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A Crosslinguistic Study of Grammaticality Judgments in Broca's Aphasia

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Crosslinguistic studies of sentence comprehension and production in Broca's aphasia have yielded two complementary findings: (1) grammatical morphology appears to be more impaired than word order principles in every language studied, but (2) the degree to which grammatical morphology is retained by aphasic patients depends upon the "strength" or importance of those morphemes in the patient's premorbid language. In an earlier study comparing violations of word order and agreement, we found that English-speaking Broca's aphasics showed greater sensitivity to errors of ordering than to errors of agreement, providing further evidence for the selective vulnerability of morphology. However, because English is a rigid word order language with a relatively weak inflectional system, it could be argued that word order is resilient to brain damage because it is the strongest source of information in this language. The present study compared the performance of

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English-speaking Broca's aphasics and normal controls with their Italian counterparts in the same grammaticality judgment experiment. Four predictions relating to our previous work were confirmed. (1) Italian aphasics, like their English-speaking counterparts, showed general preservation of grammatical knowledge and (2) they were able to use this knowledge in an "on-line" fashion. (3) Within each language, Broca's aphasics showed greater impairment in their ability to recognize errors of morphological selection (i.e., agreement) compared with errors made by moving the same words to an incorrect position downstream. Nevertheless (4), crosslinguistic differences observed in previous studies of comprehension and production were also observed in this grammaticality judgment task: a processing advantage for agreement errors in Italian normals and aphasics, and a processing advantage for ordering errors in English normals and aphasics.

INTRODUCTION

In 1983, Linebarger, Schwartz, and Saffran showed that so-called agrammatic Broca's aphasics could make subtle judgments of grammaticality. This important finding has been replicated (Wulfeck, 1988) and recently extended in studies that not only measured sensitivity to grammatical violations but also examined the decision time needed to detect these violations (Shankweiler, Crain, Gorrell, & Tuller, 1989; Wulfeck & Bates, 1990).

For example, Shankweiler et al. (1989) examined agrammatic aphasics' sensitivity to violations of closed-class morphology in an experiment that required real-time processing of sentence structure. The on-line processing manipulation was achieved by presenting each sentence only once, controlling the location of the critical word in the sentence, encouraging speedy responses, and collecting decision time as well as judgment of each sentence. Closed-class violations were either within-category substitutions (e.g., "Peter *have* planning to see a new movie Saturday night") or between-category substitutions (e.g., "The cabdriver forgot to bring the senator to *away* rally"). The authors hypothesized that detection of between-word-class substitutions would be superior to within-word-class substitutions. As predicted, between-class substitutions were easier to detect. Also, both control and aphasic subjects were faster at detecting violations that occurred relatively late in the sentence. This word position effect indicated that aphasic subjects, like normal controls, were capable of making grammaticality judgments in real-time (i.e., even *before* the complete sentence was heard). Shankweiler et al. (1989) concluded that some sensitivity to closed-class vocabulary remains in agrammatic aphasics and that this vocabulary can be used, on-line, in constructing a structural analysis of a sentence.

Wulfeck and Bates (1990) investigated the effect of morphosyntactic violation type on accuracy and processing time in English-speaking Broca's aphasic and age-matched control subjects engaged in a similar on-line error detection task. Again, both judgment accuracy and decision time were collected, so that the data would reveal not only *whether* agrammatic aphasics can detect violations, but *when* they notice them. The ungrammatical sentences were created by changing quantifiers and auxiliary verbs in one of two ways: substituting one quantifier or auxiliary for another to create number agreement errors or moving the quantifier or auxiliary "downstream" from its proper site to create word order errors. The position of the violation in the sentence and the distance relationships among sentence elements were also manipulated. Two issues were addressed in this study. (1) Does agrammatism represent a loss of grammatical knowledge or disruption to processing mechanisms which access knowledge? (2) Are all aspects of grammar equally disrupted or is there selective disruption to specific aspects of grammatical morphology?

Results suggested that agrammatic aphasic subjects do retain surprising sensitivity to grammatical knowledge. Moreover, they can use this knowledge "on-line" to formulate their decisions, as indicated by a word position effect observed for all subjects. This effect was attributed to information-processing mechanisms (attention, memory) as well as computational resources (syntactic and semantic processing). It was also observed that aphasic subjects were less sensitive to agreement than to ordering violations, a finding that was reflected in decision times as well as judgment accuracy. These results supported two conclusions. First, while the performance of the aphasic subjects was degraded relative to control subjects, overall grammatical sensitivity and relatively rapid decision times suggest that the locus of grammatical impairment may have more to do with the accessing of linguistic information than with loss of linguistic knowledge. Second, the difference between agreement and movement violations provides further evidence that morphological marking is relatively vulnerable in aphasia compared with the principles that govern word and morpheme ordering.

These are not the first studies to reveal the special vulnerability of grammatical inflections and function words for aphasic patients. For example, comprehension and production data from our crosslinguistic studies (Bates, Friederici, & Wulfeck, 1987a,b; Bates, Friederici, Wulfeck, & Juarez, 1988) across groups (controls, Broca, and Wernicke aphasics) and languages (English, Italian, and German) suggest that basic word order principles are retained in aphasia, while grammatical morphology is selectively vulnerable—even in languages that differ markedly in the relative importance of word order and morphology (i.e., English is a strong word order language with relatively weak morphology, Italian is a weak word order language with a rich morphological system, and German is a case-marked language). However, there were also significant crosslanguage differences in the degree of morphological impairment observed as a function of the differential "cue validity" and "cue strength" associated with agreement and word order information in these languages (Bates & MacWhinney, 1987, 1989). For example, Italian Broca's aphasics retained more sensitivity to agreement morphology in a sentence interpretation task than their English-speaking counterparts; conversely, the English aphasics relied more on canonical word order in the same experimental situation. Nevertheless, aphasic patients in both language groups displayed selectively greater impairment in the use of agreement cues compared with word order—*relative to normal controls in their language*. In other words, crosslinguistic differences in cue validity or information value interact with a general erosion of grammatical morphology in aphasia.

In this study, we will examine the interaction of cue validity and morphological vulnerability in an "on-line" error detection paradigm. Using an equivalent set of sentence stimuli in each language, we will compare patterns of error detection in Italian Broca's aphasics and normal controls with the performance of English-speaking aphasics in the study by Wulfeck and Bates (1990). Italian was chosen because it is a richly inflected language that permits extensive word order variation, a fact which markedly reduces the utility of word order information in assigning agent/object roles (Bates & MacWhinney, 1987, 1989). Furthermore, in contrast with case-marked languages like German, Italian has no case markers to provide supplementary information about agent/object relations. In the absence of case markers and/or reliable word order patterns, Italian listeners must rely heavily on other sources of information about sentence meaning, including a particularly rich set of agreement markers (subject–verb agreement; modifier–noun agreement; agreement between pronouns and their referents). This difference between English and Italian leads to the prediction that normal Italian listeners will be particularly sensitive to violations of agreement between two elements of a noun or verb phrase compared with English listeners exposed to similar violations in their language. Conversely, we may also expect English listeners to display more sensitivity to errors that are created by displacing one of these elements from its usual position within a noun or verb phrase.

If we find the predicted crosslinguistic differences between English and Italian normals in this error detection task, four predictions concerning the performance of English and Italian Broca's aphasics follow from our previous work. First, we should find evidence that aphasic patients in both language groups retain above-chance sensitivity to *both* word order and agreement errors. Second, aphasic patients in both language groups should demonstrate an ability to use this grammatical knowledge "on-line." Third, if the selective vulnerability of morphology observed in sentence comprehension and production tasks also applies to judgments of grammaticality, we may expect to find relatively greater erosion of sensitivity to agreement errors among Broca's aphasics *within* each language compared with normal controls. Fourth and finally, to the extent that crosslinguistic differences are preserved in aphasia, we should observe relatively greater sensitivity to agreement errors in Italian Broca's aphasics and relatively greater sensitivity to word order errors in English Broca's aphasics.

METHODS

Subjects

Two control groups participated in this study comprising 22 monolingual English-speaking college students (14 females and 8 males, mean age = 20 years) and 12 Italian college students (6 females and 6 males, mean age = 23 years) who were studying in the United States. The Italian subjects had lived in the United States, on average, for 3 years. All but one had learned formal English in grade school (mean number of years of English language instruction = 12 years), and their English language production and comprehension abilities ranged from functional to proficient. All control subjects were in good health with intact speech and language abilities as measured by an interview in their native language.

Aphasic subjects were referred for testing by neurologists and speech pathologists at our two respective research sites (San Diego, California and Rome, Italy). Each candidate had a diagnosis of Broca's aphasia. Diagnosis was made on the basis of medical history (neurological examination, CT scans, when available) together with the results of aphasia test batteries used at the respective research sites: the Boston Diagnostic Aphasia Examination—BDAE, Goodglass & Kaplan, 1983) and a comparable Italian battery of language production and comprehension tests. Aphasic subjects were defined independently within each language, according to their fit to the behavioral and neurological profiles of Broca's aphasia used by the neurologists and speech pathologists in that country.

The English-speaking subjects were five aphasic adults (four men and one woman) with a mean age of 58 years (range 53–65) and a mean educational level of 14 years. The Italian-speaking subjects were eight aphasic adults (six men and two women) with a mean age of 56 years (range 19–67) and a mean educational level of 13 years. All subjects had suffered a stroke with the exception of one Italian aphasic who suffered a ruptured aneurysm. Postonset time at testing ranged from 3 to 7 years (mean = 4 years) for the English-speaking subjects and from 1 to 10 years (mean = 5 years) for the Italian subjects. Premorbid right-handedness was reported for all aphasic subjects.

The aphasic subjects were rated to be in the moderate to severe impairment range for fluency (articulation, prosody, and phrase length) and showed a tendency toward omission of functors, relative to their language-matched controls. Auditory comprehension for the Broca's patients was relatively intact (English-speaking aphasics: BDAE mean percentile = 72; Italian-speaking aphasics: Italian auditory comprehension mean score = 80%. Data for the English-speaking aphasic subjects were taken from a previous study of grammatical sensitivity (Wulfeck & Bates, 1990). Data for the Italian-speaking aphasic subjects and both control groups were collected for the present study.

Materials

Sentence stimuli incorporated the following independent variables:

(a) Grammaticality (grammatical or ungrammatical). Grammatical and ungrammatical sentence pairs were constructed for all possible variable combinations.

(b) Grammatical target (auxiliary verb or noun quantifier). Auxiliary verbs with either the present or the past progressive tense of a main verb (e.g., is playing, have written—sta giocando, hanno scritto) and noun quantifiers (e.g., some, several, three, many—alcuni/e, tre, molti/e) were included since agreement and word order violations could be constructed for all variables of interest.

(c) Violation type (number agreement or word order). Violations of number agreement between the subject and the auxiliary verb or the quantifier and its noun were constructed. We had to restrict the number of violation types included since our design included several factors that needed counter-balancing. Hence, our study is not an exhaustive examination of grammatical sensitivity.

*He are picking the last apple from the large tree.
*Lui stanno raccogliendo l'ultima mela dal grande albero.
*Many turtle is lying in the mud near the barn.
*Molte tartaruga sta riposando nel fango vicino al fienile.

Word order violations were constructed by altering the position of the auxiliary verb with respect to the subject and main verb or the quantifier with respect to the noun.

*Under the box on the table he hidden has cookies.
*Sotto la scatola sul tavolo lui nascosto ha dei biscotti.
*Near the garden on the street bird the is singing.
*Vicino al giardino per la strada canarino il sta cantando.

(d) Position (early or late). This refers to the location of the violation in relation to the rest of the words in the sentence. For example, the two sentences below vary in that the agreement violation for the first sentence occurs early in the sentence while the agreement violation in the second sentence is later.

*Franco have broken the glass bowl on the new table.
*Franco hanno rotto la ciotola di vetro sul tavolo nuovo.
*By the new market the boy are eating an apple.
*Vicino al nuovo mercato il ragazzo stanno mangiando una mela.

(e) Distance (local or global). Distance refers to the intra- and interphrasal dependencies which exist between elements. The greater the distance between two elements (i.e., how many words intervene), the greater the necessity for long-distance tracking in order for successful syntactic analysis to take place. For example, in the following sentences containing agreement violations, the target elements are grouped together (local) in the first sentence, while there is more long-distance (global) tracking required in the second sentence.

*Maria are writing a nice letter to the new teacher.
*Maria stanno scrivendo una simpatica lettera alla nuova maestra.
*Near the door the boy with the train are singing.
*Vicino alla porta il bambino con il trenino stanno cantando.

For sentences with word order violations, two different rearrangements were used. For example, the first sentence set listed below contains an intraphrasal (local) word order transposition between the two target elements. In the second set, the word order transposition is more extreme.

*In the church near the park photographs many are hanging.
*Nella chiesa vicino al parco fotografie molte sono appese.
*Cats large hungry three are climbing on the oak tree.
*Grandi gatti affamati tre si stanno arrampicando sulla quercia.

All of these variables were systematically crossed to yield 32 sentence types. Five 8- to 10-word sentences of each type were then constructed resulting in 160 sentences (80 grammatical and 80 ungrammatical). Care was taken to use the same basic sentence structure so that differences between sentences were due primarily to the manipulations of interest. For example, although Italian does permit extensive variation of sentence order for pragmatic purposes, SVO (subject–verb–object) is the canonical order for declarative sentences in both English and Italian. To maximize comparability between the English and Italian stimulus sets, all the sentence stimuli used in this experiment follow the canonical SVO order in both languages. Some implications of this methodological decision will be discussed later.

Experiment Apparatus

Subjects' judgments and decision times were recorded using an experimental control system and software developed by Brian MacWhinney at the Department of Psychology, Carnegie-Mellon University. The system is an input/output buffer for the parallel port on IBM computers, together with a response apparatus equipped with a timer for interval measurements accurate to 1 msec. Three digital inputs are provided. For this experiment two of the inputs were connected to response pushbutton switches mounted on a movable sloped-front metal box approximately 15 × 15 × 3-cm. Care was taken to select switches which could be pushed easily but which gave positive tactile feedback when pushed.

All stimulus sentences were read once by a native English or Italian speaker. Care was taken to read the ungrammatical sentences with the intonational contour appropriate for well-formed sentences to avoid, as much as possible, intonational cues to the ungrammaticality of a sentence. Raters judged the intonational naturalness for each sentence. Sentences which were rejected were rerecorded until judged acceptable. The sentences were tape-recorded on high bias audio tapes and then digitally stored in a microcomputer using an antialiasing filter system sampling at 20 KHz and a high-speed data translation board driven by speech processing software.

The digitized stimulus sentences were then measured using speech processing software to determine the overall length of each sentence (in milliseconds), and a mark was placed (for the ungrammatical sentences) at the point where the violation occurred or where the violation rendered the sentence ungrammatical. Once the digitized stimulus sentences had been measured and marked for violation points, the stimulus sentences were placed back onto high-bias audio tapes using computer-controlled software which placed the sentence stimuli on one track of the audiotape and placed inaudible tones corresponding to each sentence type on a second track of the audiotape. These tones were later used by the experimental control software to present the stimuli to the subjects and to record responses and stimulus information. Sentence stimuli were presented in the same pseudorandom order with the constraint that no sentence was followed immediately by its grammatical or ungrammatical counterpart.

Sentence stimuli were recorded at intervals of 10 sec. The experimental control program was written so that (a) the onset of a sentence would start the timer; (b) the system would wait for 8 sec, during which time button presses and their intervals from the start of timing would be recorded; (c) after 8 sec, the system would reset the timer to zero and wait for another sentence to start the timer again. (At this point, it was also possible for an experimenter to stop and restart the experiment if the subject needed a break.) For each sentence, button presses and button-press times in milliseconds (msec) from the onset of the sentence were recorded in data files on the microcomputer.

Exact timings of the words in each sentence were saved in the computer so that the time between any sentence event and any button press could be calculated. Sentence duration for all sentence types was roughly equivalent within, but not between, languages due to systematic differences between English and Italian in word lengths and pronunciation time. Durations for English sentences were as follows: mean sentence offset = 3371 msec, mean grammatical sentence offset = 3344 msec, mean ungrammatical sentence offset = 3398 msec. For Italian, sentence lengths were: mean sentence offset = 5642 msec, mean grammatical sentence offset = 5510 msec, mean ungrammatical sentence offset = 5700 msec.

For number agreement violations, times were marked (*) from the offset of the word that rendered the sentence ungrammatical.

*The farmer on the tractor have * broken a large plow.

*Il contadino sul trattore hanno * rotto un grande aratro.

For word order violations, times were marked (*) from the offset of the "hole" made by the word that was removed and moved downstream in the sentence to render it ungrammatical.

*At the new dress store she gotten * a has present.

*Nel nuovo negozio d'abbigliamento lei comprato * un ha regalo.

Our decision about where to "start the clock" for a word order error is somewhat arbitrary. For example, we might have measured the error not from the "hole" but from the point downstream where the moved element is incorrectly placed. In principle, listeners may begin to suspect that something is wrong at the "hole," but withhold judgment until it is clear that the sentence cannot be resolved in any well-formed way. Furthermore, there are crosslanguage differences in the likelihood that one or more of these "holes" can be resolved later on, and differences in the point at which hopes for a good resolution begin to fade. For example, given the possibilities for word order variation that exist in Italian, Italian listeners may need to postpone judgments of grammaticality at the "hole" more often than their English counterparts. These differences may also interact with several of the variables under study here, including distance and target type. We will return to this point in the discussion section, with recommendations for future crosslanguage research on error detection.

Procedure

Each subject was tested in a quiet room by a native speaker of the target language. The experimenter sat next to the subject, controlling the computer and tape recorder so that the experiment could be stopped if the subject became fatigued. During the session, one channel was played to the subject, while the second was used to control the third input channel of the experimental control system. This was done by connecting the channel output from the audio tape player to a voice-operated relay of the response apparatus. Before the experiment, subjects practiced button pressing to familiarize themselves with the apparatus. Each subject also completed 20 warm-up trials in which the subject heard the word "good" ("buono") or "bad" ("cattivo") from the tape recorder and then pressed the corresponding button. This was done to establish a simple two-choice auditory reaction time baseline for use in later analyses.

Each subject was then administered some training items in order to familiarize him or her with the task and verify understanding of task instructions. The subject was instructed to indicate whether the sentence "has good grammar" by pushing either of two buttons on a button box on which was written "good" (under a smiling face) or "bad" (under a frowning face). In other words, subjects were asked to accept grammatical sentences ("good") and reject ungrammatical ones ("bad"). Subjects were instructed to listen carefully since they would only hear each sentence once and to respond as quickly as possible.

Data Reduction

Proportions of hits (accepting a grammatical sentence), false alarms (incorrectly accepting an ungrammatical sentence), and overall grammatical sensitivity were calculated for each subject in the aphasic and control groups for each sentence type used in the study. Perfect sensitivity occurs when all grammatical sentences are accepted (hit rate = 1.00) and no ungrammatical sentences are accepted (false alarm rate = 0).

The sensitivity measure used in this study is A' (Pollack and Norman, 1964; Grier, 1971). This was done to maximize comparability with other studies (Linebarger et al., 1983; Wulfeck, 1988; Wulfeck and Bates, 1990). Also while the overall proportion correct could have been used, A' corrects for extreme response bias. For a two-alternative forced-choice task, A' estimates the proportion correct. Perfect discrimination yields an A' of 1.00 and chance performance yields an A' of 0.50. Subjects' A' scores on the 16 sentence types were used in the analyses of variance and correlation described below.

Two types of reaction and decision time measures were derived:

(1) Two-choice reaction time baseline. This is the mean of 50 two-choice reaction times obtained for each subject during a warm-up task which preceded the judgment experiment.

(2) Adjusted decision time (DT). The subject's decision time is the raw button-press time from the point of violation for ungrammatical sentences. The decision time was then adjusted by subtracting the subject's mean baseline time from each reaction time to remove variability between subjects due to general motor problems. Aphasic subjects were hemiplegic and had to use their nondominant hand for responding. In some analyses, we wished to compare directly DTs of the English and Italian subjects. Since the English and Italian sentences

differed in overall duration, DTs were converted to z scores for purposes of those analyses. Each response's DT z score is the number of standard deviations from a subject's overall mean decision time across the ungrammatical sentences. In the present study, the faster the response time, the lower the z score.

RESULTS

In the introduction we outlined four predictions for the present study based on previous research.

(1) Broca's aphasics in both language groups will display an above-chance ability to detect errors of agreement and/or word order. This hypothesis will be tested by examining the A' scores for judgment accuracy for individual patients as well as patient groups.

(2) The aphasic subjects in both language groups will also display an ability to use their grammatical knowledge "on-line." The best single test of this hypothesis will come from the effects of sentence position: if patients are using their grammatical knowledge to build up expectations across the course of the sentence, then decision times should be faster when the error occurs in a late position.

(3) Overall we may expect greater sparing of sensitivity to word order violations and greater "erosion" of sensitivity to agreement violations in aphasic patients relative to normal controls within each language. This hypothesis will be tested by examining the effects of violation type (word order versus agreement) on judgment accuracy and decision times.

(4) Finally, our previous crosslinguistic studies lead to the prediction that Italian subjects will show greater sensitivity to agreement violations, while English subjects will show greater sensitivity to word order violations.

In addition to the predicted effects of position, violation type and language, the design of this experiment will also permit us to examine the effects of distance (local versus global errors) and target type (noun determiners versus verb auxiliaries). However, because we have no strong predictions regarding these two manipulations, any effects associated with distance or target type must be interpreted with caution. In general, we may expect less accuracy and/or slower reaction times for global violations compared with local violations under the assumption that global or "long-distance" violations make greater demands on memory. However, there are a number of exceptions to this prediction in the literature on production and/or detection of speech errors (Bock & Miller, 1991; Ni, 1990). With regard to the contrast between auxiliary and noun determiner errors, we might expect greater sensitivity to auxiliary errors because these involve a disruption of processing at the sentence level (i.e., the relationship between subject and verb), while the effect of determiner errors is restricted to the noun–phrase level. On the other hand, if the main verb problem that has been reported for Broca's aphasics manifests itself in

TABLE 1
MEAN *A'*S FOR ENGLISH AND ITALIAN APHASIC SUBJECTS

Sentence type	English aphasic's *A'*s	Italian aphasic's *A'*s
EGAA	.72	.84
EGAN	.59	.74
EGWA	.97	.95
EGWN	.95	.78
ELAA	.79	.81
ELAN	.74	.84
ELWA	.94	.92
ELWN	.94	.92
LGAA	.68	.74
LGAN	.69	.85
LGWA	.86	.93
LGWN	.95	.92
LLAA	.77	.85
LLAN	.65	.76
LLWA	.94	.81
LLWN	.91	.93
Mean	.82	.84

Note. Sentence Type is coded as follows. The first column denotes position (Early or Late), the second, distance (Local or Global), the third, violation type (Agreement or Word order), and the fourth, grammatical target (Noun quantifier or Auxiliary).

this modality, then we may expect relatively *less* sensitivity to verb auxiliaries in aphasic patients from either language group. Finally, because Italian listeners must rely particularly heavily on verb morphology as a clue to sentence meaning, there may be selectively greater sensitivity to verb auxiliaries in Italian normals and (perhaps) Italian aphasics compared with their English counterparts.

Grammaticality Judgments

English and Italian control groups. As expected, grammatical sensitivity for the two control groups was at ceiling (English control group mean $A' = .99$, Italian control group mean $A' = .98$). This indicates near-perfect discrimination between grammatical and ungrammatical sentences for all sentence types, obviating the need for a crosslinguistic analysis of the judgment data for normal controls. Because of these ceiling effects, it would also be inappropriate to combine aphasic and normal control data in a single analysis. We will therefore proceed to a separate analysis of the English and Italian aphasic groups.

English and Italian aphasic groups. Examination of individual data revealed that in general, when aphasic subjects made errors, they tended to accept ungrammatical sentences (elevated false alarm rates) rather than reject grammatical ones. Table 1 shows English and Italian aphasic group

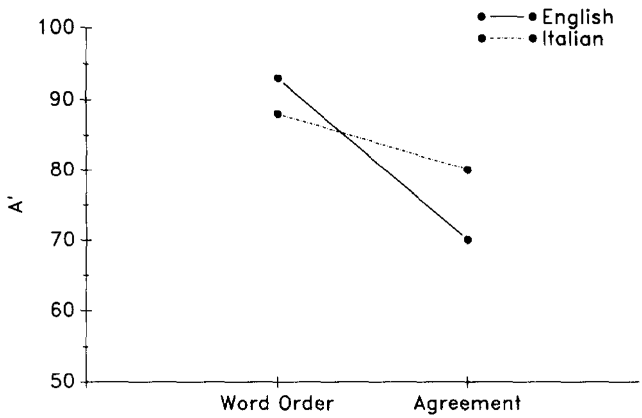

FIG. 1. Mean A's for language by violation for the aphasic groups.

mean A's for the sentences types. Although inferior to control subjects in their respective language, both aphasic groups showed overall sensitivity to grammaticality, providing support for our first prediction. This finding also replicates previous reports of relatively preserved grammatical sensitivity in English-speaking agrammatic aphasics (Linebarger et al., 1983; Wulfeck, 1988; Shankweiler et al., 1989; Wulfeck & Bates, 1990).

The A's for the two aphasic groups were then analyzed in a 2 (Language) × 2 (Position) × 2 (Distance) × 2 (Violation) × 2 (Target) analysis of variance. The ANOVA revealed a significant main effect for violation type ($F(1, 11) = 28.652$, $p < .001$), with greater sensitivity observed for word order (mean $A' = .90$) than for agreement violations (mean $A' = .77$). In other words, aphasic subjects in both languages were better at detecting violations produced by altering the order of words within a target sentence than violations of agreement. Moreover, with the exception of two Italian aphasic subjects, all subjects in both languages showed this advantage in the detection of word order compared to agreement violations. However, the interaction of language and violation was also significant ($F(1, 11) = 8.002$, $p < .05$) and is displayed in Fig. 1. Italian aphasics were more accurate than English-speaking subjects on agreement violations; conversely, English-speaking aphasics were more accurate than their Italian counterparts in detecting word order errors.

Taken together, these findings are consistent with other studies suggesting that Broca's aphasics have greater difficulties processing morphological compared to structural information, even for a language like Italian which has a rich morphological system. However, Italian aphasics do show residual sensitivity for those cues that provide important information for grammatical processing in their language. Hence the sensitivity data provide evidence for predictions 3 and 4.

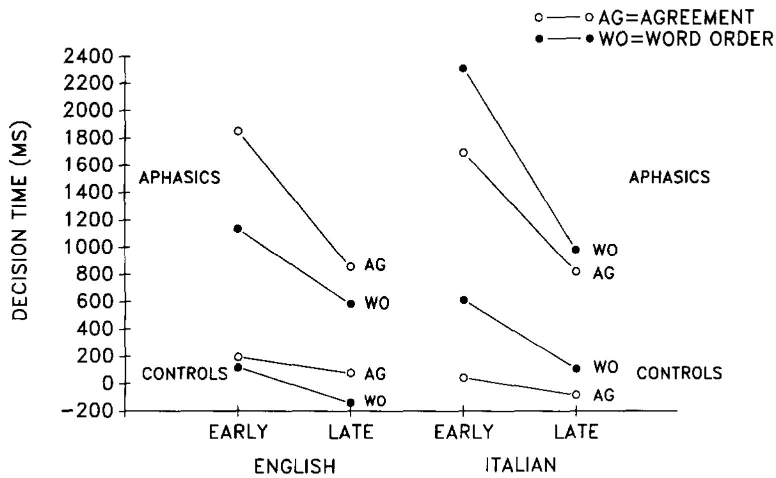

FIG. 2. Mean decision times for early and late position word order and agreement violations for control and aphasic groups in both languages.

Decision Time Results

Baselines. Subjects in both control groups had faster baseline reaction times (English control group mean = 519 msec, Italian control group mean = 743 msec) than the aphasic subjects (English aphasic group mean = 897 msec, Italian aphasic group mean = 1193 msec). The control subjects' mean reaction times ranged from 356 to 937 msec. Aphasic subjects' mean reaction times ranged from 571 to 1375 msec. The difference between languages is probably due to the difference in lengths of English or Italian words used in the baseline task. Aphasic subjects' slowing was most likely due to effects of aging and to motor problems.

Adjusted decision times. Before conducting statistical analyses, each subject's data file was examined for extreme values on the ungrammatical sentences (i.e., very early times that occurred well before the violation point) and no-response (timed-out) reaction times. These were removed prior to analysis. Less than 1% of the data fell into this category for the control group. For the aphasic subjects, the percentages of unacceptable data ranged from 0 to 9%.

Figure 2 shows the adjusted DTs for the four groups, plotted for the variables of greatest interest, i.e., position and type of violation. Two basic results can be observed in Fig. 2: (1) there is a word position effect for all groups, with late violations detected more quickly than early ones; and (2) there are language-specific differences in processing, with agreement violations detected more quickly than word order violations by Italian subjects, but word order violations detected more quickly than agreement violations for English-speaking subjects.

As noted above, because the sentences were presented in different languages, subjects' processing times might have differed due to language differences in word length and duration. To test directly for the reliability of the results in Fig. 2, adjusted DTs for the ungrammatical sentences were converted to *z* scores and entered into $2 \times 2 \times 2 \times 2 \times 2$ repeated-measures analyses of variance with language (English vs. Italian) as a between-subjects factor and the linguistic variables (Position, Distance, Violation, and Target) as within-subject factors. Because data for the respective normal and aphasic groups do not meet assumptions of homogeneity of variance, two separate analyses were performed, one for the control subjects and one for the aphasic subjects.

A significant main effect of position was observed in both analyses (Controls: $F(1, 32) = 161.046$, $p < .001$; Aphasics: $F(1, 10) = 88.221$, $p < .001$) with late-occurring violations being detected more quickly than early ones. The control groups' mean *z* score for early violations was 0.1986, while late violations resulted in faster responses (mean *z* score $= -.2235$). For the aphasic groups, mean *z* scores for early and late violations were .3945 and $-.4045$, respectively. It is important to note that the interaction of language and position did not reach significance in either analysis; in other words, all four groups show essentially the same word position effect. The difference between early and late violations among aphasic subjects is compatible with the view that real-time processing abilities are preserved in patients with focal brain injury, providing evidence for our second prediction.

Although the main effect of violation did not reach significance in either analysis, the predicted interaction between language and violation type was observed for controls and for aphasics (Controls: $F(1, 32) = 112.796$, $p < .001$); Aphasics: $F(1, 10) = 14.306$, $p < .01$). Moreover, the pattern of results was the same in each analysis. Figure 3 shows the *z* scores for each of the four groups. Overall, Italian subjects were faster at detecting agreement violations, and English subjects were faster at detecting word order violations in both analyses. Because the predicted crosslinguistic differences are preserved in aphasic patients (albeit at lower levels), these data provide support for prediction 4.

A significant interaction between position and violation was observed for the controls ($F(1, 32) = 33.584$, $p < .001$). A significant three-way interaction of language, position, and violation was obtained ($F(1, 10) = 12.304$, $p < .01$) for the aphasic groups only. Figure 4 displays the mean *z* scores for all four groups. To understand these effects, it may also be useful to consider the actual (untransformed) decision times associated with each position and violation type (see Fig. 2).

Among the English normals, decision times (in milliseconds) break down as follows: late word order errors are fastest (−140 msec), followed by late agreement errors (75 msec), early word order errors (116 msec),

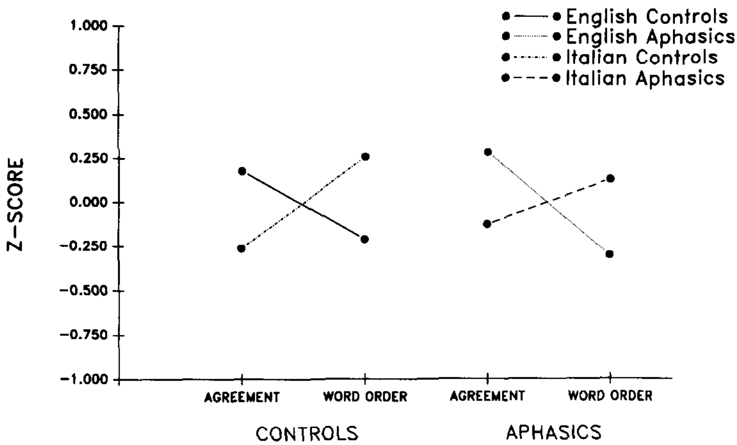

FIG. 3. Mean *z* scores of decision times for word order and agreement violations for control and aphasic groups in both languages.

and early agreement errors (194 msec). These differences reached significance in a separate analysis of variance conducted for English normals only ($F(1, 21) = 12.107$, $p < .01$). The same pattern was also observed in English Broca's aphasics, although their overall decision times were much slower: late word order violations produce the fastest response (582 msec), followed by late agreement errors (856 msec), early word order errors (1136 msec), and early agreement errors (1851 msec). These effects also reached significance in a separate analysis of variance on the untransformed reaction times for English-speaking Broca's aphasics ($F(1, 4) = 47.638$, $p < .01$). Clearly, English-speaking aphasics experience

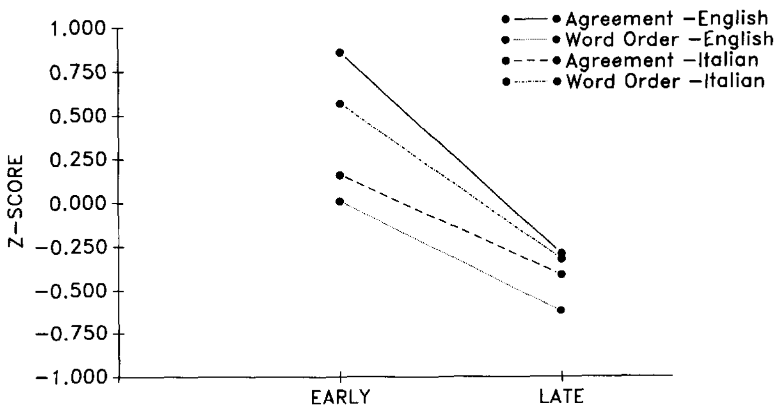

FIG. 4. Mean *z* scores of decision times for language by position by violation for the aphasic groups.

serious problems in detecting early agreement violations. However, the English disadvantage in processing agreement errors is somewhat reduced when context effects have built up toward the end of the sentence.

A different hierarchy of difficulty emerges for the Italian normals in the position by violation type analysis. As illustrated in Fig. 2, Italian normals respond quickly to late agreement errors (−83 msec), followed by early agreement errors (42 msec), late word order errors (106 msec), and early word order errors (612 msec). The extraordinarily late reaction times for early word order errors suggest that Italian normals are unwilling to make a decision on these items until more information is available. A separate analysis of variance on the untransformed decision times for Italian normals confirms this pattern ($F(1, 11) = 20.161$, $p < .001$). By contrast, there was no significant interaction between position and violation type in a corresponding analysis for the Italian Broca's only. This is due in part to the erosion of sensitivity to early agreement errors in this group compared with normal Italian listeners, leaving main effects of violation type and word position but no interaction between the two (see Fig. 2).

To summarize the results so far, we have solid confirmation for all four of the predictions derived from our previous work. Aphasic patients in both language groups retain above-chance sensitivity to violations of grammaticality (reflected in their A' scores) and they appear to make their judgments on-line (reflected in the word position effect). There appears to be support for the view that agreement morphology is selectively vulnerable in brain-damaged patients compared with normal speakers of the same language (based on the judgment accuracy data for both aphasic groups). However, Italian- and English-speaking Broca's aphasics still retain language-specific patterns of sensitivity to agreement errors (better preserved in Italian) and word order errors (better preserved in English). This conclusion is evident in the interactions of language and violation type obtained in analyses of judgment accuracy and decision time. It is also borne out by detailed analyses of the interaction between violation type and word position within each language and patient group.

We now turn to the effects associated with distance and target type, where our predictions are much less clear. We will take a more exploratory approach to these effects as a source of hypotheses for future crosslinguistic research on error detection in normal listeners and aphasic patients.

Main effects and interactions involving distance. The distance manipulation was included to test the hypothesis that error sensitivity would erode as a function of the distance between the error and its source (Bock & Miller, 1991; Ni, 1990). Instead, results suggest that the distance factor interacts with language, position, and violation type, with contradictory findings in many cases.

Although the main effect of distance was not reliable for normals or aphasics, a modest language by distance interaction was observed for the control subjects only ($F(1, 32) = 7.486$, $p < .05$). Italian controls showed relatively faster detection of local (−.0920) compared to global (.0855) violations, while English controls appear to be unaffected by the local/global manipulation (local = −.0088, global = −.0261). This pattern was confirmed by separate analyses of variance within each normal control group, using the untransformed decision times: there was no main effect of distance in the analysis of English normals, but the main effect of distance did reach significance in the analysis of normal Italian speakers only ($F(1, 11) = 21.175$, $p < .001$).

Among the controls (but not the aphasics), there was also a significant interaction of position and distance ($F(1, 32) = 55.293$, $p < .001$) and a significant interaction of language, position, and distance ($F(1, 32) = 12.737$, $p < .01$). To explore these effects further, we return to the analyses of untransformed reaction times described above, separating English-speaking normals and Italian normals. The position by distance interaction did reach significance among the English-speaking subjects ($F(1, 21) = 22.922$, $p < .001$). In this analysis, the fastest decision times were obtained with late local violations (mean untransformed DT = −.84 msec), the slowest reaction times were obtained with early local violations (mean untransformed DT = 225 msec), with early and late global violations falling somewhere in between (86 msec for early global and 20 msec for late global). In other words, the effect of distance between an error and its source depends upon word position in English. By contrast, there was no significant interaction between distance and word position among the Italian normals. Instead, Italian subjects showed consistently faster decision times for local violations compared to global ones, regardless of sentence position.

Returning to the main analyses, significant interactions of distance and violation type were observed for the control groups ($F(1, 32) = 16.398$, $p < .001$) and the aphasic groups ($F(1, 10) = 13.218$, $p < .01$). However, a significant three-way interaction of language, distance, and violation type was only observed for the two control groups ($F(1, 32) = 14.807$, $p < .001$). This interaction is shown in Fig. 5. As can be seen, Italian control subjects show a particularly large *disadvantage* in processing global word order violations. English control subjects, on the other hand, show the expected advantage for word order violations whether or not the violations are local or global. This conclusion is confirmed by separate analyses within each group: the distance by violation interaction did reach significance for the Italian controls ($F(1, 11) = 20.124$, $p < .001$) but not for the English-speaking control subjects. A similar (albeit degraded) pattern was also observed for the aphasic subjects with a significant interaction of distance by violation obtained for the Italian aphasic subjects only ($F(1, 6) = 6.033$, $p < .05$). Although we did not predict these

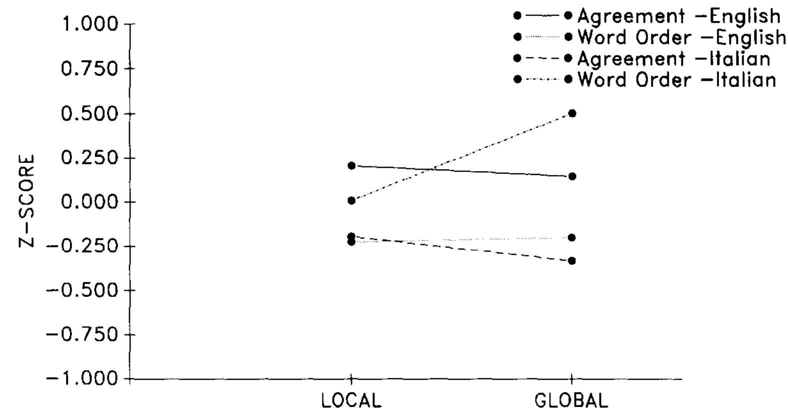

FIG. 5. Mean z scores of decision times for language by distance by violation for the control groups.

effects, they do make sense if we assume that Italians are "holding back" when they encounter a possible word order error, waiting for more information before they decide that the sentence cannot be resolved. For local word order errors, the requisite disambiguating information comes fairly soon; for global word order errors, the disambiguating information is much further downstream. By contrast, English subjects make a decision that word order principles have been violated as soon as they detect the "hole" from which a determiner or auxiliary has been moved; because these movement errors are detected immediately, it does not matter how far we move the displaced element downstream.

Effects of target type (verb auxiliaries versus noun determiners). A significant main effect of target was observed in both analyses (Controls: $F(1, 32) = 47.622$, $p < .001$; Aphasics: $F(1, 10) = 9.643$, $p < .05$) with violations involving auxiliaries processed more quickly (Controls' mean z score = $-.1197$; Aphasics' mean z score = $-.1134$) than violations involving noun determiners (Controls' mean z score = .0948; Aphasics' mean z score = .1034). This result is compatible with the notion that sentence-level errors are "more important" than phrase-level errors. However, there was also a significant language by target interaction among the normal controls ($F(1, 32) = 124.555$, $p < .001$). Italian normals processed auxiliaries (mean z score = $-.3453$) faster than they processed determiners (mean z score = .3387). However, English controls showed little difference between these item types: mean z scores for violations of auxiliary and noun determiner were .0034 and $-.0383$, respectively. This language difference may reflect the fact that Italians must rely more heavily on agreement morphology to assign agent/object relations (MacWhinney, Bates, & Kliegl, 1984), resulting in greater sensitivity to errors that involve the verbal auxiliary. Separate analyses of the untransformed decision times for English and Italian controls confirm this view: the main effect of target type reached significance for the Italians ($F(1, 11) = 259.896$, $p < .001$); the same effect did not reach significance in the analysis of English control subjects. While there was no significant language by target type interaction among the aphasic subjects, the results were in same direction but weaker (main effect of target for the Italian aphasics—$p = .09$).

Both analyses also revealed significant interactions between violation and target (Controls: $F(1, 32) = 47.662$, $p < .001$; Aphasics: $F(1, 10) = 13.966$, $p < .01$). There was also a significant three-way interaction among language, violation, and target type for the normals ($F(1, 32) = 8.333$, $p < .01$); the same interaction just missed significance in the analysis of aphasic patients ($p = .069$). To assist in the interpretation of these complex effects, we turn again to separate analyses of variance on the untransformed decision times within each of the four groups.

Among the English-speaking control subjects, the violation by target type interaction did reach significance ($F(1, 21) = 9.834$, $p < .01$). The decision time differences in this group break down as follows: word order errors on auxiliaries are fastest (−40 msec), followed by word order errors on determiners (17 msec), agreement errors on determiners (102 msec), and agreement errors on auxiliaries (168 msec). Clearly, these English normals are experiencing some difficulty in the detection of auxiliary agreement errors, a result that is consistent with the observation that auxiliary agreement errors are frequent in American English (Bock & Miller, 1991). The same interaction did not reach significance among the English aphasics.

The violation by target type interaction also reached significance among the normal Italian speakers ($F(1, 11) = 76.838$, $p < .001$), but the decision time hierarchy was quite different: the fastest decision times were observed for agreement errors on auxiliary verbs (−141 msec), followed by ordering errors for auxiliary verbs (10 msec), and agreement errors for determiners (100 msec), with a huge delay in decision time observed for ordering errors on noun determiners (710 msec). The same interaction also reached significance among the Italian aphasics ($F(1, 6) = 22.187$, $p < .01$), but this analysis yielded yet another decision time hierarchy: the fastest decision times were observed for agreement errors involving noun determiners (1134 msec), followed by ordering errors on verb auxiliaries (1141 msec), agreement errors on verb auxiliaries (1382 msec), and order errors on noun determiners (2153 msec). Although Italian normals and Italian aphasics share the same "trouble spot" (i.e., markedly slow reaction times for misplaced noun determiners), the aphasics did not show the same sensitivity to auxiliary substitutions displayed by normal Italian speakers. This suggests that the "selective vulnerability of morphology" is partic-

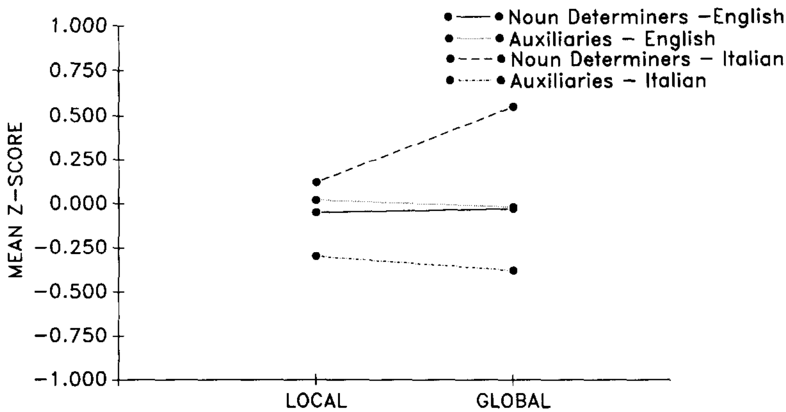

FIG. 6. Mean z scores of decision times for language by distance by target for the control groups.

ularly marked for auxiliary verbs in this language—a possible interaction between morphological erosion and the general insensitivity to verbs that has been reported for agrammatic Broca's aphasics in this language (Miceli, Silveri, Villa, & Caramazza, 1984).

Finally, both analyses yielded a complex set of significant interactions involving distance and target type. These include two-way interactions between distance and target type in each analysis (Controls: $F(1, 32) = 13.206$, $p < .001$; Aphasics: $F(1, 10) = 32.528$, $p < .001$) and significant interactions among language, distance, and target that were revealed in both the control group ($F(1, 32) = 12.583$, $p < .01$) and the aphasic

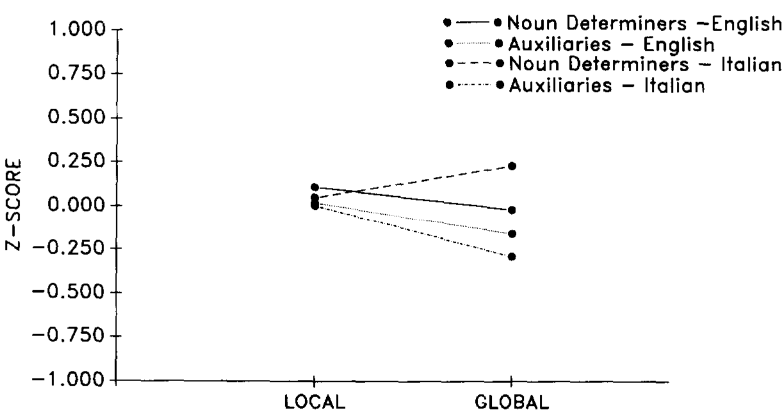

FIG. 7. Mean z scores of decision times for language by distance by target for the aphasic groups.

group ($F(1, 10) = 15.371$, $p < .01$) analyses. These are plotted in Figs. 6 (Control groups) and 7 (Aphasic groups).

Other significant effects include a three-way interaction among position, distance, and target in each analysis and two four-way interactions involving language by distance by position by target, and language by distance by violation by target. Most of these complex effects can be explained by one cell of the design: extremely slow reactions by Italian normals and Italian aphasics to late, global word order violations on noun determiners (see also Figs. 6 and 7). These effects are not strong or consistent enough to mitigate our interpretation of the predicted language, position, and violation effects described earlier. However, the difficulty that Italians experience with this particular item type does deserve comment.

We have already noted that Italian listeners tend to "wait and see" how word order errors will be resolved. Unlike their English counterparts, Italians are not willing to make judgments of grammaticality as soon as they detect the "hole" from which a misplaced element has been moved. On late word order errors involving noun determiners, Italian listeners who have postponed a grammaticality decision may be led down a number of garden paths. In a language that permits a great deal of word order variation, determiners that are encountered in a surprising place may signal the beginning of a new noun phrase in a legal (albeit improbable) position. Presumably, this possibility must be entertained until further information is received. The parsing problem is even more severe when the late-occurring noun determiner is a singular or plural feminine article (i.e., "la" or "le"), because these articles are identical in form to pronoun object clitics (which, in turn, suggest even more parsing alternatives). Such items may be particularly disastrous when they are encountered late in the sentence, because they force the Italian listener to suspend or indeed "undo" a great deal of sentence processing.

Because these materials were not designed for a careful test of these subtle but important differences between English and Italian, further speculation is unwarranted. We will return to a consideration of the distance and target type effects later on in our recommendations for further cross-linguistic research on error detection in normal and aphasic subjects.

Correlational Analyses of A's and Adjusted DTs for the Aphasic Subjects

In our earlier study of grammaticality judgments in English-speaking aphasics (Wulfeck & Bates, 1990), we examined the relationship between the ability to detect violations (A') and the processing time involved in detection (Adjusted DTs) and found no evidence of any kind of a speed–accuracy trade-off (i.e., a positive correlation between accuracy and speed suggesting that mistakes were a function of acting too quickly). We did find a strong negative correlation ($r = -.6798$, $p < .001$) for word order violations but the correlation for agreement violations was not significant. We interpreted this to mean that when English-speaking aphasic subjects made correct judgments, they also made them more quickly, at least for word order violations.

In the present study we examined the same relationships for the Italian aphasic subjects and also found no evidence for a speed–accuracy trade-off (i.e., no positive correlation between accuracy and speed). However, while the correlation between sensitivity and processing speed was not significant for word order violations among the Italian aphasic subjects, a moderate negative correlation was observed for agreement violations ($r = -.3237$, $p < .05$). In other words, Italian aphasics were able to respond quickly when they detected an agreement error; slow reaction times reflect those cases in which the error was missed altogether. These analyses are consistent with the language by violation type interaction reported for the A' results above. That is, Italian-speaking aphasic subjects have lost some sensitivity to agreement violations (compared with Italian normals), but they are also more sensitive to agreement violations when their data are compared with results for English-speaking aphasic subjects.

DISCUSSION

In earlier crosslinguistic studies of comprehension and production (Bates et al., 1987a, b, 1988), we obtained evidence that focal brain damage and crosslinguistic differences both contribute to the processing profiles of our aphasic and control subjects. On the one hand, we found that some aspects of grammatical processing (i.e., grammatical morphology) appear more vulnerable to the effects of brain damage than others (i.e., basic word order); on the other hand, the degree of impairment observed in aphasic patients reflects the relative importance of these grammatical structures in the patient's premorbid language. This second conclusion is compatible with the idea that grammatical symptoms in aphasia reflect deficits in processing across a largely preserved knowledge base. This conclusion is buttressed by several recent studies of grammaticality judgment in English-speaking Broca's aphasics, showing that these patients retain surprising sensitivity to grammatical violations even in "real-time" processing tasks. (Linebarger et al., 1983; Shankweiler et al., 1989; Wulfeck, 1988; Wulfeck & Bates, 1990).

The purpose of the present study was to draw these lines of research together, investigating the interacting effects of focal brain damage and language-specific factors on the error detection abilities of English-speaking control and Broca's aphasic subjects compared with Italian control and Broca's aphasic subjects exposed to an equivalent set of sentence materials. Four predictions relating to our previous work were proposed: (1) preservation of the ability to make grammaticality judgments in Broca's aphasia, (2) an ability to make those judgments "on-line," (3) selectively greater erosion of sensitivity to agreement errors, compared with word order errors, in aphasic subjects from both language groups, but (4) selectively greater sensitivity to agreement errors in Italian Broca's aphasics, and selectively greater sensitivity to word order errors in English Broca's aphasics. All four predictions were confirmed.

Real-time grammatical sensitivity in aphasia. Based on findings from a growing body of research with English-speaking agrammatic aphasic subjects (Linebarger et al., 1983; Wulfeck, 1988), we predicted that our Italian aphasics would show some preservation of grammatical sensitivity and this was confirmed. Italian aphasics, like their English-speaking counterparts, showed overall preservation of grammatical knowledge, although they did not show the near-perfect performance observed in the control subjects. Moreover, grammaticality sensitivity did not suffer as a function of the on-line manipulation, substantiating claims by Shankweiler et al. (1989) and Wulfeck and Bates (1990) that agrammatic aphasics are able to perform grammaticality judgments in real-time while still maintaining better-than-chance accuracies.

Evidence of real-time processing came from our findings that aphasic and control groups demonstrated a word position effect. All groups were much faster at noticing violations when they came near the end of the sentences. Our results are consistent with those of Shankweiler et al. (1989) and Wulfeck and Bates (1990) and provide clear evidence that agrammatic subjects are capable of on-going analysis of the input string, integrating information as it builds up over the course of the sentence. The word position effect has been taken as evidence of the speed with which normal listeners can integrate syntactic and semantic information from the input string (Marslen-Wilson & Tyler, 1980, 1981; Tyler & Marslen-Wilson, 1982; Tyler, 1985). In addition to computational analyses, we believe other more general information-processing mechanisms (e.g., attention, memory) also may contribute to this effect. However, in a more detailed discussion (Wulfeck & Bates, 1990) we have suggested that the word position effect is only a rough index of moment-to-moment processing and that any buildup observed in the predictability of errors across a sentence must be a reflection of a variety of very specific structural and semantic factors. Moreover, the facilitating effects of semantic and syntactic context may rise and fall repeatedly across the course of a sentence. To our knowledge, no grammaticality judgment studies to date (including our own) have examined such linguistic and timing factors in sufficient detail to elucidate fully real-time error detection processes. (But see below and Wulfeck & Bates, 1990 for descriptions of new studies underway).

Crosslinguistic variation. We expected that normal English and Italian listeners would be equally sensitive to violations; indeed this is what we observed. However, as predicted, we also observed crosslinguistic differences in speed of processing as a function of violation type. Italian control subjects were faster at detecting agreement errors, while English subjects were faster when errors involved a misordering of the same sentence elements. To our knowledge, this is the first demonstration of a crosslinguistic difference in the nature and timing of grammaticality judgments among normal adult listeners. These crosslinguistic differences are consistent with well-known differences in the nature of these two languages: English is a rigid word order language with a relatively weak inflectional system, and Italian is a richly inflected language that permits extensive word order variation. According to the Competition Model outlined by Bates and MacWhinney (1987, 1989), listeners should attend more closely and react more quickly to sentence elements that are high in cue validity, i.e., cues that carry the most reliable information about aspects of sentence meaning. This leads to the prediction that English listeners will attend more closely to word order, while Italian listeners will attend more closely to agreement markers. Note, however, that this prediction pertains primarily to the use of word order and agreement cues in a sentence interpretation task (see MacWhinney and Bates, 1989, for a summary of crosslinguistic results using a sentence interpretation paradigm). Our results for normal controls in the present study extend the Competition Model to a grammaticality judgment task, in which subjects are not required to extract sentence meaning. The crosslinguistic effects observed here provide new evidence concerning the importance and generality of cue validity effects on real-time sentence processing (see also Kilborn, 1989).

Still more important for our purposes here, a similar (albeit weaker) interaction between language and violation type was noted for the two aphasic groups. We now have a substantial body of crosslinguistic evidence on sentence interpretation in Broca's aphasics and other patient groups (see Bates & Wulfeck, 1989a,b for reviews), suggesting that subjects retain language-specific profiles of cue utilization when they are required to process a sentence for meaning. In the present study, we have shown that nonfluent Broca's aphasics also display language-specific profiles in their on-line judgments of grammaticality.

An array of other crosslinguistic differences emerged in the effects of distance (global versus local violations) and target type (auxiliaries versus noun determiners). All of these effects were stronger in the normal controls. For example, Italian normals showed a local/global contrast at all sentence positions (with faster response overall to local violations); the same contrast interacted with sentence position in the data for English normals, applying primarily to errors that are located late in the sentence. These distance effects were, in turn, mitigated by violation type: for Italian listeners, the local/global contrasts were most evident for order violations, with markedly slower performance on global word order errors; by contrast, English normals showed no significant interaction between distance and violation type. These results are compatible with the fact that Italian listeners must cope with all the possibilities for word order variation in their language. That is, decisions about local violations can be made quickly but when the violations extend across phrase boundaries, Italian listeners must be more cautious (slower processing) before rejecting a sentence, because many word order options remain that could still render the sentence grammatical.

Finally, there were a number of complex interactions involving target type (noun determiners versus verb auxiliaries), interactions that were also observed in the data for aphasic subjects. Because we did not offer strong predictions for these effects, there is no point in dwelling on them here in any detail. Suffice it to say that the patterns of on-line processing observed in English and Italian differ as a function of the expectations set up by auxiliary verbs and noun determiners at different points across the sentence. Italians appear to resolve agreement errors of any kind as soon as those errors can be detected, but they apparently prefer to "wait and see" on word order violations, and the amount of time they are willing to wait (or compelled to wait) depends upon the range of alternative structures that must be entertained from the point at which a "hole" opens up in the sentence. In addition, the unexpected appearance of an auxiliary or (in particular) a noun determiner at a point far downstream forces the Italian listener to open up additional structural options that he might not have otherwise entertained. By contrast, English listeners appear to have strong expectations about the elements that ought to appear in particular positions as they move from left to right across the sentence—expectations that increase toward the end of the sentence. Hence they dispense with order violations quickly (i.e., as soon as they detect a "hole" in sentence structure) and do not bother with discrepancies that occur later in the sentence (when the moved element finally appears in an incorrect position).

These crosslinguistic differences in the effects of distance and target type are quite reasonable, but they should be investigated with a finer-grained set of materials, controlling for the number and range of structural alternatives that are available at each point in sentence processing. Because we now know that aphasic patients are also capable of making grammaticality judgments on-line, the same fine-grained manipulations should be applied in crosslinguistic studies of aphasia. Studies of that sort are now underway in our laboratories.

Selective vulnerability of morphology. In earlier crosslinguistic aphasia work, we obtained evidence suggesting that grammatical morphology is selectively vulnerable compared with syntactic aspects of linguistic performance (Bates et al., 1987a,b, 1988). In our on-line study of grammaticality judgments in English-speaking Broca's aphasics (Wulfeck & Bates, 1990), we also found greater sensitivity for word order compared to agreement violations. However, because English is a strong word order language with a weak inflectional system, we could not rule out the possibility that our results reflected the fact that the strongest cues in a language (e.g., word order) are the most resilient to brain damage. In other words, we needed the crosslinguistic comparison (i.e., languages that contrast in the information value of grammatical morphology) to further substantiate our claim of the selective vulnerability of morphology. Evidence for the vulnerability of morphology was obtained: Broca's aphasics in both languages showed more impairment in their ability to recognize errors of morphological selection (i.e., agreement) compared to ordering errors. However, it is equally clear that the vulnerability of morphology interacts with language-specific differences in the strength of morphological cues.

Crosslinguistic variation and preservation in aphasia. Following the interaction between universal and language-specific facts seen in our other crosslinguistic studies of aphasia, we have obtained further evidence that language differences are preserved in aphasic subjects despite a general "softening" of sensitivity to agreement; Italian aphasic subjects were more sensitive to agreement errors than their English counterparts, who were in turn more sensitive to errors of ordering. Moreover, correlational analyses of grammatical sensitivity and decision times provided additional crosslinguistic evidence—a significant negative correlation was obtained for word order (but not agreement) violations for the English-speaking aphasics, while a significant negative correlation for agreement (but not word order) violations was obtained for the Italian aphasics.

CONCLUSION

In sum, this study extends our own previous crosslinguistic findings to a different modality and adds to a growing body of evidence suggesting that morphology is selectively vulnerable in aphasia. However, the degree of vulnerability that we see is affected by structural and statistical differences between natural languages. Our findings suggest that language-specific knowledge is largely preserved in Broca's aphasia, requiring an account of language breakdown based on deficits in the processes by which this preserved knowledge (i.e., competence) is accessed and deployed (i.e., performance). To this end, we are developing several new on-line processing tasks (error detection, word monitoring, sentence interpretation, cross-modal naming) that are tailored to the specific characteristics of four languages (English, Italian, Hungarian, and Chinese). We have chosen these languages because they contrast in degree and type of inflectional morphology, flexibility of word order, and lexical/semantic configurations. These new experiments will be used with several subgroups (Broca's and Wernicke's aphasics, normal controls) and will provide a much more thorough investigation of the patterns of grammatical sparing and impairment that are observed within and across processing modalities, in aphasia.

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