complexity of sentences that can practicably be tested with aphasic patients. We therefore need to establish whether the experimental paradigm chosen here is sensitive enough to detect effects of lexical biases in normals in the relatively simple sentence types to be examined with the aphasic patients.

Three types of syntactic structures are tested which have been the focus of previous studies of aphasic sentence comprehension: active, passive, and intransitive. The crucial manipulation concerns the match or mismatch between lexical bias and sentence structure. In one set of conditions, the sentence type (transitive for the active and passive sentences, or intransitive) matches the lexical bias of the main verb. In a second set of conditions, the transitivity of the sentence is the opposite of the verb's bias. The conditions in which the sentence type matches the lexical bias of the main verb will be referred to as the ''concordant'' conditions. The conditions in which the sentence type does not match the lexical bias of the verb will be referred to as the ''discordant'' conditions. Sentences of the concordant and discordant type are exemplified in (4) and (5). The examples all use the verb *melt*, which is more often intransitive than transitive. As a consequence, the intransitive sentence appears in the concordant condition, and the transitive sentence types (active transitive and passive) appear in the discordant conditions. For transitive-bias verbs, active transitive and passive sentences form the concordant condition, and intransitives form the discordant condition.

(4) Concordant: Sentence conforms to intransitive verb bias
a. *The butter melted in the pot.* (Intransitive)

(5) Discordant: Sentence does not conform to intransitive verb bias:
a. *The cook melted the butter.* (Transitive – Active)
b. *The butter was melted by the cook.* (Transitive – Passive)

To ascertain listeners' comprehension of these sentence types, we used a plausibility judgement task. Subjects were asked to listen to sentences, some of which were semantically anomalous. Subjects were then asked to decide whether the sentences they heard were plausible or implausible. The implausible sentences were derived from their plausible counterparts by reversing the order of the noun phrases in each sentence, e.g., by transforming *The cook melted the butter* into #*The butter melted the cook*.

In addition to examining the effects of the match between lexical bias and syntactic structure, the materials were designed to investigate the effects of syntactic structure, in particular the effects of major constituent order. For the group of nonaphasic controls, we did not predict a significant effect of syntactic structure for these relatively simple sentence types. The contrast between concordant and discordant sentences was the focus of Experiment 1.

Method

Design and Materials. A total of 20 verbs were tested, 10 biased towards being transitive, and 10 biased towards being intransitive. Verb bias was originally estimated based on semi-automatic corpus counts (described in Gahl, 1998a,b) and for some verbs, on hand counts, of all occurrences of the verbs in the 100 million word British National Corpus. Verb occurrences in the corpus were classified as ''transitive'', ''intransitive'', or ''neither''. Verb uses that were classified as neither transitive nor intransitive included speech act uses of verbs like *begin* (as in ''*But, didn't you know?*'', *he began*.) and *close*. For technical reasons, sentences containing more than one occurrence of a given verb were excluded from the automatic counts. Subsequent hand counts of 100 randomly chosen occurrences of each verb that were done as part of a separate project (cf. Roland et al., 2000) revealed that 4 of the 20 verbs (*crack*, *melt*, *merge*, and *rip*) did not have a strong transitive or intransitive bias. As the estimates of transitivity bias from these two separate counts did not agree, these four verbs were excluded from the analysis, leaving eight intransitive-bias verbs and eight transitive-bias ones. Although it was not possible to obtain two sets of verbs that were precisely matched for frequency, each set contained one high-frequency verb and approximately equal numbers of low- and medium-frequency verbs. The 16 verbs are listed in Table 1, along with the two different frequency counts of transitive and intransitive uses in the BNC.

Three types of sentence structure were tested: active transitive, passive transitive, and intransitive. Half of the sentences were plausible and half were implausible. Two sets of noun phrases were used with each verb, so that each verb appeared twice in each sentence type. To keep sentence length approximately equal across all the conditions, the intransitive sentences contain prepositional phrases in addition to the subject noun phrase. For example, for the verb *dissolve*, the 12 sentences listed in Table 2 were used. The complete design is summarised in Table 3. There are 16 stimuli in each cell. The list of all 192 stimulus sentences can be found in Appendix A.

TABLE 1
Corpus counts and transitivity biases for the verbs used in the study

Verb	Frequency in BNC	Transitive	Intransitive
Transitive-bias verbs			
clog	249	180 (36)	35 (7)
pour	3682	2538 (74)	930 (23)
soften	915	609 (63)	271 (22)
open	23498	13902* (55)	9078* (16)
dissolve	1445	828 (64)	449 (32)
heat	1385	787* (62)	362* (2)
tear	2862	1610* (62)	865* (3)
shut	5497	2439* (26)	1517* (0)
Intransitive-bias verbs			
explode	1502	116 (10)	1335 (89)
crumble	556	59* (5)	449* (71)
shrink	792	106* (12)	614* (52)
sink	3334	717 (15)	2494 (79)
burst	2491	252* (7)	1690* (75)
harden	712	181* (22)	469* (59)
grow	17307	2320* (18)	11148* (42)
boil	999	365* (1)	618* (24)

Corpus counts for the 16 verbs used in the plausibility judgement task. The first column shows the verbs. The second column shows the total number of times the verb is found in the British National Corpus. The third and fourth columns show the results of the corpus counts. Figures not in parentheses represent all occurrences of the verbs in the British National Corpus. Figures in parentheses represent manual counts of 100 randomly chosen occurrences of the verb in the British National Corpus. Figures marked with an asterisk represent automatic counts, figures not marked with an asterisk represent the results of manual counts.

TABLE 2
Stimulus sentences for the verb dissolve

Plausible	Implausible
Active transitive	
The researchers dissolved the crystals.	# The crystals dissolved the researchers.
The baker dissolved the sugar.	# The sugar dissolved the baker.
Passive	
The crystals were dissolved by the researchers.	# The researchers were dissolved by the crystals.
The sugar was dissolved by the baker.	# The baker was dissolved by the sugar.
Intransitive	
The crystals dissolved in the solution.	# The researchers dissolved in the solution.
The sugar dissolved in the milk.	# The banker dissolved in the milk.

TABLE 3
Design of the plausibility judgement experiment, with examples of each sentence type

Condition	*Verb bias*	*Plausible sentences*	*Implausible sentences*
A. Concordant			
Active	transitive	The researchers dissolved the crystals.	# The crystals dissolved the researchers.
Passive	transitive	The crystals were dissolved by the researchers.	# The researchers were dissolved by the crystals.
Intransitive	intransitive	The butter melted in the pot.	# The pot melted in the butter.
B. Discordant			
Active	intransitive	The cook melted the butter.	# The butter melted the cook.
Passive	intransitive	The butter was melted by the cook.	# The cook was melted by the butter.
Intransitive	transitive	The crystals dissolved in the solution.	# The researchers dissolved in the solution.

Subjects. The subjects were five males with no known history of neurological or psychiatric disease. Background information on these subjects is presented in Table 4

Procedure. The sentences were tape recorded by a male native speaker of American English at a natural pace and with standard intonation. The recording of each sentence was then digitised. The experiment was presented on a Macintosh Performa, using the PsyScope experimental software (Cohen, MacWhinney, Flatt, & Provost, 1993). Subjects listened to the sentences over headphones.

The order of presentation of the stimuli was random and different for each subject. The sentences were presented in random order to avoid any possible effect of structural priming or learning effects. Structural priming (previously heard sentences predisposing subjects to produce a particular sentence structure) has been demonstrated to be effective with nonaphasic subjects (Bock, 1986) and nonfluent aphasics (Hartsuiker & Kolk, 1998; Marin & Schwartz, 1998). Each sentence was played back once, followed by a variable pause during which the subect indicated his or her response. Subjects indicated their decision by pushing one of two buttons on a PsyScope button box. Subjects could not respond before the end of the sentence. The implications of features of the experimental setup for the analysis of response times are discussed in Gahl (2000). Before starting, the subjects were read the following instructions:

TABLE 4
Subject information, nonaphasic subjects

Subject	*Age (years)*	*Gender*	*Education (yrs)*	*Handedness*
AA1	72	Male	12	right
AA2	62	Male	15	right
JB1	63	Male	12	right
JB2	68	Male	12	right
GJ	74	Male	14	right

> You will hear a tape recording of some sentences. Some of the sentences won't make any sense. After you hear each sentence, you are to decide if the sentence is a good sentence or a sentence that does not make sense. A sentence that does not make sense is one that describes something that is not likely to happen in real life.
>
> If the sentence you heard made sense, press the green button. If the sentence did not make any sense, press the yellow button.

Five practice trials were provided, with feedback and explanation as needed. The practice trials were repeated until subjects responded accurately on the practice trials. Sentence-specific feedback was discontinued for the actual trials.

Mandatory rest breaks occurred once every 20 sentences, but the duration of these breaks varied from subject to subject. Subjects were tested individually in a quiet room at the Aphasia and Related Disorder Center at the Martinez Outpatient Clinic of the Northern California Health Care System in Martinez, California. All subjects completed the testing in a single session of less than 1 hour, including breaks.

We recorded the responses (''plausible'' or ''implausible''), as well as the response times. Only the data on response accuracy will be examined here. The response times are discussed in Gahl (2000).

Results and discussion

The responses were classified as correct or incorrect. ''Plausible'' responses to plausible sentences, and ''implausible'' responses to implausible sentences were classified as correct; conversely, ''implausible'' responses to plausible sentences, and ''plausible'' responses to implausible sentences were classified as incorrect. The numbers of errors each subject made are shown in Table 5.

TABLE 5
Experiment 1: Nonaphasic subjects

		Active		*Passive*		*Intransitive*	
Subject	*Sentence type*	*Conc.*	*Disc.*	*Conc.*	*Disc.*	*Conc.*	*Disc.*
AA1	Plaus.	2	1	0	3	0	2
	Impl.	2	1	0	0	1	3
AA2	Plaus.	0	1	0	0	0	2
	Impl.	0	1	0	0	1	4
JB1	Plaus.	0	2	2	1	1	1
	Impl.	0	2	1	2	0	3
JB2	Plaus.	0	1	0	0	0	1
	Impl.	0	0	0	2	0	0
GJ	Plaus.	0	0	0	0	0	0
	Impl.	0	2	0	0	1	1

Number of errors (16 sentences in each condition).
Conc. = Concordant.
Disc. = Discordant.
Plaus. = Plausible.
Impl. = Implausible.

The effect of match between verb bias and syntactic structure on response accuracy was examined in a three factor, Match (concordant, discordant) × Syntactic Structure (Active, Passive, Intransitive) × Plausibility (plausible, implausible), repeated measures ANOVA.

The main effect of Match was significant, $F(1,4) = 27.78$, $p = .006$, reflecting higher error rates in the discordant conditions compared to the concordant conditions. There were no significant main effects of Syntactic Structure, $F(2,8) = 1.49$, $p = .282$, or Plausibility, $F(1,4) = 2.28$, $p = .105$, and no significant interactions between the three factors. These results are illustrated in Figure 1.

Using partial η^2 as the measure of effect size, Match accounted for 87.4% of the total variability in the response accuracy. By comparison, Plausibility accounted for 36.3% and Syntactic Structure for 27.1% of the variability.

The absence of significant main effects of Syntactic Structure or Plausibility is not surprising, given the small sample size, and given how few errors subjects made overall. Previous studies using plausibility judgement tasks with subjects in a similar age range, such as Obler et al. (1991) and Davis and Ball (1989) found effects of syntactic structure reaching significance only for larger groups of subjects, or on structures of far greater syntactic complexity.

Of greater importance for the current study is the finding that a mismatch between lexical bias and syntactic context can have a significant effect on normal listeners, even for the relatively simple sentence types that were tested in this experiment. In light of the low overall error rate and the small sample size, this point calls for further research.

EXPERIMENT 2

Experiment 1 established that the plausibility judgement task is capable of detecting effects of mismatch between lexical bias and sentence context on the comprehension of listeners with no neurological damage. With the normal data in hand, we turn to exploring the effects of match between lexical bias and sentence context on aphasic listeners. In contrast to normal listeners, aphasic patients can be expected to experience comprehension difficulties even on sentences with relatively simple syntactic structure.

Numerous previous studies of aphasic sentence comprehension have observed differences in the patterns of miscomprehension in nonfluent aphasia types compared

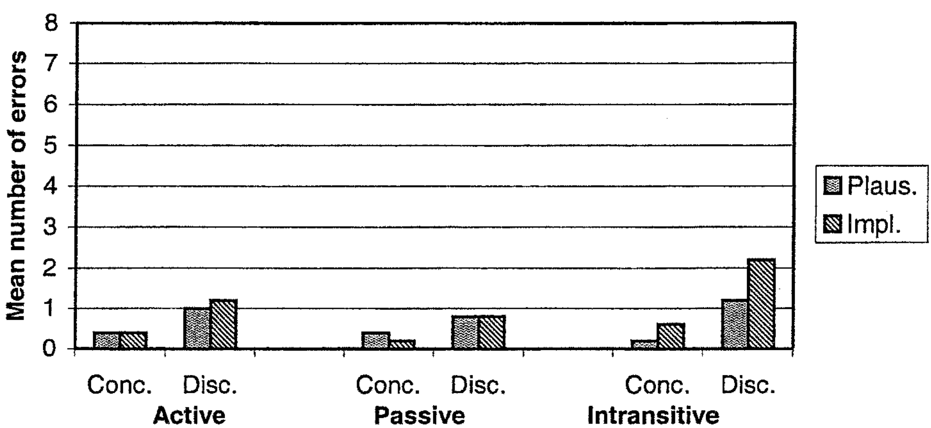

Figure 1. Mean number of errors, Experiment 1 (five nonaphasic subjects).

to fluent aphasia types. We therefore explored the effect of match between verb bias and syntactic frame in these two groups separately. In addition, studies of the noun–verb asymmetry in aphasic processing led us to believe that Match might affect patients with anomic aphasia differently from those with other fluent aphasia types.[2] We therefore performed separate analyses of the results from the participants with anomic aphasia and the remaining fluent participants.

Method

The materials and procedure were the same as in Experiment 1. The subjects were 18 aphasic patients. Of these, six carried a diagnosis of Broca's aphasia, four Wernicke's aphasia, two conduction aphasia, and six anomic aphasia. Background information on these subjects is presented in Table 6. All aphasic subjects had suffered a left-hemisphere cerebro-vascular accident at least 1 year prior to data collection. Diagnosis of aphasia type was based on performance on the Western Aphasia Battery (WAB; Kertesz, 1982), and for some patients also on the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 1983). The ages of the aphasic patients ranged from 41 years to 79 years.

TABLE 6
Subject information, aphasic subjects

Subject	*Age (years)*	*Years post onset*	*Gender*	*BDAE*	*WAB*	*Handednss*	*Education (in years)*
AK	64	7	male	unclassifiable	Broca's	right	16
HM	70	11	male	Broca's	Broca's	right	12
LI	54	7	male	n.a.	Broca's	right	12
DM	41	2	male	n.a.	Broca's	ambidextrous	16
DO	62	1.8	female	n.a.	Broca's	right	13
WR	55	9	male	unclassifiable	Broca's	right	14
JC	73	4	male	n.a.	Wernicke's	right	12
WG	79	1	male	n.a.	Wernicke's	right	13
JT	74	6	male	n.a.	Wernicke's	left	14
WT	64	1.3	male	n.a.	Wernicke's	right	16+
JCn	50	13 mos.	male	Within normal limits	anomic	right	14
JD	72	12	male	anomic	anomic	right	20
AF	55	5	female	n.a.	anomic	right	11
BK	53	3	male	anomic	anomic	right	16
NP	69	2	male	n.a.	anomic	right	14
FY	75	5	male	n.a.	conduction	right	12
RM	67	1.8	male	n.a.	anomic	right	16
GB	52	2	male	n.a.	conduction	right	14

[2] Patients with anomic aphasia may be fluent or nonfluent. All the anomic patients in the current study were fluent, as measured by the fluency test on the Western Aphasia Battery (WAB; Kertesz, 1982).

Results

The treatment of the data was the same as for Experiment 1. Error rates for each condition are given in Table 7. As the patients with different clinical diagnoses were not matched for severity, no direct between-group comparisons were carried out. An overall analysis was performed for the group of 18 aphasic patients, along with separate analyses for the nonfluent and fluent subgroups of the patients. Within the group of fluent patients, we also conducted separate analyses for the participants with anomic aphasia and the patients with Wernicke's aphasia or conduction aphasia.

Subject LI was unable to complete the five practice trials successfully, even after several attempts with specific feedback. He was therefore excluded from further analysis. On the actual trials, he was at chance in all of the conditions.

For the remaining group of 17 aphasic patients, the effect of Match was analysed in the same manner as the data from the group of normal listeners, i.e., in a three factor, Match (concordant, discordant) $\times$ Syntactic Structure (active, passive, intransitive) $\times$ Plausibility (plausible, implausible), repeated measures ANOVA. The effect of Match was significant, $F(1, 16) = 8.38$, $p = .011$, reflecting higher error rates in the discordant conditions compared to the concordant conditions. The effects of Syntactic Structure, $F(2, 32) = 16.06$, $p < .001$, and Plausibility, $F(1, 16) = 12.62$, $p = .003$, were also significant; mean error rates were lowest for the active sentences for both the plausible and the implausible sentences. Error rates were also higher in all implausible conditions than in the plausible conditions. There was a significant interaction between Syntactic Structure and Plausibility $F(2, 114) = 9.62$, $p < .001$, reflecting the fact that the relative difficulty of passive and intransitive sentences differed in the plausible and implausible conditions: In the plausible condition, passives elicited higher mean error rates on average than intransitives, whereas in the implausible condition, intransitives elicited more errors than passives. Neither the interaction between Match and Syntactic Structure, nor that between Match and Plausibility was significant: for Match $\times$ Syntactic Structure, $F(2, 114) = 0.96$, $p = .386$, for Match $\times$ Plausibility, $F(1, 114) = 0.41$, $p = .525$.

Again using partial η^2 as the measure of effect size, Match accounted for 34.4% of the total variability in the response accuracy. Plausibility accounted for 44.1% of the variability and Syntactic Structure for 50.1%. The results are illustrated in Figure 2.

For the group of five participants with Broca's aphasia, there was no significant effect of Match between verb bias and sentence structure, $F(1, 4) = 1.75$, $p = .257$. The main effect of Plausibility was also not significant, $F(1, 4) = 1.71$, $p = .261$. There was a significant effect of Syntactic Structure, $F(1, 4) = 4.55$, $p = .048$, reflecting greater number of errors on passive and intransitive sentences compared to active transitives. There were no significant interactions between the three factors. Using partial η^2 as the measure of effect size, Syntactic Structure accounted for 53.2% of the variability in performance. Despite the fact that neither Plausibility nor Match yielded significant effects, each produced small effects, with Plausibility accounting for 30.0% of the variability, and Match 30.4%. These results are illustrated in Figure 3.

For the group of 12 participants with fluent aphasia, the effect of Match was significant, $F(1, 11) = 6.55$, $p = .027$. The main effect of Syntactic Structure was also significant, $F(2, 22) = 11.42$, $p < .001$, due to the fact that error rates for both Passives and Intransitives were higher than for Active sentences. The main effect of Plausibility was also significant, $F(1, 11) = 11.49$, $p = .006$, reflecting higher error rates on the implausible sentences than on the plausible ones. The interaction between Syntactic Structure and Plausibility was also significant, $F(2, 22) = 9.00$, $p = .001$, but neither the interaction

TABLE 7
Experiment 2: Aphasic subjects

		Active		Passive		Intransitive	
Subject	*Sentence type*	*Conc.*	*Disc.*	*Conc.*	*Disc.*	*Conc.*	*Disc.*
AK	Plaus.	5	6	3	7	9	5
	Impl.	4	3	4	7	4	4
DM	Plaus.	1	3	2	3	5	2
	Impl.	9	10	11	7	11	12
DO	Plaus.	3	2	4	4	4	1
	Impl.	2	8	13	9	13	12
HM	Plaus.	7	11	9	7	7	12
	Impl.	2	9	3	11	9	4
LI	Plaus.	10	9	5	6	9	7
	Impl.	10	12	9	9	6	12
WR	Plaus.	3	4	1	5	2	4
	Impl.	5	5	7	8	6	8
AF	Plaus.	0	2	2	4	2	1
	Impl.	4	5	10	9	8	11
BK	Plaus.	0	1	1	1	0	0
	Impl.	4	3	7	5	8	11
GP	Plaus.	1	0	1	1	0	0
	Impl.	0	0	0	1	1	3
JC2	Plaus.	0	4	2	5	2	5
	Impl.	0	4	2	7	4	5
JD	Plaus.	1	1	1	2	0	1
	Impl.	2	1	5	5	7	7
RM	Plaus.	2	3	0	0	2	0
	Impl.	3	2	1	8	4	6
JC1	Plaus.	5	5	6	8	8	6
	Impl.	8	6	6	8	9	6
JT	Plaus.	4	2	4	3	2	4
	Impl.	7	11	9	12	9	10
WG	Plaus.	6	7	8	6	6	6
	Impl.	6	5	10	8	8	10
WT	Plaus.	0	2	3	4	1	1
	Impl.	14	11	14	13	11	14
FY	Plaus.	3	3	0	2	1	1
	Impl.	0	2	2	4	2	3
GB	Plaus.	0	0	0	0	0	0
	Impl.	1	0	0	1	0	1

Number of errors (16 stimuli in each condition).
Conc. = Concordant.
Disc. = Discordant.
Plaus. = Plausible.
Impl. = Implausible.

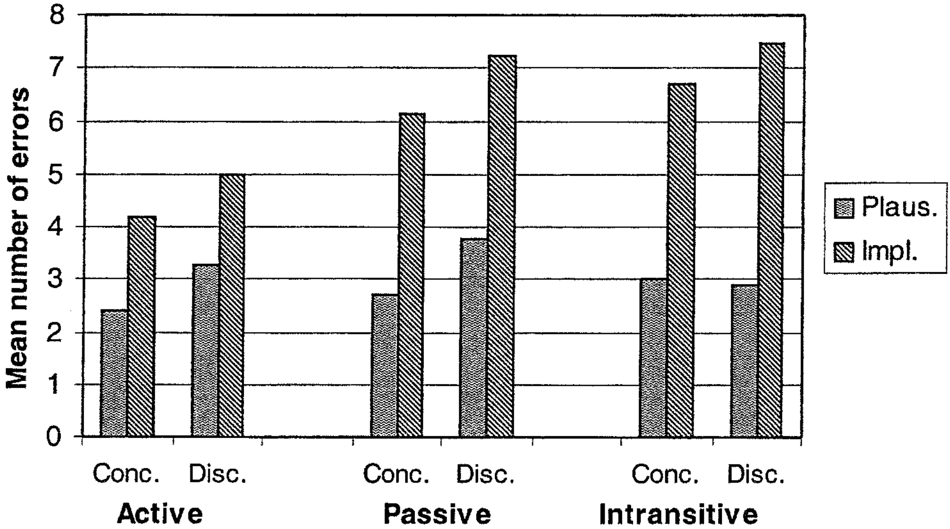

Figure 2. Mean number of errors, Experiment 2 (17 aphasic subjects).

between Syntactic Structure and Match, or between Match and Plausibility, was significant. As for the size of the effects, again measured by partial η^2, Match accounted for 37.3% of the variability, Plausibility for 51.1%, and Syntactic Structure for 50.9%. These results are illustrated in Figure 4.

Considering now the six participants with anomic aphasia within the ''fluent'' group, error rates were higher in the discordant conditions compared to the concordant conditions in all sentence types, but this effect was only marginally significant, $F(1, 5) = 4.34$, $p = .092$. The main effects of Syntactic Structure and Plausibility were significant: Syntactic Structure, $F(2, 10) = 11.27$, $p = .003$; Plausibility, $F(1, 5) = 10.33$, $p = .024$. There was no significant interaction between Match and Syntactic Structure, $F(2, 10) =$

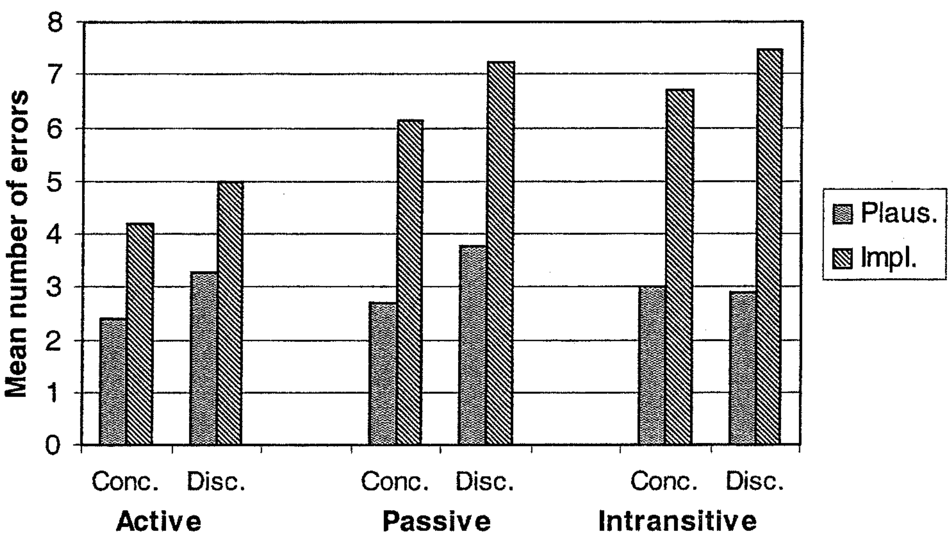

Figure 3. Mean number of errors, Experiment 2 (five subjects with Broca's aphasia).

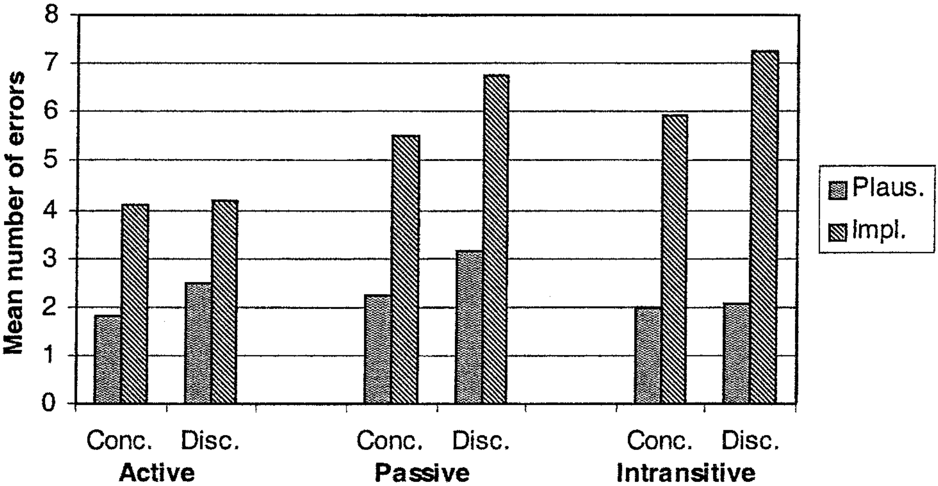

Figure 4. Mean number of errors, Experiment 2 (12 fluent aphasic subjects).

0.34, p = .723, or between Match and Plausibility, $F(1, 5) = 0.72$, p = .434. There was a significant interaction between Syntactic Structure and Plausibility, $F(2, 10) = 14.36$, p = .001. Again using partial η^2 to measure the effect size, Plausibility accounted for 67.4% of the variability in performance, Syntactic Structure for 69.3%, and Match for 46.5%. The mean error rates for the six participants with anomic aphasia are illustrated in Figure 5.

For the remaining fluent participants, i.e., the four participants with Wernicke's aphasia and two with conduction aphasia, the effect of Match was not significant, $F(1, 5) = 2.48$, p = .176, and neither was the effect of Plausibility, $F(1, 5) = 3.66$, p = .114. The effect of Syntactic Structure was significant, $F(2, 10) = 4.82$, p = .034. There were no significant interactions. As for the size of the effects, Plausibility accounted for 42.2% of the variability, Syntactic Structure for 49.1%, and Match for 33.2%. The mean error rates for these six patients are illustrated in Figure 6.

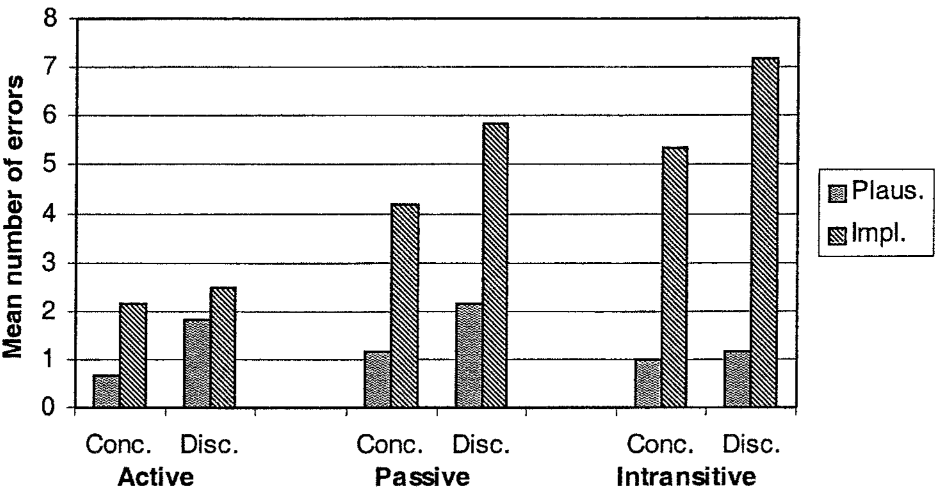

Figure 5. Mean number of errors, Experiment 2 (six fluent subjects with anomic aphasia).

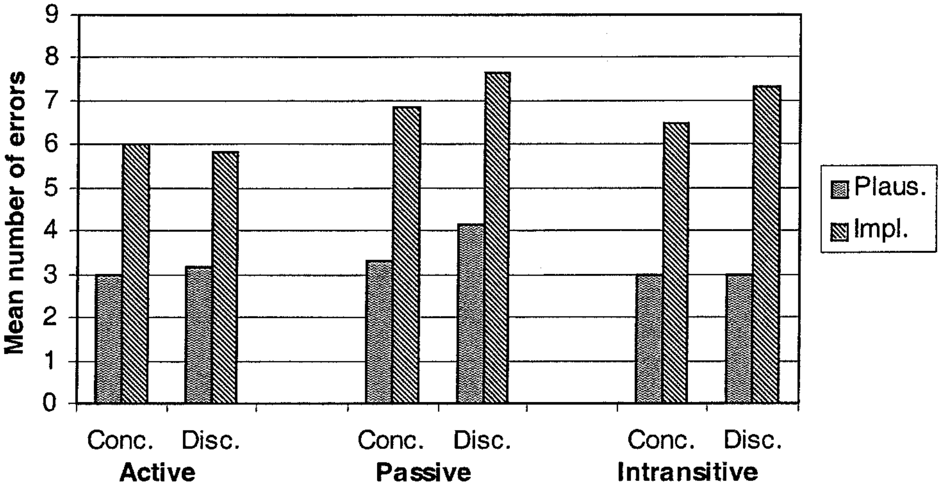

Figure 6. Mean number of errors, Experiment 2 (six fluent aphasic subjects: (four Wernicke's, two conduction aphasics).

SUMMARY OF FINDINGS AND PRELIMINARY DISCUSSION

The group of normal listeners made very few errors overall, as was to be expected on a task that these subjects found very easy. However, the normal listeners' error rates were statistically significantly higher on ''discordant'' sentences than on ''concordant'' ones. Surprising though it may be, this finding is consistent with other recent findings on interpretation accuracy of simple sentences, such as Ferreira and Stacey (2002) and Ferreira, Bailey, and Ferraro (in press). These studies suggests that normal listeners' comprehension of implausible passive sentences (and even, to some extent, active transitives) is extremely vulnerable to misinterpretation, particularly when syntactic information is at odds with lexical semantic information in the sentence. Our findings on normal listeners suggest that lexical bias is another factor capable of affecting interpretation accuracy in normal listeners.

Our observed effect of lexical biases on normal comprehension is further consistent with earlier findings on the effects of lexical biases, such as Ferreira and Henderson (1990), McElree (1993), Trueswell et al. (1993), Mitchell, Cuetos, Corley, and Brysbaert (1995), and Spivey-Knowlton and Sedivy (1995), among others. However, these earlier studies generally examined sentence types of greater complexity than in the current study, or they used on-line measures of processing load, not accuracy of interpretation, as a measure of processing difficulty. The fact that, in the present study, mismatches between lexical bias and sentence structure actually induced comprehension errors for such simple sentence types as simple active transitive and intransitive sentences is intriguing.

The aphasic patients as a group showed a significant effect of match between verb transitivity bias and sentence structure, making more errors whenever verb bias and sentence structure were at odds, or ''discordant''. We saw further that the group of five nonfluent subjects, considered separately, showed no significant effect of match between verb bias and sentence structure. However, several individuals in this group did make more errors in the discordant conditions than in the concordant conditions.

In the group of 12 participants with fluent aphasia types, the effect of match between verb bias and sentence structure was significant, *contra* Russo et al.'s findings (1998). The effect was only marginally significant when we considered just the six participants with anomic aphasia among the participants with fluent aphasia types, and was not significant for the other six fluent patients. As was the case with the participants with Broca's aphasia, several of the fluent, non-anomic patients showed a trend towards making more errors on sentences where verb bias and sentence structure did not match. Because of the high amount of variability, we are reluctant to conclude on the basis of these findings that individuals with fluent aphasia types other than anomic aphasia are generally not sensitive to verb bias. In a more recent experiment (reported in Gahl et al., 2002), we found that a mixed group of aphasic patients, none of whom had participated in the present study, also displayed a sensitivity to lexical bias, apparently regardless of aphasia type or aetiology.

DISCUSSION

The purpose of this study was to probe for effects of lexical biases in normal and aphasic comprehension. More specifically, we set out to test the lexical bias hypothesis, which states that aphasic sentence comprehension, like normal sentence comprehension, is influenced by lexical biases, and that some aphasic errors result from the influence of lexical biases. Our principal finding was that normal and aphasic listeners alike were sensitive to the match or mismatch between verb transitivity bias and sentence structure. This finding is consistent with previous findings on lexical biases in normal sentence comprehension (e.g., Ferreira & Henderson, 1990; Trueswell et al., 1993). The only previous study that investigated the effects of lexical biases in aphasia was Russo et al. (1998), who found no effect of lexical bias for a group of fluent aphasic patients.

In the sections to follow, we will consider the following points: (1) the apparent contradiction between our results and those of the only previous studies of the role of verb argument structure in aphasic comprehension (Russo et al., 1998); (2) the methodological implications of our findings for future investigations of aphasic sentence comprehension; (3) the extent to which the findings of the present study might account for previous observations about patterns in aphasic miscomprehension. Finally, we will consider some limitations of the present study and questions for future research.

Lexical biases in aphasic sentence comprehension

The only previous study that investigated the effects of lexical biases on aphasic comprehension was that of Russo et al. (1998), who predicted—and observed—that individuals with fluent aphasia types, unlike nonaphasic controls, showed no effect of verb bias. Thus, there is an apparent contradiction between the findings of the current study: like Russo et al., the current study found an effect for normals; unlike Russo et al., the current study found the effect for patients with fluent aphasia as well.

Russo et al. used the methodology and the stimuli that were used with normal subjects in Clifton, Frazier, and Connine (1984) and Shapiro, Nagel, & Levine (1993). Subjects listened to transitive and intransitive sentences like the following (examples from Russo et al., 1998, p. 538):

(6) The ageing pianist taught his * solo with great dignity.

(7) The ageing pianist taught with his * entire family.

While the sentence was being presented auditorily, a visual probe consisting of a string of letters appeared briefly on a screen, at the point marked with the asterisk in examples (6) and (7). Subjects had to decide whether the probe was an English word or not. In one half of the test sentences, the verbs are used in their preferred form (transitive or intransitive). In the other half of the test sentences, the verb occurs in its non-preferred form. Using this methodology, Clifton et al. (1984) and Shapiro et al. (1993) found that reaction times in the lexical decision task increased for nonaphasic subjects when the verbs were encountered in their non-preferred syntactic environment, indicating that normal listeners were sensitive to argument structure preferences.

Russo et al. (1998) found that a group of four participants with various fluent aphasia types (two participants with anomic aphasia, one with Wernicke's aphasia, and one with conduction aphasia) did not appear to be sensitive to the lexical bias of the verb.

The failure to observe this effect in fluent aphasia is intriguing, but does not constitute proof that the effect is not present in these patients. Also, there were significant individual differences among the subjects in Russo et al. (1998). The sole participant with Wernicke's aphasia in the study did show increased reaction times on the trials involving dispreferred argument structures. Hence it is possible that the absence of an effect only held for the heterogeneous group in the study, not for aphasic comprehension in general, and not for fluent aphasia types in particular.

Variability in aphasic sentence comprehension

One implication of this study concerns the large amount of variability and discrepancies observed among previous studies. For example, the greater difficulty of passive sentences compared to actives has been held up as a prime example of a comprehension impairment pointing to specific syntactic deficits in patients with "agrammatic" comprehension. Yet Berndt, Mitchum, & Haendiges (1996), in a meta-analysis of published studies of the phenomenon, report that only about a third of the patients reported in the literature in fact showed below-chance comprehension of passives along with above-chance comprehension of active sentences. The literature on the relative difficulty of active transitive and intransitive sentences shows a picture of conflicting findings that, if anything, is even more bewildering than the findings on passives (for a review, see Jonkers, 1998).

The results of the present study point to lexical factors as one source of variability in different studies. The choice of verbs used in sentences representing a particular syntactic pattern will affect the goodness of fit between lexical bias and syntactic pattern.

The role of lexical biases in previously observed patterns in aphasic comprehension

The current study did not set out to document how frequency-based effects might account, for example, for the oft-observed greater difficulty of passives compared to actives. Nor was the current study designed to account for the relative difficulty of active, passive, and intransitive sentences, or to compare these sentence types to one another. The crucial comparison for the present study was between sentences that matched the transitivity bias of the verb and those that did not. Yet we can ask if lexical biases and other frequency-based factors might be a contributing factor to known patterns in aphasic comprehension. Besides the frequency of a given syntactic context *for a given verb*, the activation of a syntactic frame may well be influenced by the *overall* frequency of that syntactic frame.

The most widely discussed pattern in aphasic sentence comprehension concerns the difference in comprehension difficulty between actives and passives. Active voice occurs much more frequently in English than passive (see e.g., Givón, 1979). According to Givón (1979), passives occur, on average, about 20% of the time.[3] Similarly, Lalami (1997) reports that only about 9% of the sentences in the Penn Treebank database (Marcus, Santorini, & Marcinkiewicz, 1993) are passive, and 91% active. Accordingly, we would expect a substantial difference in processing efficiency of actives and passives on the basis of the difference in frequency alone.

If our interpretation of the findings in the current study is correct, then we would expect that passive sentences containing verbs that are more frequently passive than active should be understood more readily than passives of verbs that have the opposite bias. Indeed, exactly this effect was documented for normal listeners in Lalami (1997) and for a mixed group of aphasic patients by Gahl et al. (2002). The results reported in Gahl et al. (2002), which are based on a different, more recent experiment than the current study, confirm that effects of sentence type (active, passive, and intransitive) are modulated by lexical bias towards each structure. Gahl et al. (2002), using a plausibility judgement task similar to the one employed in the current study, again found that, for all sentence types, ‘‘discordant’’ sentences induced significantly more errors than ‘‘concordant’’ ones in a mixed group of aphasic patients, none of whom had participated in our earlier study. Moreover, even structures that are considered to be particularly difficult for aphasic comprehenders, such as passives, elicited few errors, provided that the lexical bias of the main verb matches the sentence structure. We found that ‘‘concordant’’ passives were no more difficult for our subjects than ‘‘discordant’’ actives.

Gahl et al. (2002) also address a further point of relevance to the intransitive sentences in the current study. The intransitive sentences in the present study have Undergoer (or ‘‘Theme’’)-like subjects (e.g., *The door* opened, cf. My neighbour opened *the door*). It has been argued (Kegl, 1995) that Undergoer-first sentences should be difficult for many aphasic listeners. Gahl et al. (2002) examined the relative difficulty of four different sentence types: active transitive, passive, intransitive with Undergoer subjects, and intransitives with Agent subjects. We found that, if verb bias was controlled for, Undergoer-first sentences were not generally more difficult for aphasic listeners than Agent-first sentences.

Some limitations and questions for future research

Returning to the lexical bias hypothesis, we can ask what mechanism might be responsible for the effect of verb bias on aphasic sentence comprehension. An answer to this question is suggested by a hypothesis formulated by Menn et al. (1998, p. 218) about aphasic speech production. According to Menn et al. (1998), the syntactic frame that is most frequent for a given verb has a lower activation threshold and is therefore retrieved more easily than other syntactic frames in which the verb can occur. Access to infrequently used frames may then be hampered by a variety of factors, including lesions interfering with normal functioning of the brain. Production problems in aphasia—and, we hypothesise, comprehension problems as well—could be ‘‘simulated by any device—

[3] As Givón (1979) observes, the frequency of passives in a given text is strongly dependent on the type of discourse in which it occurs. Passives may make up 30% or more of scientific tests, whereas sports reports, a much more informal register, contained only about 4% passives.

probably noisy channels would be sufficient—that would make it difficult for the passive forms to reach a sufficient level of activation greater than the active voice'' (Menn et al., 1998, p. 218). The findings in the present study may be accounted for by a model identical to that described by Menn et al. if we extend their proposal to all infrequently used frames for a given verb. Notice that all three factors considered here (plausibility, syntactic structure, and lexical bias) are well established in normal language processing. The increased error rate in aphasic comprehension could be due to changes in the ability of low-probability patterns to reach sufficient activation levels. In this regard, this research is compatible with, and receives further motivation from, attempts to understand aphasic language as differing quantitatively, not qualitatively, from normal speech and comprehension errors, such as Dell et al. (1997), Bates et al. (1987), and the growing body of research attributing aphasic symptoms to changes in processing capacity or working memory (e.g., Haarmann, Just, & Carpenter, 1994; Miyake, Carpenter, & Just, 1994) or in the time course of language processing (Haarmann & Kolk, 1991).

CONCLUSION

This paper adds to the growing body of evidence for exposure-based and frequency-based effects in language processing. Our results are further consistent with models of language processing in which word-level information plays a decisive role in sentence processing. While this idea has gained widespread acceptance in the literature on normal language processing, research on aphasic sentence comprehension has tended to focus on structural factors, not on information that is contingent on sentence-level *and* lexical information. One reason for this lies in the sheer difficulty of obtaining reliable frequency information (other than single word frequency) without the help of corpus linguistics. Such information on language usage will continue to shed light on the interplay of linguistic and general cognitive mechanisms in language processing.

Manuscript received 8 March 2001
Manuscript accepted 15 March 2002

REFERENCES

Bates, E., Friederici, A.D., & Wulfeck, B. (1987) Comprehension in aphasia: A cross-linguistic study. *Brain and Language*, *32*, 19–67.

Berndt, R.S., & Caramazza, A. (1999). How ''regular'' is sentence comprehension in Broca's aphasia? It depends how you select the patients. *Brain and Language*, *67*, 242–247.

Berndt, R.S., Haendiges, A.N., Mitchum, C.C., & Sandson, J. (1997a). Verb retrieval in aphasia. 1. Characterizing single word impairments. *Brain and Language*, *56*, 68–106.

Berndt, R.S., Mitchum, C.C., Haendiges, A.N. (1996). Comprehension of reversible sentences in ''agrammatism'': A meta-analysis. *Cognition*, *58*, 289–308.

Berndt, R.S., Mitchum, C.C., Haendiges, A.N., & Sandson, J. (1997b). Verb retrieval in aphasia. 2. Relationship to sentence processing. *Brain and Language*, *56*, 107–137.

Berndt, R.S., Mitchum, C.C., & Wayland, S. (1997c). Patterns of sentence comprehension in aphasia: A consideration of three hypotheses. *Brain and Language*, *60*, 197–221.

Berndt, R.S., & Zingeser, L.B. (1991). Grammatical class effects in word production: Finding the locus of the deficit. *Brain and Language*, *41*, 597–600.

Blumstein, S.E., Byma, G., Kurowski, K., Hourihan, J., Brown, T., & Hutchinson, A. (1998). On-line processing of filler-gap constructions in aphasia. *Brain and Language*, *61*, 149–168.

Bock, K. (1986). Syntactic persistence in language production. *Cognitive Psychology*, *18*, 355–387.

Boland, J.E., Tanenhaus, M.K., Garnsey, S.M., & Carlson, G.N. (1995). Verb argument structure in parsing and interpretation: evidence from wh-questions. *Journal of Memory and Language*, *34*, 774–806.

Caplan, D., Baker, C., & Dehaut, F. (1985). Syntactic determinants of sentence comprehension in aphasia. *Cognition*, *21*, 117–75.

Caramazza, A., & Zurif, E.B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, *3*, 572–82.

Clifton, C., Frazier, L., & Connine, C. (1984). Lexical expectations in sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, *23*, 696–708.

Cohen J.D., MacWhinney B., Flatt M., & Provost J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers*, *25*, 257–271.

Damasio, A., & Tranel, D. (1993). Nouns and verbs are retrieved with differently distributed neural systems. *Proceedings of the National Academy of Science*, *USA*, *90*, 4957–4960.

Davis, G.A., & Ball, H.E. (1989). Effects of age on comprehension of complex sentences in adulthood. *Journal of Speech and Hearing Research*, *32*, 143–150.

Dell, G.S., Schwartz, M.F., Martin, N., Saffran, E.M., & Gagnon, D.A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, *104*, 801–838.

Ferreira, F., Bailey, K.G.D., & Ferraro, V. (2002). Good enough representations in language comprehension. *Current Directions in Psychological Science*, *11*, 11–15.

Ferreira, F., & Henderson, J. (1990). The use of verb information in syntactic processing: A comparison of evidence from eye movements and word-by-word self-paced readng. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 555–568.

Ferreira, F., & Stacey, J. (2002). *The misinterpretation of passive sentences.* Manuscript submitted for publication.

Frazier, L. (1995). Constraint satisfaction as a theory of sentence processing. *Journal of Psycholinguistic Research*, *24*, 437–468.

Frazier, L., & Clifton, C. (1996). *Construal*. Cambridge, MA: MIT Press.

Friederici, A.D. (1988). Agrammatic comprehension: Picture of a computational mismatch. *Aphasiology*, *2*, 279–284.

Gahl, S. (1998a) Automatic extraction of subcorpora based on subcategorization frames from a part-of-speech tagged corpus. *Proceedings of the 1998 COLING-ACL conference*, Montréal, Canada (Vol. I, pp. 428–432).

Gahl, S. (1998). Automatic extraction of subcategorization frames for corpus-based dictionary-building. In *Proceedings of the Eighth EURALEX International Congress*, Liège, Belgium (Vol. II, p. 445–452).

Gahl, S. (2000). *A usage-based model of aphasic sentence comprehension*. UC Berkeley doctoral dissertation.

Gahl, S., Menn, L., Ramsberger, G., Jurafsky, D., Elder, E., Rewega, M., & Holland, A. (2002). Syntactic frame and verb bias in aphasia: Plausibility judgments of undergoer-subject sentences. *Brain and Cognition*.

Garnsey, S.M., Pearlmutter, N.J., & Lotocky, M.A. (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language*, *37*, 58–93.

Gerratt, B.R., & Jones, D. (1987). Aphasic performance on a lexical decision task: Multiple meanings and word frequency. *Brain and Language*, *30*, 106–115.

Givón, T. (1979). *Understanding grammar*. New York: Academic Press.

Goodglass, H. (1968). Studies on the grammar of aphasics. In S. Rosenberg & J. Koplin (Eds.), *Developments in applied psycholinguistics research* (pp. 177–208). New York: Macmillan.

Goodglass, H., & Kaplan, E. (1983). *Boston Diagnostic Aphasia Examination*. Malvern, Philadelphia: Lea & Febiger.

Goodglass, H., & Menn, L. (1985). Is agrammatism a unitary phenomenon? In M.-L. Kean (Ed). *Agrammatism. Perspectives in Neurolinguistics, Neuropsychology, and Psycholinguistics* (pp. 1–26). Orlando, FL: Academic Press.

Gottfried, M., Menn, L., & Holland. A. (1997). Verb argument structure and aphasic repetition. *Brain and Language*, *60*, 37–38.

Grishman, R., Macleod, C., & Meyers, A. (1994). *COMLEX Syntax: Building a computational lexicon*. Presented at Coling 1994, Kyoto.

Haarmann, H.J., Just, M.A., & Carpenter, P.A. (1994). Computational modeling of normal and aphasic sentence comprehension. *Brain and Language*, *47*, 389–391.

Haarmann, H.J., & Kolk, H.H.J. (1991). A computer model of the temporal course of agrammatic sentence understanding: The effects of variation in severity and sentence complexity. *Cognitive Science*, *15*, 49–87.

Haarmann, H.J., & Kolk, H.H.J. (1994). On-line sensitivity to subject–verb agreement violations in Broca's aphasics: The role of syntactic complexity and time. *Brain and Language*, *46*, 493–516.

Hagoort, P. (1993). Impairments of lexical-semantic processing in aphasia: Evidence from the processing of lexical ambiguities. *Brain and Language*, *45*, 189–232.

Hagoort, P. (1997). Semantic priming in Broca's aphasics at a short SOA: No support for an automatic access deficit. *Brain and Language*, *56*, 287–300.

Hartsuiker, R.J., & Kolk, H.H.J. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and Language*, *62*, 221–254.

Jones, E.V. (1984). Word order processing in aphasia: Effect of verb semantics. In F.C. Rose (Ed.), *Advances in neuropsychology*, *Vol. 42: Progress in aphasiology*. New York: Raven Press.

Jonkers, R. (1998). Comprehension and production of verbs in aphasic speakers. Rijksuniversiteit Groningen doctoral dissertation. *Groningen Dissertations in Linguistics*, *25*.

Jonkers, R., & Bastiaanse, R. (1996). The influence of instrumentality and transitivity on action naming in Broca's and anomic aphasia. *Brain and Language*, *55*, 37–39.

Jonkers, R., & Bastiaanse, R. (1997). Verb retrieval in isolation and sentence context in Broca's aphasics: The effect of transitivity. *Brain and Language*, *60*, 33–36.

Kegl, J. (1995). Levels of representation and units of access relevant to agrammatism. *Brain and Language*, *50*, 151–200.

Kertesz, A. (1982). *Western Aphasia Battery*. New York: Grune & Stratton.

Kim, M., & Thompson, C.K. (1998). Comprehension and production of nouns and verbs in agrammatism. *Brain and Language*, *65*, 30–33.

Kohn, S.E., Lorch, M.P., & Pearson, D.M. (1989). Verb finding in aphasia. *Cortex*, *25*, 57–69.

Lalami, L. (1997). *Frequency in sentence comprehension*. University of Southern California doctoral dissertation.

MacDonald, M.C. (1994). Probabilistic constraints and syntactic ambiguity resolution. *Language and Cognitive Processes*, *9*, 157–201.

MacDonald, M.C. (1997). Lexical representations and sentence processing: An introduction. *Language and Cognitive Processes*, *12*, 121–136.

Marcus, M.P., Santorini, B., & Marcinkiewicz, M.A. (1993). Building a large annotated corpus of English: The Penn Treebank. *Computational Linguistics*, *19*, 313–330.

Marin, J., & Schwartz, M.F. (1998). Facilitating sentence planning in nonfluent aphasia. *Brain and Language*, *65*, 174–177.

McElree, B. (1993). The locus of lexical preference effects in sentence comprehension: A time-course analysis. *Journal of Memory and Language*, *32*, 536–571.

Menn, L. (2000). It's time to face a simple question: What makes canonical form simple? *Brain and Language*, *71*, 157–159.

Menn, L., Reilly, K.F., Hayashi, M., Kamio, A., Fujita, I., & Sasanuma, S. (1998). The interaction of preserved pragmatics and impaired syntax in Japanese and English aphasic speech. *Brain and Language*, *61*, 183–225.

Meyers, A., Macleod, C., & Grishman, R. (1995). *COMLEX Syntax 2.0 Manual for Tagged Entries*. Proteus Project, New York University.

Miceli, G., Silveri, M., Villa, G., & Caramazza, A. (1984). The basis for the agrammatic's difficulty in producing main verbs. *Cortex*, *20*, 207–220.

Miceli, G., Silveri, M.C., Nocenti, U., & Caramazza, A. (1988). Patterns of dissociation in comprehension and production of nouns and verbs. *Aphasiology*, *2*, 351–358.

Milberg, W., Blumstein, S.E., & Dworetzky, B. (1988). Phonological processing and lexical access in aphasia. *Brain and Language*, *34*, 279–293.

Mitchell, D.C. (1989). Verb guidance and other lexical effects in parsing. *Language and Cognitive Processes*, *4*, 123–154.

Mitchell, D.C., Cuetos, F., Corley, M.M.B., & Brysbaert, M. (1995). Exposure-based models of human parsing: Evidence for the use of coarse-grained (non lexical) statistical records. *Journal of Psycholinguistic Research*, *24*, 469–488.

Miyake, A., Carpenter, P., & Just, M.A. (1994). A capacity approach to syntactic comprehension disorders: Making normal adults perform like aphasic patients. *Cognitive Neuropsychology*, *11*(6), 671–717.

Obler, L.K., Fein, D., Nicholas, M., & Albert, M.L. (1991). Auditory comprehension and aging: Decline in syntactic processing. *Applied Psycholinguistics*, *12*, 433–452.

Roland, D., Jurafsky, D., Menn, L., Gahl, S., Elder, E., & Riddoch, C. (2000). Verb subcategorization frequency differences between business-news and balanced corpora: The role of verb sense. In *Proceedings of the Workshop on Comparing Corpora*, 28–34, Hong Kong.

Russo, K.D., Peach, R.K., & Shapiro, L.P. (1998). Verb preference effects in the sentence comprehension of fluent aphasic individuals. *Aphasiology*, *12*, 537–545.

Schwartz, M.F., Saffran, E.M., & Marin, O.S.M. (1980). The word order problem in agrammatism I: Comprehension. *Brain and Language*, *10*, 249–262.

Shapiro, L.P., Levine, B.A. (1990). Real-time sentence processing in aphasia. In T. Prescott (Ed.), *Clinical aphasiology*. San Diego, CA: College Hill Press.
Shapiro, L.P., Nagel, N., & Levine, B. (1993). Preferences for a verb's complements and their use in sentence processing. *Journal of Memory and Language*, *32*, 96–114.
Silver, L.S., & Halpern, H. (1992). Word-finding abilities of three types of aphasic subjects. *Journal of Psycholinguistic Research*, *21*, 317–348.
Spivey-Knowlton, M., & Sedivy, J.C. (1995). Resolving attachment ambiguities with multiple constraints. *Cognition*, *55*, 227–267.
Stevenson, S., & Merlo, P. (1997). Lexical structure and parsing complexity. *Language and Cognitive Processes*, *12*, 349–399.
Swaab, T., Brown, C., & Hagoort, P. (1995). Delayed integration of lexical ambiguities in Broca's aphasics: Evidence from event-related potentials. *Brain and Language*, *51*, 159–161.
Swaab, T., Brown, C., & Hagoort, P. (1997). Spoken sentence comprehension in aphasia: Event-related potential evidence for a lexical integration deficit. *Journal of Cognitive Neuroscience*, *9*, 39–66.
Swinney, D.A., Zurif, E., & Nicol J. (1989). The effects of focal brain damage on sentence processing: an examination of the neurological organization of a mental module. *Journal of Cognitive Neuroscience*, *1*, 25–37.
Trueswell, J.C., Tanenhaus, M.K., & Kello, C. (1993). Verb-specific constraints in sentence processing: Separating effects of lexical preference from garden-paths. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 528–553.
Tyler, L.K., & Ostrin, R.K. (1994). The processing of simple and complex words in an agrammatic patient: Evidence from priming. *Neuropsychologia*, *32*, 1001–1013.
Tyler, L.K., Ostrin, R.K., Cooke, M., & Moss, H.E. (1995). Automatic access of lexical information in Broca's aphasics: Against the automaticity hypothesis. *Brain and Language*, *48*, 131–162.
Williams, S.E., & Canter, C.J. (1987). Action-naming performance in four syndromes of aphasia. *Brain and Language*, *32*, 124–136.

APPENDIX: STIMULUS SENTENCES FOR EXPERIMENTS 1 AND 2

1. Concordant conditions

1.1 Sentence type: Active transitive

	A. Plausible	B. Implausible
1.	My neighbor opened the door.	The door opened my neighbor.
2.	The teacher opened the box.	The box opened the teacher.
3.	The traffic was clogging the streets.	The streets were clogging the traffic.
4.	The leaves clogged the pipe.	The pipe clogged the leaves.
5.	The waiter poured the wine.	The wine poured the waiter.
6.	The waiter poured the water.	The water poured the waiter.
7.	The researchers dissolved the crystals.	The crystals dissolved the researchers.
8.	The baker dissolved the sugar.	The sugar dissolved the baker.
9.	The heat softened the butter.	The butter softened the heat.
10.	The heat softened the cheese.	The cheese softened the heat.
11.	The cook heated the soup.	The soup heated the cook.
12.	The nurse heated the milk.	The milk heated the nurse.
13.	The professor shut the door.	The door shut the professor.
14.	The assistant shut the store.	The store shut the assistant.
15.	The teacher tore the paper.	The paper tore the teacher.
16.	The girl tore her sweater.	The sweater tore the girl.

1.2 Sentence type: Passive

	A. Plausible	B. Implausible
1.	The door was opened by my neighbor.	My neighbor was opened by the door.
2.	The box was opened by the teacher.	The teacher was opened by the box.
3.	The streets were clogged by the traffic.	The cars were clogged by the traffic.
4.	The pipes were clogged by the leaves.	The leaves were clogged by the pipe.
5.	The wine was poured by the waiter.	The waiter was poured by the wine.
6.	The drinks were poured by the waiter.	The waiter was poured by the drinks.
7.	The crystals were dissolved by the researchers.	The researchers were dissolved by the crystals.
8.	The sugar was dissolved by the baker.	The baker was dissolved by the sugar.
9.	The butter was softened by the heat.	The heat was softened by the butter.
10.	The cheese was softened by the heat.	The heat was softened by the cheese.
11.	The soup was heated by the cook.	The cook was heated by the soup.
12.	The milk was heated by the nurse.	The nurse was heated by the milk.
13.	The door was shut by the professor.	The professor was shut by the door.
14.	The store was shut by the assistant.	The assistant was shut by the store.
15.	The paper was torn by the teacher.	The teacher was torn by the paper.
16.	The sweater got torn by the girl.	The girl got torn by the sweater.

1.3 Sentence type: Intransitive

	A. Plausible	B. Implausible
1.	Mushrooms grow in the dark.	The dark grew in the mushrooms.
2.	The flowers grew in clusters.	The clusters grew in the flowers.
3.	The boat sank in the storm.	The storm sank in the boat.
4.	The ship sank in the bay.	The bay sank in the ship.
5.	The bomb exploded in the street.	The street exploded in the bomb.
6.	The dynamite exploded in a side street.	The side street exploded in the dynamite.
7.	The clay hardened in the sun.	The sun hardened in the clay.
8.	The concrete hardened in the sun.	The sun hardened in the concrete.
9.	The jeans shrank in the wash.	The wash shrank in the jeans.
10.	The shirt shrank in the wash.	The wash shrank in the shirt.
11.	The cake crumbled in my hands.	My hands crumbled in the cake.
12.	The crackers crumbled in the box.	The wrapper crumbled in the cheese.
13.	The balloon burst behind the boy.	The boy burst behind the balloon.
14.	The bubble burst behind the girl.	The girl burst behind the bubble.
15.	The soup boiled in the pot.	The cook boiled in the pot.
16.	The milk boiled in the kettle.	The nurse boiled in the kettle.

2. Discordant conditions

2.1 Sentence type: Active transitive

	A. Plausible	B. Implausible
1.	My neighbor grows mushrooms in the yard.	Mushrooms grow my neighbor in the yard.
2.	His parents grow flowers on their balcony.	Flowers grow his parents on their balcony.
3.	The waves sank the boat.	The boat sank the waves.
4.	The storm sank the ship.	The ship sank the storm.
5.	The guards exploded the bomb.	The bomb exploded the guards.
6.	The crooks exploded the dynamite.	The dynamite exploded the crooks.
7.	The sun hardened the clay.	The clay hardened the sun.
8.	The sun hardened the sand.	The sand hardened the sun.
9.	The photographer shrank the pictures.	The pictures shrank the photographer.
10.	The hot water shrank the shirt.	The shirt shrank the hot water.
11.	The cook crumbled the cake.	The cake crumbled the cook.
12.	The children crumbled the crackers.	The crackers crumbled the children.
13.	The boy burst the balloon.	The balloon burst the boy.
14.	The girl burst the bubble.	The bubble burst the girl.
15.	The cook boiled the soup.	The soup boiled the cook.
16.	The chef boiled the water.	The water boiled the chef.

2.2 Sentence type: Passive

	A. Plausible	B. Implausible
1.	The mushrooms were grown by my neighbor.	My neighbor was grown by the mushrooms.
2.	The flowers were grown by my parents.	My parents were grown by the flowers.
3.	The boat was sunk by the wave.	The huge wave was sunk by the boat.
4.	The ship was sunk in the storm.	The wave was sunk by the ship.
5.	The bomb was exploded by the guards.	The guards were exploded by the bomb.
6.	The dynamite was exploded by the crooks.	The crooks were exploded by the dynamite.
7.	The clay was hardened by the sun.	The sun was hardened by the clay.
8.	The sand was hardened by the sun.	The sun was hardened by the sand.
9.	The pictures were shrunk by the photographer.	The photographer was shrunk by the pictures.
10.	The shirt was shrunk by the woman.	The woman was shrunk by the shirt.
11.	The cake was crumbled by the cook.	The cook was crumbled by the cake.
12.	The crackers were crumbled by the children.	The children were crumbled by the crackers.
13.	The balloon was burst by the boy.	The boy was burst by the balloon.
14.	The bubble got burst by the girl.	The girl got burst by the bubble.
15.	The soup was boiled by the cook.	The cook was boiled by the soup.
16.	The water was boiled by the chef.	The chef was boiled by the water.

2.3 Sentence type: Intransitive

	A. Plausible	B. Implausible
1.	The door opened after a short while.	My neighbor opened after a short while.
2.	The box opened after a short while.	The teacher opened after a short while.
3.	The streets clogged during rush hour.	The traffic clogged during rush hour.
4.	The pipe clogged after the rain.	The leaves clogged after the rain.
5.	The wine poured over the table.	The table poured over the wine.
6.	The water poured out of the pitcher.	The pitcher poured out of the water.
7.	The crystals dissolved in the solution.	The researchers dissolved in the solution.
8.	The sugar dissolved in the milk.	The baker dissolved in the milk.
9.	The butter softened in the heat.	The heat softened the butter.
10.	The cheese softened in the heat.	The heat softened in the cheese.
11.	The soup heated in the pot.	The cook heated in the soup.
12.	The water heated in the cup.	The nurse heated in the cup.
13.	The door shut behind the professor.	The professor shut behind the door.
14.	The store shut at six o'clock.	The assistant shut at six o'clock.
15.	The paper tore in two pieces.	The pieces tore in the paper.
16.	The sweater tore along the seams.	The seams tore along the sweater.